LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
CENSUS OFFICE,
WASHINGTON, D. C., *September* 24, 1884.

Hon. H. M. TELLER,
Secretary of the Interior.

SIR: I have the honor to transmit herewith the tenth volume of the quarto series comprising the final report on the Tenth Census. The volume contains three reports, viz: (1) On the Production, Technology, and Uses of Petroleum and its Products, by S. F. Peckham; (2) on the Manufacture of Coke, by Joseph D. Weeks; (3) on the Building Stones of the United States and Statistics of the Quarry Industry, by George W. Hawes *et al.*

The report on the building stones of the United States was originally confided to the late Dr. George W. Hawes, curator of the department of mineralogy and lithology in the National Museum, whose regretted death prevented its completion by himself. After his decease the work was continued on the general plan originally designed, and under the subsequent supervision of Mr. Henry Gannett was brought to completion. The names of the authors who assisted in its preparation are appended to such chapters or parts as were contributed by them.

I have the honor to be, very respectfully, your obedient servant.

C. W. SEATON,
Superintendent of Census.

LITHOTYPE PRINTING CO., GARDNER, MASS. NEW YORK OFFICE, 114 NASSAU ST.

A PETROLEUM FIELD.
(An Original Photograph.)

REPORT

ON THE

PRODUCTION, TECHNOLOGY, AND USES

OF

PETROLEUM AND ITS PRODUCTS.

BY

S. F. PECKHAM,
SPECIAL AGENT.

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LETTER OF TRANSMITTAL.

PROVIDENCE, R. I., *October* 6, 1882.

Hon. C. W. SEATON,
Superintendent of Census.

SIR: I herewith submit my report as special agent for collecting the statistics of the mining and manufacture of petroleum for the year ending May 31, 1880.

The statistics of mining were gathered, as stated in the chapter devoted to their consideration, by personal interviews with those parties who handled the oil, and from a careful examination of the localities producing it.

The statistics of manufacture were obtained by means of a printed schedule of questions, which was addressed to each firm or corporation engaged in manufacturing petroleum. The answers to the questions contained in these schedules were consolidated into the separate items as given in the report.

An examination of the literature of petroleum revealed a very large number of articles and references, some of which were of even classical antiquity, but the larger number of which had been published within the present century. Very few bound volumes have been devoted to the general consideration of the subject; and none of these, while each valuable as presenting some of its particular aspects, were to be considered as embracing the results of a comprehensive research with reference to all of its varied details. It was therefore thought advisable to make this report an authority upon the subject of which it treats, as embodying the results of a careful examination of the entire literature of petroleum, as well as a careful use of all other available sources of information. The three aspects of the subject—the natural history, technology, and uses of petroleum and its compounds—were each considered under its several appropriate divisions, these forming the subjects of separate chapters. Each of these several chapters, in turn, represents a special research and constitutes a separate independent essay. This arrangement, it is hoped, will facilitate the use of the report for all the varied purposes for which it may be sought. Any further details will, I think, be readily apparent upon an inspection of the work itself.

I wish herewith to express my great obligations to all of those from whom I have solicited assistance in the collection of the statistical material for this report. Without the cordial co-operation of the officers of the great corporations which produce, distribute, and manufacture petroleum, together with a very large number of private individuals, my labors would have been in vain; and I make this statement, appreciating the fact that this assistance in a great number of instances involved a large amount of perplexing labor, gratuitously rendered from an appreciative estimate of the work upon which the Census Office has been engaged. When hundreds of persons throughout the country, engaged in the production, transportation, and manufacture of petroleum, uniformly rendered all of the assistance in their power, it is both difficult and unfair to make distinctions. I had rather repeat what I have said privately: that the patience, forbearance, and uniform courtesy with which I have been met by all parties representing the petroleum interest has been extremely gratifying.

In securing information other than statistical I am under great obligations to Professor J. P. Lesley and his assistants, of the second geological survey of Pennsylvania, particularly Mr. J. F. Carll, of Pleasantville, Pennsylvania. Beside the obligation involved in extensive quotation from Mr. Carll's published reports, his personal assistance in the way of introduction to both persons and places throughout the oil-producing section proved invaluable. I feel that whatever value the report may possess in reference to the geology of West Virginia is due to Mr. F. W. Minshall, of Parkersburg, West Virginia, who, in addition to furnishing the geological sections, rendered me further assistance in introductions and information involving a long correspondence.

In collecting the statistics of foreign localities I am under special obligations to Mr. Boverton Redwood, of London, England; Mr. E. W. Binney, of Manchester, England; Dr. Ferd. Roemer, of Breslau, Silesia; M. P. E. De Ferrari, of Genoa, Italy; Rev. J. N. Cushing, of Prome, Burmah; Dr. James Harris, of Yokohama, Japan; and William Brough, esq., of Franklin, Pennsylvania. To all of these gentlemen I am indebted for the careful collection of statistics and private correspondence.

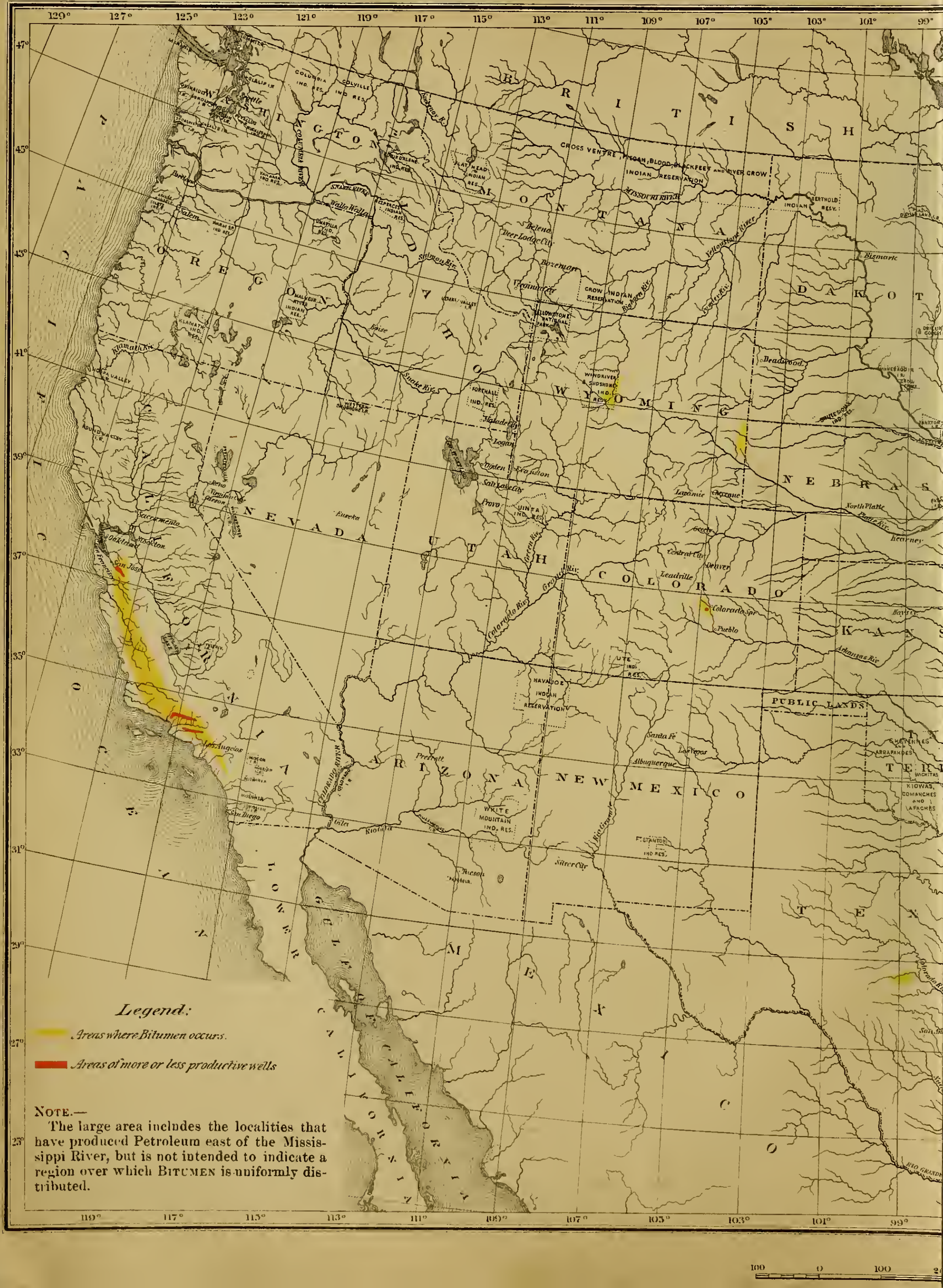
The extent and value of my researches upon the literature of petroleum have been largely due to the assistance that I have received from the librarians of Brown University, Harvard College, the Boston Public Library, and the American Philosophical Society, and especially to Professor J. D. Whitney, whose valuable private library was generously placed at my disposal. With the exception of a few East Indian publications, these libraries enabled me to verify all of the references with which I came in contact.

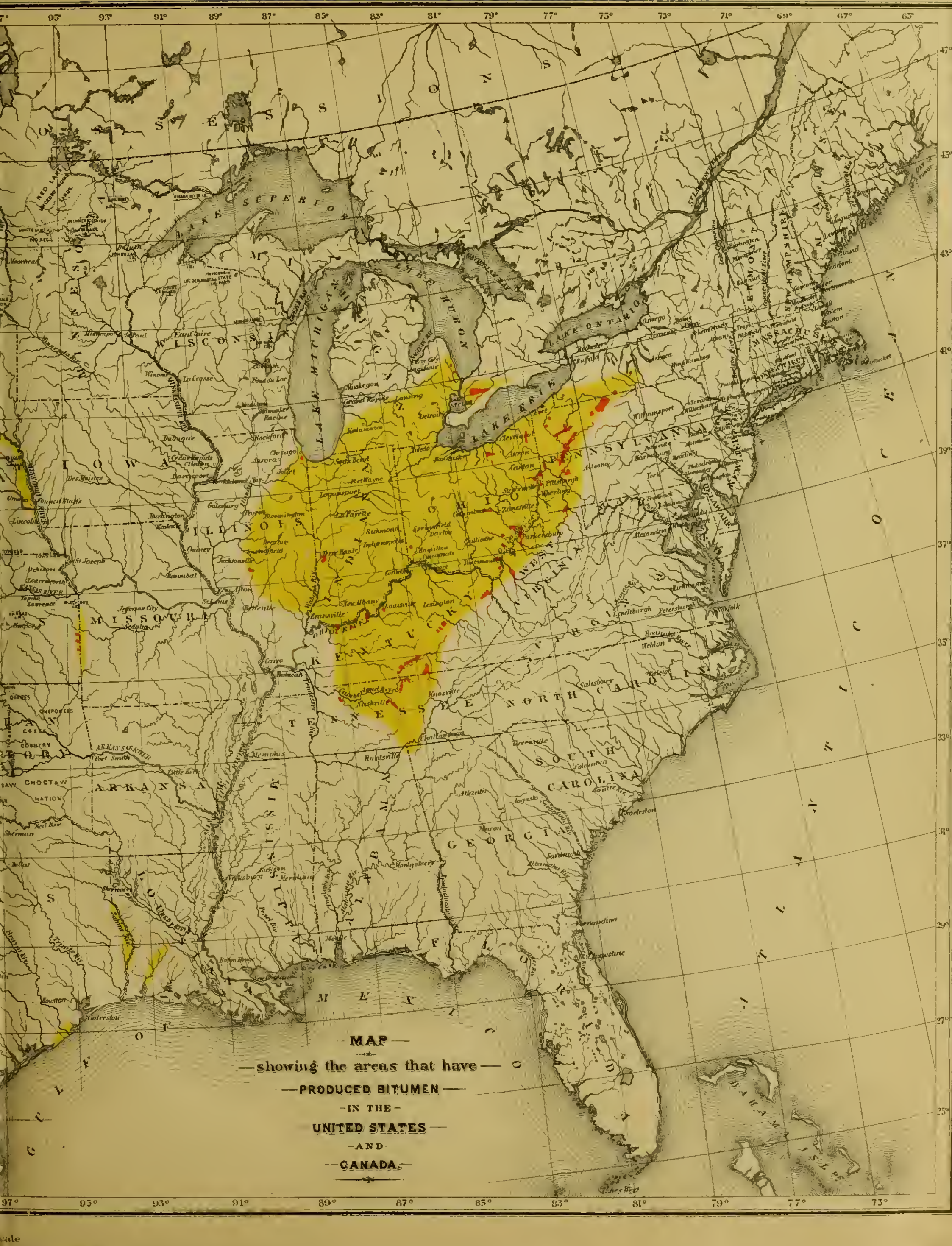
Mr. J. C. Welch, of New York, whose statistics and reports bear such a deservedly high reputation for reliability, has rendered me much varied and valuable assistance not otherwise available.

I wish further to express my obligations to Miss Laura Linton, who has assisted me in the preparation of this report, and to whose varied accomplishments I am indebted for many of the translations, and illustrations that add completeness and embellishment to the work; also to the officials of the Census Office, to whose uniform courtesy I am indebted for assistance in a somewhat arduous and perplexing undertaking.

Very respectfully,

S. F. PECKHAM,
Special Agent.


Legend:
Areas where Bitumen occurs.
Areas of more or less productive wells
NOTE.—
The large area includes the localities that have produced Petroleum east of the Mississippi River, but is not intended to indicate a region over which BITUMEN is uniformly distributed.
BRITISH
MONTANA
DAKOTA
WYOMING
NEBRASKA
COLORADO
KANSAS
NEVADA
UTAH
ARIZONA
NEW MEXICO
PUBLIC LANDS
LOWER CALIFORNIA
MEXICO
Salt Lake City
San Francisco
San Jose
Oakland
Stockton
Sacramento
Los Angeles
San Diego
Colorado Spr.
Pueblo
Denver
Leadville
Santa Fe
Albuquerque
Helena
Bozeman
Virginia City
Bismarck
Deadwood
Cheyenne
Laramie
Ogden
Logan
Provo
Eureka
Prescott
Tucson
Silver City
Salem
Walla Walla
Boise
Yellowstone River
Missouri River
Snake River
Colorado River
Arkansas River
Rio Grande
North Platte
Kearney



Scale
300 400 500 600 Miles

PART I.

THE NATURAL HISTORY OF PETROLEUM,

TOGETHER WITH

A DESCRIPTION OF THE METHODS EMPLOYED IN THE PRODUCTION, TRANSPORTATION, AND SALE OF PETROLEUM IN THE UNITED STATES,

AND

STATISTICS OF THE PRODUCTION OF PETROLEUM IN THE UNITED STATES AND FOREIGN COUNTRIES

DURING THE

YEAR ENDING MAY 31, 1880.

PART I.

Chapter I.—HISTORY OF THE DISCOVERY OF PETROLEUM AND THE DEVELOPMENT OF THE PETROLEUM INDUSTRY.

Section 1.—HISTORICAL NOTICE OF BITUMEN PRIOR TO THE YEAR 1800.

The word petroleum means rock-oil, and in its present form it is adopted into English from the Latin. Its equivalents in German are *Erdöl* (earth-oil) and *Steinöl* (stone-oil); in French and the other languages of southern Europe the word is *Pétrole*—equivalent to petroleum. Within a few years the Germans have also used the word "petroleum".

Petroleum is one of the forms of bitumen, and cannot be discussed historically except in connection with the other forms. These are:

Solid: Asphaltum.—German, *Asphalt*, *Erdharz*, or *Erdpech;* French, *Asphalte.*

Semi-fluid: Maltha.—French, *Goudron minéral;* Spanish, *Brea.*

Fluid: Petroleum; Volatile: Naphtha.—German, *Naphta*, from Persian *Nafta* or *Neft gil.*

Gaseous: Natural gas.—Of burning springs.

The word *Nafta* appears to have been used by the Persians, and its equivalent, *Naphtha*, has been frequently used in European literature to designate what is now called petroleum, and not the most volatile form of fluid bitumen occurring in nature. Solid bitumen is to be distinguished from coal in the manner of its occurrence, and also by the action of various solvents, especially benzole and carbon disulphide, which dissolve asphaltum, but have no action upon coal.

Bitumen has been known and applied to the uses of mankind from the dawn of history. Its very wide distribution has led to its frequent notice by observers of natural phenomena, and the records of such observations have been as widely extended as the occupation of the earth by civilized man. Herodotus wrote of the springs in the island of Zante as follows:

> I have myself seen pitch drawn up out of a lake and from water in Zacynthus; and there are several lakes there; the largest of them is seventy feet every way, and two orgyœ in depth; into this they let down a pole with a myrtle branch fastened to the end, and then draw up pitch adhering to the myrtle; it has the smell of asphalt, but is, in other respects, better than the pitch of Pieria. They pour it into a cistern dug near the lake, and when they have collected a sufficient quantity they pour it off from the cisterns into jars. (*a*)

The springs called Oyun Hit (the fountains of Hit) are celebrated by the Arabs and Persians, the latter calling them *Cheshmeh Kir* (the fountain of pitch). This liquid bitumen they call *Nafta;* and the Turks, to distinguish it from pitch, give it the name of *Hara sakir* (black mastic). Nearly all modern travelers who went to Persia and the Indies by way of the Euphrates before the discovery of the cape of Good Hope speak of this fountain of bitumen. Herodotus mentions that "eight days' journey from Babylon stands another city called Is, on a small river of the same name, which discharges its stream into the Euphrates. Now this river brings down with its water many lumps of bitumen, from whence the bitumen used in the wall of Babylon was brought". (*b*)

The people of the country have a tradition that when the tower of Babel was building they brought the bitumen from hence. At the pits of Kir ab ur Susiana bitumen is still collected in the same manner as related by Herodotus. (*c*) He says:

> At Ardericca is a well which produces three different substances, for asphalt, salt, and oil are drawn up from it in the following manner: It is pumped up by means of a swipe, and, instead of a bucket, half a wine skin is attached to it. Having dipped down with this, a man draws it up, and then pours the contents into a reservoir, and, being poured from this into another, it assumes these different forms: the asphalt and the salt immediately become solid, but the oil they collect, and the Persians call it *Rhadinance;* it is black, and emits a strong odor.

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a Herodotus, i, 119, iv, 195; B. S. G. F., xxv, 62; J. S. A., vii, 639. *b Ibid.*, i, 179; J. S. A., vii, 639, 640. *c Ibid.*, vi, 119.

Strabo (*a*) mentions the occurrence of bitumen in the valley of Judea, and describes the commerce carried on in this article by the Arab Nabathenes with the Egyptians for the purpose of embalming; also the manner of its occurrence, rising during or after earthquake shocks to the surface of the Dead sea and forming masses resembling islands. Diodorus, of Sicily, describes the lake Asphaltites and the manner in which the savage inhabitants of the country construct rafts, and continues:

These barbarians, who have no other kind of commerce, carry their asphalt to Egypt and sell it to those who make a profession of embalming bodies, because, without the mixture of this material with the other aromatics, it would be difficult for them to preserve them for a long time from the corruption to which they are liable. (*b*)

This bitumen, with that from the springs of Hit, on the Euphrates, of which Eratosthenes has given such interesting details, and which served to cement the bricks of Babylon, is also used for coating ships, (*c*) and is still used in our own time for coating boats on the Euphrates. (*d*)

The semi-fluid bitumen was used in the construction of Nineveh and Babylon to cement bricks and slabs of alabaster, and the grand mosaic pavements and beautifully inscribed slabs used in the palaces and temples of these ancient cities, many of which were of enormous size, were fastened in their places with this material. It was also used to render cisterns and silos for the preservation of grain water-tight, and some of these structures of unknown antiquity are still found intact in the ancient cities of Egypt and Mesopotamia. The naphtha is more highly valued than the solid bitumen, the most fluid varieties being used in lamps. The Persians also manufacture dried dung in long sticks, which are dipped in naphtha and burned for lights, and it is also used for cooking and heating; but in order to avoid the unendurable smell a peculiar kind of chimney is carried into each room. Cotton wicks are also used in naphtha to some extent. The white or colorless naphtha, which is most rare, is used by the apothecaries. (*e*)

Aristotle, Strabo, Plutarch, Pliny, and others describe at some length deposits of bitumen occurring in Albania, on the eastern shores of the Adriatic sea, (*f*) and similar notices of petroleum springs and gas wells in China occur in the earliest records of that ancient people. Pliny and Dioscorides described the oil of Agrigentum, which was used in lamps, under the name of "Sicilian oil".

The soft bitumen in the Euphrates valley is that of which we have the earliest mention. (*g*) The word translated *slime* in the English version of Genesis xi, 3, is *ἄσφαλτος* in the Septuagint and *bitumen* in the Vulgate, and this is what is meant. The great abundance of petroleum at Baku, on the Caspian sea, and the remarkable sight presented by the flaming streams of oil and discharges of gas, have been the subject of many descriptions. The fire temple at Baku has had a special interest in connection with India, not only from its general similarity to that of Jawálamúhki, near Kangra, in the Punjab, (*h*) but also from the circumstance that the Baku temple has for a long time and down to the present day been, like the other, a place of Hindoo pilgrimage. The great conflagrations of oil upon the ground have not been constant, and hence many travelers do not mention them.

Marco Polo describes the great abundance of the discharges of oil at Baku, and says that people came from a vast distance to collect it. (*i*) Baku is described by Kaempfer, who was there in 1684. (*j*) In 1784 it was visited by Forster, on his journey from India to England, who has given an account of the place and of the Hindoo merchants and mendicants residing there.

Between Kaempfer and Forster came Jonas Hanway, who gives a description of Baku, the fire temple, and the Hindoos, and the great quantities of oil obtained at that time, chiefly from certain islands in the Caspian sea. Descriptions are given by other travelers, ancient and modern, of this oil region,(*k*) of the copious discharges of white and black naphtha, the streams of flaming oil on the hillsides, the gas and the fire temple, and the explosive effects of the ignition of the gas mixed with atmospheric air. (*l*)

A tradition is preserved in Plutarch that a Macedonian who had charge of Alexander's baggage is said to have dug on the banks of the Oxus: "There came out, which diffired nothing from natural oile, having the glosse and fatness so like as there could be discovered no differense between them." (*m*)

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a Tome XVI, ch. ii.

b Tome 1 L, II., cap. xxix.

c Strabo, I, xvi, cxii.

d Lartet, B. S. G. F., xxiv, p. 12.

e Ritter's *Erdkunde*, II, 578.

f Strabo, VI, 763; Pliny, N. H., VII, 13; Josephus, B. I., IV, 8, 4; Tacitus, Hist., V, 6; Mandeville, Rochon, etc. Plutarch: Life of Sylla; Dion Cassius, Rom. Hist. c. XLI; Ælian Variæ Hist., XIII, 16; quoted in B. S. G. F., xxv, 21.

g Herod, I, 179; Philostr. Apoll. Tyan., I, 17; D'Herbelot, Biblioth. *Or. o. v. Hit.*

h G. T. Vigne, *Travels in Cashmir and Little Thibet*, 1842, p. 133.

i Book I, ch. III (vol. I, p. 46, Col. Yule's ed., 1871), note in Marsden's ed.

j Amoenit. Exot., p. 224. Colburn's Nat. Libr., i, 263.

k *Wonders of the East*, by Friar Jordanus, p. 50 (Colonel Yule's note); *Keppel's Journey from India to England*, 1824; *A Journey from London to Persepolis*, by J. Usher, 1865; Morier's *Journey*; Kinneir's *Persia*; *Some Years' Travels*, by Tho. Herbert, 1638.

l I am indebted for many of the preceding facts and references to an excellent article on "Naphtha" by M. C. Cooke, J. S. A., vii, 638; also, Colonel R. Maclagan, on the "Geographical Distribution of Petroleum and Allied Products", P. B. A. A. S., 1871, 180.

m Sir Thomas North's translation of *Plutarch's Lives*, ed. 1631, p. 702.

The occurrence of petroleum in North America was noticed by the earliest explorers, as the Indians dwelling in the vicinity of the great lakes applied it to several purposes, and thus brought it to the attention of those who went among them; but the earliest mention that has come under my notice is of 1629. A Franciscan missionary, Joseph de la Roche D'Allion, who crossed the Niagara river into what is now the state of New York, wrote a letter, in which he mentions the oil-springs and gives the Indian name of the place, which he explained to mean, "There is plenty there." This letter was published in Sagard's *Histoire du Canada*, 1632, and subsequently in *Le Clerc.*

Peter Kalm published in Swedish about the middle of the last century a book of travels, in which was a map, on which the springs on Oil creek were properly located. This book has been translated into English, and an edition was published in London in 1772.

In the first volume of the *Massachusetts Magazine*, published in 1789, appears the following notice: (*a*)

In the northern part of Pennsylvania is a creek called Oil creek, which empties into the Allegheny river. It issues from a spring, on which floats an oil similar to that called Barbadoes tar, and from which one may gather several gallons in a day. The troops sent to guard the western posts halted at this spring, collected some of the oil, and bathed their joints with it. This gave them great relief from the rheumatism with which they were afflicted. The water, of which the troops drank freely, operated as a gentle purge.

The earliest records of voyages and travels among the Seneca Indians who occupied northwestern Pennsylvania and southwestern New York contain observations respecting the reverence paid the oil-springs of Oil creek and the contiguous valleys by this people, not only using it for medicinal purposes, but also in religious observances.

The French commander of Fort Duquesne in the year 1750 writes as follows to General Montcalm:

I would desire to assure you that this is a most delightful land. Some of the most astonishing natural wonders have been discovered by our people. While descending the Allegheny, fifteen leagues below the mouth of the Conewango and three above the Venango, we were invited by the chief of the Senecas to attend a religious ceremony of his tribe. We landed, and drew up our canoes on a point where a small stream entered the river. The tribe appeared unusually solemn. We marched up the stream about half a league, where the company, a band it appeared, had arrived some days before us. Gigantic hills begirt us on every side. The scene was really sublime. The great chief then recited the conquests and heroism of their ancestors. The surface of the stream was covered with a thick scum, which, upon applying a torch at a given signal, burst into a complete conflagration. At the sight of the flames the Indians gave forth the triumphant shout that made the hills and valleys re-echo again. Here, then, is revived the ancient fire-worship of the East; here, then, are the children of the Sun. (*b*)

In 1765 the English government sent an embassy to the court of Ava, in Burmah. In the journal of that embassy, by Major Michael Symes, may be found a description of the petroleum wells in the neighborhood of Yenangyoung (Earth-oil creek), a small tributary of the Irrawaddy. For an unknown period the whole of Burmah and portions of India have been supplied with illuminating oil from this source, particularly those regions that are reached by the Irrawaddy and its tributaries.

On page 261 of Symes' *Journal* we read:

After passing various lands and villages, we got to Yenangyoung, or Earth-oil creek, about two hours past noon. We were informed that the celebrated wells of petroleum which supply the whole empire and many parts of India with that useful product were five miles to the east of this place. The mouth of the creek was crowded with large boats waiting to receive a lading of oil, and immense pyramids of earthen jars were raised in and around the village, disposed in the same manner as shot and shell are piled in an arsenal. This is inhabited only by potters, who carry on an extensive manufactory and find full employment. The smell of the oil is extremely offensive. We saw several thousand jars filled with it ranged along the bank; some of these were continually breaking, and the contents, mingling with the sand, formed a very filthy consistence.

Late in the last century springs of petroleum were noticed in West Virginia, in Ohio, and in Kentucky, as explorers and settlers began to penetrate the country west of the Alleghany mountains.

SECTION 2.—HISTORICAL NOTICE OF BITUMEN FROM THE YEAR 1800 TO 1850.

In Europe, early in the present century, chemists examined the bitumen of the Val de Travers. (*c*) The gas springs of Karamania, noticed by Ctesias more than two thousand years before, again attracted attention, (*d*) and the asphalt deposits of Albania, mentioned by Strabo and Pliny, were again described by Pouqueville. (*e*)

In 1811 Dr. Nicholas Nugent visited the West Indies, and on his return to England wrote an account of the famous pitch lake of Trinidad, near the mouth of the river Orinoco. (*f*) He described the wonderful beauty of the tropical island, with its more wonderful lake of solid yet plastic bitumen, on which were pools of water containing fish and islands of verdure thronged with brilliant birds.

From 1820 to 1830 remarkable activity was manifested in the investigation of the nature and occurrence of bituminous substances. The Hon. George Knox read a communication to the Royal Society of Great Britain, in which he noticed the wide distribution of these substances in nature, and the fact that even so-called eruptive rocks

a Am. C., iii, 174.
b Henry's *Early and Later History of Petroleum*, p. 11.
c De Saussure, A. C. N. P. (2), iv, 314, 620, 308.
d Beaufort: *Survey of the Coast of Karamania*, 1820, p. 24.
e *Voyage en Grèce*, 1820, 1, 271; B. S. G. F., xxv, 22.
f T. G. S., (1) 1, 63.

were rarely found entirely destitute of bitumen as an ingredient. This paper attracted much attention. (*a*) In 1824 Reichenbach discovered paraffine in the products of the destructive distillation of wood, (*b*) and in the following year Gay-Lussac analyzed it. (*c*)

In 1826 the British government sent a second embassy to Ava, and in the journal of that embassy the ambassador, Hon. John Crawfurd, again describes the petroleum wells of Rangoon, and furnishes many details respecting the method of their operation and the amount of their product. (*d*)

Boussingault investigated the bitumen of Pechelbronn, on the lower Rhine, and compared its peculiarities with those of bitumens from other localities. His work on these substances became very celebrated, and has been very widely quoted. (*e*) These researches created a lively interest in France, and led to much experimenting upon both solid and liquid bitumens, with a view to ascertaining the purposes to which they might be applied.

During this period the first well was bored in the United States that produced petroleum in any considerable quantity. As the first well bored or drilled for brine was the legitimate precursor of all the petroleum wells in the country, an historical account of it is introduced here, taken from a paper written by Dr. J. P. Hale, of Charleston, West Virginia, for the volume prepared by Professor M. F. Maury, and issued by the State Centennial Board, on the resources and industries of the state. He says:

It was not until 1806 that the brothers, David and Joseph Ruffner, set to work to ascertain the source of the salt water, to procure, if possible, a larger supply and of better quality, and to prepare to manufacture salt on a scale commensurate with the growing wants of the country.

The Salt Lick, or "the Great Buffalo Lick", as it was called, was just at the river's edge, 12 or 14 rods in extent, on the north side, a few hundred yards above the mouth of Campbell's creek, and just in front of what is now known as the "Thoroughfare Gap", through which, from the north, as well as up and down the river, the buffalo, elk, and other ruminating animals made their way in vast numbers to the lick. * * *

In order to reach, if possible, the bottom of the mire and oozy quicksand through which the salt water flowed they (the Ruffner brothers) provided a straight, well-formed, hollow sycamore tree, with 4 feet internal diameter, sawed off square at each end. This is technically called a "gum". This gum was set upright on the spot selected for sinking, the large end down, and held in its perpendicular position by props or braces on the four sides. A platform, upon which two men could stand, was fixed about the top; then a swape was erected, having its fulcrum in a forked post set in the ground close by. A large bucket, made from half of a whisky barrel, was attached to the end of the swape by a rope, and a rope was attached to the end of the pole, to pull down on, to raise the bucket. With one man inside the gum, armed with pick, shovel, and crowbar, two men on the platform on top to empty and return the bucket, and three or four to work the swape, the crew and outfit were complete.

After many unexpected difficulties and delays the gum at last reached what seemed to be rock bottom at 13 feet. Upon cutting it with picks and crowbars, however, it proved to be but a shale or crust about 6 inches thick of conglomerated sand, gravel, and iron. Upon breaking through this crust the water flowed up into the gum more freely than ever, but with less salt.

Discouraged at this result, the Ruffner brothers determined to abandon this gum and sink a well out in the bottom, about 100 yards from the river. This was done, encountering, as before, many difficulties and delays. When they had gotten through 45 feet of alluvial deposit they came to the same bed of sand and gravel upon which they had started at the river. To penetrate this they made a 3½-inch tube of a 20-foot oak log by boring through it with a long-shanked auger. This tube, sharpened and shod with iron at the bottom, was driven down, pile-driver fashion, through the sand to the solid rock. Through this tube they then let down a glass vial with a string, to catch the salt water for testing.

They were again doomed to disappointment. The water, though slightly brackish, was less salt than that at the river. They now decided to return to the gum at the river, and, if possible, put it down to the bed-rock. This they finally succeeded in doing, finding the rock at 16 to 17 feet from the surface.

As the bottom of the gum was square and the surface of the rock uneven, the rush of outside water in the gum was very troublesome. By dint of cutting and trimming from one side and the other, however, they were at last gotten nearly to a joint, after which they resorted to thin wedges, which were driven here and there as they would "do the most good".

By this means the gum was gotten sufficiently tight to be so bailed out as to determine whether the salt water came up through the rock. This turned out to be the case. The quantity welling up through the rock was extremely small, but the strength was greater than any yet gotten, and this was encouraging. They were anxious to follow it down, but how? They could not blast a hole down there under water; but this idea occurred to them: They knew that rock-blasters drilled their powder holes 2 or 3 feet deep, and they concluded they could, with a longer and larger drill, bore a correspondingly deeper and larger hole. They fixed a long iron drill, with a 2½-inch chisel bit of steel, and attached the upper end to a spring pole with a rope. In this way the boring went on slowly and tediously, till on the 1st of November, 1807, at 17 feet in the rock, a cavity or fissure was struck, which gave an increased flow of stronger brine. This gave new encouragement to bore still further; and so, by welding increasing length of shaft to the drill from time to time, the hole was carried down to 28 feet, where a still larger and stronger supply of salt water was gotten.

Having now sufficient salt water to justify it, they decided and commenced to build a salt furnace, but, while building, continued the boring, and on the 15th January, 1808, at 40 feet in the rock and 58 feet from the top of the gum, were rewarded by an ample flow of strong brine for their furnace, and ceased boring.

Now was presented another difficulty: how to get the stronger brine from the bottom of the well, undiluted by the weaker brines and fresh water from above. There was no precedent here; they had to invent, contrive, and construct anew. A metal tube would naturally suggest itself to them; but there were neither metal tubes, nor sheet metal, nor metal workers, save a home-made blacksmith, in all this region, and to bore a wooden tube 40 feet long, and small enough in external diameter to go in the 2½-inch hole, was impracticable. What they did do was to whittle out of two long strips of wood two long half tubes of the proper size, and, fitting the edges carefully together, wrap the whole from end to end with small twine. This, with a bag of wrapping near the lower end, to fit as nearly as practicable, water tight, in the 2½-inch hole, was cautiously pressed down to its place, and found to answer the purpose perfectly, the brine flowed up freely through the tube into the gum, which was now provided with a water-tight floor or bottom to hold it, and from which it was raised by the simple swape and bucket.

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a P. T., 1823; A. C. et P. (2), xxv, 178.
b P. M. (2), i, 402.
c A. C. et P. (2), l, 78.
d *Journal of an Embassy to the Court of Ava*, 1834.
e *Constitution of Bitumens*, P. J. (2), ix, 487.

Thus was bored and tubed, rigged and worked, the first rock-bored salt-well west of the Alleghanies, if not in the United States. The wonder is not that it required eighteen months or more to prepare, bore, and complete this well for use, but, rather, that it was accomplished at all under the circumstances. In these times, when such a work can be accomplished in as many days as it then required months, it is difficult to appreciate the difficulties, doubts, delays, and general troubles that then beset them. Without preliminary study, previous experience, or training, without precedents in what they undertook, in a newly settled country, without steam-power, machine-shops, skilled mechanics, suitable tools or materials, failure rather than success might reasonably have been predicted. * * *

For interesting facts in this history of the boring of the first well I am indebted to a MS. by the late Dr. Henry Ruffner, and for personal recollections and traditions I am indebted to General Lewis Ruffner, Isaac Ruffner, W. D. Shrewsberry, Colonel B. H. Smith, Colonel L. I. Woodyard, W. C. Brooks, and others, and my own experiences for the last thirty years. * * *

Other important improvements were gradually made in the manner of boring, tubing, and pumping wells, etc. The first progress made in tubing, after Ruffner's compound wood-and-wrapping-twine tube, was made by a tinner who had located in Charleston. * * * He made tin tubes in convenient lengths, and soldered them together as they were put down the well. The refinement of screw joints had not yet come, but followed shortly after, in connection with copper pipes, which soon took the place of tin, and these are recently giving place to iron.

In the manner of bagging the wells, that is, in forming a water-tight joint around the tube to shut off the weaker waters above from the stronger below, a simple arrangement, called a "seed-bag", was fallen upon, which proved very effective, and which has survived to this day, and has been adopted wherever deep boring is done as one of the standard appliances for the purpose for which it is used. This seed-bag is made of buckskin or soft calfskin, sewed up like the sleeve of a coat or leg of a stocking, made 12 to 15 inches long, about the size of the well hole, and open at both ends; this is slipped over the tube and one end securely wrapped over knots placed on the tube to prevent slipping. Some six or eight inches of the bag is then filled with flaxseed, either alone or mixed with powdered gum tragacanth; the other end of the bag is then wrapped like the first, and the tube is ready for the well. When to their place—and they are put down any depth to hundreds of feet—the seed and gum soon swell from the water they absorb, till a close fit and water-tight joint are made. * * *

In 1831 William Morris, or "Billy" Morris, as he was familiarly called, a very ingenious and successful practical well-borer, invented a simple tool, which has done more to render deep boring practicable, simple, and cheap than anything else since the introduction of steam.

This tool has always been called here "slips", but in the oil regions they have given it the name of "jars". It is a long double-link, with jaws that fit closely, but slide loosely up and down. They are made of the best steel, are about 30 inches long, and fitted, top and bottom, with pin and socket joint, respectively. For use they are interposed between the heavy iron sinker, with its cutting chisel-bit below, and the line of auger poles above. Its object is to let the heavy sinker and bit have a clear, quick, cutting fall, unobstructed and unincumbered by the slower motion of the long line of auger poles above. In the case of fast auger or other tools in the well, they are also used to give heavy jars upward or downward, or both, to loosen them. From this use the oil-well people have given them the name of "jars".

Billy Morris never patented his invention, and never asked for nor made a dollar out of it; but as a public benefactor he deserves to rank with the inventors of the sewing-machine, reaping-machine, planing-machine, printing cylinders, cotton-gin, etc. This tool has been adopted into general use wherever deep boring is done, but outside of Kanawha few have heard of Billy Morris, or know where the slips or jars came from. * * *

The Kanawha borings have educated and sent forth a set of skillful well-borers all over the country, who have bored for water for irrigation on the western plains, for artesian wells for city, factory, or private use, for salt water at various places, for oil all over the country, for geological or mineralogical explorations, etc.

Nearly all the Kanawha salt-wells have contained more or less petroleum, and some of the deepest wells a considerable flow. Many persons now think, trusting to their recollections, that some of the wells afforded as much as 25 to 50 barrels per day. This was allowed to flow over from the top of the salt cisterns to the river, where, from its specific gravity, it spread over a large surface, and by its beautiful iridescent hues and not very savory odor could be traced for many miles down the stream. It was from this that the river received the nickname of "Old Greasy", by which it was for a long time familiarly known by Kanawha boatmen and others.

At that time this oil not only had no value, but was considered a great nuisance, and every effort was made to tube it out and get rid of it. It is now the opinion of some competent geologists, as well as of practical oil men, that very deep borings, say 2,500 feet, would penetrate rich oil-bearing strata, and possibly inexhaustible supplies of gas.

In Ohio salt was manufactured at the "Old Scioto salt works", in Jackson county, as early as 1798, from brine obtained from dug wells. In 1808, after the successful boring of the Ruffner well on the Kanawha, bored wells were substituted for dug wells very successfully, and salt-wells were soon in operation in other localities. The valley of the Muskingum from Zanesville to Marietta soon became noted, and the valley of Duck creek, since the center of the Washington county petroleum fields, was first famous for its salt-wells.

The following description is from an article in the *American Journal of Science* (1), xxiv, 63, by Dr. S. P. Hildreth, of Marietta:

Since the first settlement of the regions west of the Appalachian range the hunters and pioneers have been acquainted with this oil. Rising in a hidden and mysterious manner from the bowels of the earth, it soon arrested their attention, and acquired great value in the eyes of these simple sons of the forest. Like some miraculous gift from heaven, it was thought to be a sovereign remedy for nearly all the diseases common to those primeval days, and from its success in rheumatism, burns, coughs, sprains, etc., was justly entitled to all its celebrity. It acquired its name of Seneca oil, that by which it is generally known, from having first been found in the vicinity of Seneca lake, New York. From its being found in limited quantities, and its great and extensive demand, a small vial of it would sell for 40 or 50 cents. It is at this time in general use among the inhabitants of the country for saddle bruises and that complaint called the scratches in horses. It seems to be peculiarly adapted to the flesh of horses, and cures many of their ailments with wonderful certainty and celerity. Flies and other insects have a natural antipathy to its effluvia, and it is used with much effect in preventing the deposit of eggs by the "blowing fly" in the wounds of domestic animals during the summer months. In neighborhoods where it is abundant it is burned in lamps in place of spermaceti oil, affording a brilliant light, but filling the room with its own peculiar odor. By filtering it through charcoal, much of this empyreumatic smell is destroyed and the oil greatly improved in quality and appearance. It is also well adapted to prevent friction in machinery, for, being free of gluten, so common to animal and vegetable oils, it preserves the parts to which it is applied for a long time in free motion; where a heavy vertical shaft runs in a socket, it is preferable to all or any other articles. This oil rises in greater or less abundance in most of the salt-wells of the Kanawha, and, collecting as it rises, in the head on the water, is removed from time to time with a ladle.

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On the Muskingum river the wells afford but little oil, and that only during the time the process of boring is going on; it ceases soon after the wells are completed, and yet all of them abound more or less in gas. A well on Duck creek, about 30 miles north of Marietta, owned by Mr. McKee, furnishes the greatest quantity of any in this region. It was dug in the year 1814, and is 475 feet in depth.

The rocks passed were similar to those on the Muskingum river above the flint stratum, or like those between the flint and salt deposit at McConnellsville. A bed of coal 2 yards in thickness was found at the depth of 100 feet, and gas at 144 feet, or 41 feet above the salt-rock. The hills are sandstone based on lime, 150 or 200 feet in height, with abundant beds of stone-coal near their feet. The oil from this well is discharged periodically at intervals of from two to four days, and from three to six hours duration at each period. Great quantities of gas accompany the discharges of oil, which for the first few years amounted to from 30 to 60 gallons at each eruption. The discharges at this time are less frequent, and diminished in quantity, affording only about a barrel per week, which is worth at the well from 50 to 75 cents a gallon. A few years ago, when the oil was most abundant, a large quantity had been collected in a cistern holding 30 or 40 barrels. At night, some one engaged about the works approached the well-head with a lighted candle. The gas instantly became ignited and communicated the flame to the contents of the cistern, which, giving way, suffered the oil to be discharged down a short declivity into the creek, whose waters pass with a rapid current close to the well. The oil still continued to burn most furiously; and, spreading itself along the surface of the stream for half a mile in extent, shot its flames to the tops of the highest trees, exhibiting the * * * spectacle of a river actually on fire.

It is probable that wells were drilled for salt in the neighborhood of Tarentum, on the Allegheny river, above Pittsburgh, about 1810. These wells were all comparatively shallow, but in many of them small quantities of petroleum often interfered more or less with their successful operation.

Salt-wells were bored along the Big Sandy river and its tributaries across Kentucky and into Tennessee, and in many of them petroleum appeared in sufficient quantity to be troublesome. In 1818 or 1819 a well was bored on the south fork of the Cumberland river, in Wayne county, Kentucky, that produced petroleum in such quantities that it was abandoned for brine and was almost forgotten for more than thirty years. This well has acquired some notoriety under the name of the Beatty well, and is still yielding small quantities of oil. Farther west, in Barren and Cumberland counties, Kentucky, along the Cumberland river and its tributaries, numerous salt-wells were bored, and in many of them petroleum appeared. In 1829 the famous American well was bored near the bed of Little Rennox creek, near Burkesville, Kentucky. The following account of the phenomena attending its completion is to be found in *Niles' Register* (3), xiii, 4:

Some months since, in the act of boring for salt water on the land of Mr. Lemuel Stockton, situated in the county of Cumberland, Kentucky, a vein of pure oil was struck, from which it is almost incredible what quantities of the substance issued. The discharges were by floods, at intervals of from two to five minutes, at each flow vomiting forth many barrels of pure oil. I witnessed myself, on a shaft that stood upright by the aperture in the rock from which it issued, marks of oil 25 or 30 feet perpendicularly above the rock. These floods continued for three or four weeks, when they subsided to a constant stream, affording many thousand gallons per day. This well is between a quarter and a half mile from the bank of the Cumberland river, on a small rill (creek), down which it runs to the Cumberland river. It was traced as far down the Cumberland as Gallatin, in Sumner county, Tennessee, nearly 100 miles. For many miles it covered the whole surface of the river, and its marks are now found on the rocks on each bank. About 2 miles below the point on which it touched the river it was set on fire by a boy, and the effect was grand beyond description. An old gentleman who witnessed it says he has seen several cities on fire, but that he never beheld anything like the flames which rose from the bosom of the Cumberland to touch the very clouds.

Referring to this article and the well, a correspondent of the *Burkesville Courier*, C. L. S. Mathews, esq., under date October 11, 1876, says:

This well, from the long continued yield of oil, is one of the most remarkable wells in America. When first struck, oil flowed from it at the rate of 1,000 barrels per day, and for many years, in fact, until the year 1860, it yielded a plentiful supply of oil. We have been informed by several old citizens, who witnessed the burning of the oil on the surface of the river, that the oil burned down the river about 56 miles, and that for miles all the vegetation and foliage along the river bank was destroyed. Some years after this strike was made several individuals took charge of the well, saved the oil, and put up several hundred thousand bottles, which they sold all through this country and some parts of Europe as the "American Medicinal Oil, Burkesville, Kentucky".

During the decade from 1830 to 1840 the attention of the most distinguished French chemists was directed to the investigation of bitumens. Boussingault continued his general researches, and in 1837 published a classical paper on the subject. (*a*) Virlet d'Oust propounded the first theory regarding the origin of bitumens in 1834, (*b*) and the asphalt of the Dead sea, (*c*) of Pyrmont, (*d*) and near Havana, Cuba, were examined. (*e*) Hess wrote on the products of dry distillation (*f*) and was reviewed by Reichenbach, (*g*) who, with Laurent, (*h*) continued his researches upon paraffine. In 1833 Professor Benjamin Silliman, sr., contributed an article to the *American Journal of Science* (1), xxiii, 97, in which he describes the celebrated oil-spring of the Seneca Indians near Cuba, New York, as follows:

The oil-spring, or fountain, rises in the midst of a marshy ground; it is a muddy and dirty pool of about 18 feet in diameter, and is nearly circular in form. There is no outlet above ground, no stream flowing from it, and it is, of course, a stagnant water, with no other circulation than that which springs from changes of temperature and from the gas and petroleum which are constantly rising through the pool.

We are told that the odor of petroleum is perceived at a distance in approaching the spring. This may not improbably be true in particular states of the wind, but we did not distinguish any peculiar smell until we arrived on the edge of the fountain. Here its

a A. C. et P. (2), lxiv, 141.
b B. S. G. F. (1), iv, 372.
c *Journal des Savants*, 1855, 596.
d Rozet, B. S. G. F. (1), vii, 138.
e Taylor & Clemson, P. M., x, 161.
f *Pog. An.*, xxxvi, 417, xxxvii, 534.
g *Jour. für Ökonom. Chem.*, viii, 445.
h Laurent, A. C. et P. (2), liv, 392, lxiv, 321.

peculiar character becomes very obvious. The water is covered with a thin layer of petroleum or mineral oil, giving it a foul appearance, as if coated with dirty molasses, having a yellowish-brown color. Every part of the water was covered by this film, but it had nowhere the iridescence which I recollect to have observed at Saint Catharine's well, a petroleum fountain near Edinburgh, in Scotland. There the water was pellucid, and the lines produced by the oil were brilliant, giving the whole a beautiful appearance. The difference is, however, easily accounted for. Saint Catharine's well is a lively, flowing fountain, and the quantity of petroleum is only sufficient to cover it partially, while there is nothing to soil the stream; and in the present instance the stagnation of the water, the comparative abundance of the petroleum, and the mixture of leaves and sticks and other productions of a dense forest, preclude any beautiful features. There are, however, upon this water, here and there, spots of what seems to be a purer petroleum, probably recently risen, which is free from mixture, and which has a bright, brownish-yellow appearance, lively and sparkling; and were the fountain covered entirely with this purer production it would be beautiful.

They collect the petroleum by skimming it, like cream from a milk-pan. For this purpose they use a broad, flat board, made thin at one edge like a knife; it is moved flat upon and just under the surface of the water, and is soon covered by a coating of the petroleum, which is so thick and adhesive that it does not fall off, but is removed by scraping the instrument upon the lip of a cup. It has then a very foul appearance, like very dirty tar or molasses, but it is purified by heating and straining it while hot through flannel or other woolen stuff. It is used by the people of the vicinity for sprains and rheumatism and for sores on their horses, it being in both cases rubbed upon the part. It is not monopolized by any one, but is carried away freely by all who care to collect it, and for this purpose the spring is frequently visited. I could not ascertain how much is annually obtained; the quantity must be considerable. It is said to rise more abundantly in hot weather than in cold.

I cannot learn that any considerable part of the large quantities of petroleum used in the eastern states under the name of Seneca oil comes from the spring now described. I am assured that its source is about 100 miles from Pittsburgh, on Oil creek, which empties into the Allegheny river in the township and county of Venango. It exists there in great abundance, and rises in purity to the surface of the water; by dams, inclosing certain parts of the river or creek, it is prevented from flowing away, and it is absorbed by the blankets, from which it is wrung.

The petroleum sold in the eastern states under the name of Seneca oil is of a dark brown color, between that of tar and molasses, and its degree of consistence is not dissimilar, according to the temperature; its odor is strong and too well known to need description.

In an article entitled "Observations on the bituminous coal deposits of the valley of the Ohio" Dr. S. P. Hildreth, in 1836, notices the occurrence of petroleum on the Little Kanawha. (*a*)

The decade from 1840 to 1850 was remarkable for the number of travelers who, in different parts of the world, noticed the occurrence of bitumen, and also for several elaborate researches upon the geological occurrence and chemical constitution of its different varieties. Travelers visited the far east, and even China, (*b*) and gave glowing descriptions of the naphtha springs of Persia, (*c*) the fire-worshipers of Baku, and the fire wells of China. (*d*) The naphtha springs of Persia are nowhere else described in such detail as in Ritter's *Erdkunde*, published in 1841. (*e*) Boussingault (*f*) continued his researches in France, and in our own country, Percival, (*g*) in Connecticut, and Beck, (*h*) in New York, called attention to the fact that bitumen was of frequent occurrence in thin veins traversing the metamorphic and eruptive rocks of Connecticut, New York, and New Jersey. In 1842 E. W. Binney first called attention to the occurrence of petroleum in the Down Holland Moss, which may be said to have been the first step toward the great paraffine oil industry of Scotland. (*i*)

SECTION 3.—THE RISE OF THE PARAFFINE OIL INDUSTRY.

This decade witnessed the rise of the paraffine-oil industry in Europe and the United States. The success of the manufacture of shale oil at Bathgate, Scotland, by E. W. Binney & Co., from so-called Boghead coal, has been more popularly known through Mr. James Young, one of Mr. Binney's associates. The lessening supply of sperm and whale oils, and their consequent advance in price, led to various attempts to invent or discover a cheaper substitute, and as a consequence the oils manufactured at Bathgate were eagerly sought in the market, especially when lamps were formed that would burn them with complete success. Mr. Binney claims to have first called these oils paraffine oils, but those used for illumination have been more widely known as kerosene. (*j*)

In the United States experiments were commenced in the winter of 1850–'51 by Luther and William Atwood near Boston, which resulted in the establishment in 1853 of the United States Chemical Manufacturing Company at Waltham, Massachusetts. This company manufactured from coal-tar an oil called "Coup oil", which was used, mixed with cheap animal and vegetable oils, for lubricating machinery. In 1854 Mr. Joshua Merrill became connected with this company, but in 1855 he left it and became connected with the Downer Kerosene Oil Company of Boston, with which he has remained to the present time. These three gentlemen were the pioneers in the manufacture of paraffine oils in the United States. In 1857 the Downer Kerosene Oil Company commenced the manufacture of hydrocarbon oils from the Albert coal (a kind of asphaltum), obtained from New Brunswick, and they had works in Boston, Massachusetts, and in Portland, Maine. William Atwood had charge of the works in

a A. J. S. (1), xxix, 121.
b Pottinger; W. Robinson; Ainsworth.
c Kinnier: *Persia.*
d Humboldt: *Asie Centrale*, ii, 519; *Cosmos*, 1, 232; Bohn 1, 221.
e *Die Erdkunde von Asien*, vols. vii, viii, ix, x, and xi.
f A. C. et P. (2), lxxiii, 442.
g A. J. S. (3), xvi, 130.
h A. J. S. (1), xlv, 335.
i Papers read before the Manchester (England) Geological Society, 1842–'43.
j Communication from Mr. Binney to S. F. P.

NOTE.—The claims of Selligue as the original inventor of paraffine oils distilled from shale are stated elsewhere. I think the paraffine-oil industry took its rise at this time.

Portland, Joshua Merrill of those in Boston, and Luther Atwood of a large establishment belonging to the New York Kerosene Oil Company near Brooklyn, Long Island. Before these gentlemen left Waltham they had "experimented upon bituminous coals, bituminous shales, asphaltum, and petroleums—petroleums and bitumens from nearly all the known sources, and many different varieties of coals and shales. They succeeded in producing what they regarded at that time as a good lubricating oil from each of those sources". (*a*)

Previous to going to Portland Mr. William Atwood spent about eighteen months on the island of Trinidad attempting to produce crude lubricating oils from the asphalt of the celebrated Pitch lake.

Meantime, parties in New Bedford, Massachusetts, who had been engaged in the manufacture of whale and sperm oils, commenced the manufacture of paraffine oils from the Boghead mineral of Scotland, which they imported for that purpose. The rich cannel coals of West Virginia and Kentucky soon attracted attention, and works for the manufacture of paraffine oils from them were established at Cloverport, Kentucky, and at Newark, Ohio. On the Allegheny river, in Westmoreland county, Pennsylvania, the Lucesco works were the largest in the country in 1859, having a capacity for producing 6,000 gallons of crude oil per diem. At Canfield, Mahoning county, Ohio, was another, and at Cannelton, West Virginia, was another with refining works at Maysville, Kentucky. By 1859 Luther Atwood had introduced his method of downward distillation, in which a tower was filled with 25 tons of coal or Boghead mineral and a fire kindled on the upper surface by means of anthracite coal or pine wood. (*b*) A downward draft was created by a steam-jet in the pipe leading from the base of the tower, and the heated products of combustion, descending through the coal, expelled the volatile materials at the lowest possible temperature.

In a recent letter, Mr. E. W. Binney, of Manchester, England, who, as before stated, was associated with Mr. James Young, at Bathgate, Scotland, tells me that when Mr. Young, in his celebrated patent lawsuit, testified that he obtained paraffine oil from petroleum before he resorted to coal, and it became known on this side of the Atlantic, the American firms licensed under their patent refused to pay any more royalties and went to work manufacturing petroleum. This is doubtless true as a statement of fact, but it conveys a wrong impression. The fact is that an inadequate supply alone prevented the use of petroleum in this country prior to 1859, and really Mr. Young and those on this side of the Atlantic were then in precisely the same situation as regards petroleum; but at the end of 1859 the situation in America became revolutionized, while that in Scotland remained as before.

Section 4.—HISTORICAL NOTICE FROM 1850 TO THE COMPLETION OF DRAKE'S WELL (AUGUST, 1859).

While Mr. Everett was engaged in making oil from cannel coal at Canfield, Ohio, Dr. J. S. Newberry sent him some petroleum from Mecca, Ohio, which was pronounced "as good or better than crude oil from coal". Oil had been gathered along Mill creek, in Erie, Pennsylvania, since 1854, and had been sold to druggists for a dollar a gallon. At Oxbow hill, not far from Union City, Erie county, Pennsylvania, Mr. P. G. Stranahan and his brothers dug out a spring about 1845 from which oil has flowed ever since.

William C. and Charles Hyde were engaged in lumbering on Oil creek, near the present village of Hydetown, from 1845 to 1850. The former, being well acquainted at that time with the oil-springs near Titusville, went to Pittsburgh and inquired of R. Robinson & Co., grocers, for a cheap oil for lighting mills, and got a half-barrel of amber oil, called "rock-oil", which was used in a vessel resembling a tea-kettle, the wick projecting from the nozzle, and burned much better than the green oil of Oil creek. The latter had long been collected from curbed pits, in which the oil arose and floated upon the water. Blankets were spread upon the water, which absorbed the oil, which was then wrung from them. Mr. J. D. Angier contrived a series of pits, one above another, and allowed the water to flow out from beneath the oil, and in this way he obtained what was then considered a large amount—six gallons a day.

From 1845 to 1855 parties were actively engaged in manufacturing salt at Tarentum, on the Allegheny river, above Pittsburgh, among them a Mr. Kier, whose son, Samuel M. Kier, was a druggist in Pittsburgh. Mr. Kier bored a well for brine at Tarentum and obtained oil that looked like brandy with the water, and this was allowed to flow into the canal leading to Pittsburgh. Mr. Samuel M. Kier's wife was sick, as was supposed, with consumption, and her physician prescribed "American oil". It helped her, and her husband was led to compare it with that obtained from his father's well. Concluding, as they possessed the same odor, that they were the same thing, he submitted them to a chemist, who pronounced them identical. Mr. S. M. Kier soon after commenced to bottle American oil for sale, and after a few years, supposed to be about 1855, in company with Mr. McKuen, he first refined petroleum from his father's wells at Tarentum. The oils were treated like the crude oils obtained from coal, and were made into burning oils and heavier oils, that were sold to the woolen factory at Cooperstown for cleansing wool, for which they were found very valuable. This refinery created a demand for crude petroleum, and led people to reflect upon the possibility of procuring it in larger quantity.

While Kier was at work in Pittsburgh, the firm of Brewer & Watson were engaged in a large lumbering and general merchandise business at Titusville, on Oil creek. In the summer of 1854 Dr. F. B. Brewer, whose

a Testimony of William Atwood in case of Merrill *vs.* Youmans.

b Antisell, page 135.

father was at the head of this firm, visited relatives at Hanover, New Hampshire, and carried a bottle of petroleum to Professor Crosby, of Dartmouth College, of which institution the doctor was a graduate, and Mr. A. H. Crosby, a son of the professor, and now a physician in Concord, New Hampshire, became greatly interested in his representations respecting the petroleum and the oil-springs. At this time Mr. George H. Bissell, also a native of Hanover, and a graduate of Dartmouth, was on a visit to his old home, and was induced by the others to join an enterprise for forming a stock company for procuring petroleum on Oil creek. Mr. Bissell was then engaged in the practice of law in New York as a member of the firm of Eveleth & Bissell. After some time spent in negotiation, during which Dr. Crosby had visited Oil creek and advised boring as a means of obtaining the oil in larger quantities, an arrangement was effected with Messrs. Brewer & Watson, under which Messrs. Eveleth & Bissell proceeded to organize a company.

Under date of November 6, 1854, these gentlemen informed Dr. Brewer that they "had forwarded several gallons of the oil to Mr. Atwood, of Boston, an eminent chemist, and his report of the qualities of the oil and the uses to which it may be applied was very favorable. Professor Silliman, of Yale College, is giving it a thorough analysis, and he informs us that, so far as he has yet tested it, he is of opinion that it contains a large proportion of benzole and naphtha, and that it will be found more valuable for purposes of application to the arts than as a medicinal, burning, or lubricating fluid".

The first deed from Brewer, Watson & Co. was dated November 10, 1854, and conveyed to George H. Bissell and Jonathan G. Eveleth, of New York city, 105 acres of land on what was known as the "Watson flats", embracing the island at the junction of Pine and Oil creeks. It was on this island that Mr. Angier's pits were dug, and also where the first well was drilled five years later.

As a result of this purchase, the Pennsylvania Rock Oil Company was incorporated on the 30th of December, 1854, under the laws of the state of New York. In order to satisfy several residents of New Haven who took an interest in the enterprise in consequence of Professor Silliman's report, which was made in April, 1855, the property of the company was purchased by Messrs. Ives & Pierpont, and was leased by them to a new company bearing the same title and organized under the laws of Connecticut, the official residence of the company being transferred to the city of New Haven. By the 23d of March, 1857, the Pennsylvania Rock Oil Company had leased the property on Oil creek to the New Haven stockholders, who organized under the name of "The Seneca Oil Company", and E. L. Drake was engaged the following spring to go out to Titusville and drill an artesian well for oil.

Mr. Drake, called Colonel Drake on Oil creek, arrived in Titusville about May 1, 1858. At that time Titusville was a lumbering village, and the nearest point at which tools and machinery could be obtained was Erie, Pennsylvania, nearly 100 miles north, or Pittsburgh, still farther south. Drake commenced operations by attempting to sink a shaft in one of the old timbered pits once supposed to be of prehistoric origin, but hatchets of French manufacture have been discovered in or about these pits. His idea appears to have been at first to sink a shaft or ordinary well by digging; but water and quicksands continually thwarted him, and he finally resorted to the expedient of driving an iron pipe from the surface to the solid rock. This device is supposed to have been original with Drake; but if it was, he never attempted to reap any advantage from it, although it has been of great value ever since in artesian boring.

He appears to have prepared for boring during the season of 1858 by driving his pipe 36 feet to the rock and getting his engine, tools, and pump-house in order; but the men he had engaged to drill early in the season had secured another job, and the work was suspended until the following season, when Mr. William Smith and his two sons were engaged, they having had large experience on salt-wells. These men arrived at Titusville about the middle of June, bringing with them all the necessary tools for drilling. After many vexatious delays, they were fairly under way by the middle of August and had drilled 33 feet, when, on the 28th of August, 1859, the drill struck a crevice, into which it fell six inches. The following day being Sunday, Smith visited the well in the afternoon and found the drill-hole full to within a few feet of the top, and on fishing up a small quantity in a tin cup it was found to be petroleum. Such is the story of the first petroleum well. (*a*)

As soon as Mr. Watson heard the news he sprang upon a horse and hastened down Oil creek to lease the farm on which the McClintock spring was situated; but Drake telegraphed to Mr. Bissell, who thereupon bought up all the stock of the Pennsylvania Rock Oil Company that he could get hold of, and, immediately visiting Oil creek, leased large tracts of land that afterward yielded abundantly.

Section 5.—HISTORICAL NOTICE OF THE PETROLEUM INDUSTRY IN THE UNITED STATES SINCE THE COMPLETION OF DRAKE'S WELL (AUGUST, 1859).

The territory over which operations were conducted was for a long time confined to the valleys of the Allegheny river and its tributaries, on the supposition that the present configuration of surface was related to the strata containing the oil. For this reason wells were drilled in the valley of Oil creek from Titusville to Oil City, on French creek from Union City to Meadville and Franklin, and on the Allegheny at Tidioute. Although the coal-oil manufactories all over the country, with scarcely an exception, commenced to work petroleum instead of

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a I am indebted to Henry's *Early and Later History of Petroleum*, which is indorsed by Mr. Bissell, and to many conversations with residents of Titusville and the vicinity, for the facts contained in the above narration.

coal, the production was so enormous, as compared with the demand, that the market was soon glutted and the price fell to almost nothing. An extended demand, and the partial exhaustion of the territory then being worked, led to better prices in 1865, and the immediate result was the boring of wells over an immense extent of country, from Manitoulin island to Alabama, and from Missouri to central New York. In Europe companies were also formed, and wells were put down wherever an oil-spring existed. In the United States the result was the permanent development of a small territory in southern Kentucky, another still larger in West Virginia and in Washington county, Ohio, and another in Trumbull county, Ohio, at Mecca. In Pennsylvania oil was found at Smith's Ferry, on the Ohio river, in Beaver county, and the hill region lying in the angle formed by Oil creek and the Allegheny river from Tidioute across to Titusville was explored and several localities of great richness were opened up.

Henry, in *Early and Later History of Petroleum*, pages 109 and 110, says:

> The total daily product of all the wells in June, 1860, was estimated at 200 barrels. By September, 1861, the daily production had reached 700 barrels, and then commenced the flowing-well period, with an addition to the production of 6,000 or 7,000 barrels a day. The price fell to 20 cents a barrel, then to 15, and then to 10. Soon it was impossible to obtain barrels on any terms, for all the coopers in the surrounding country could not make them as fast as the Empire well could fill them. Small producing wells were forced to cease operations, and scores of operators became disheartened and abandoned their wells. The production during the early part of 1863 was scarcely half that of the beginning of 1862, and that of 1864 was still less. In May, 1865, the production had declined to less than 4,000 barrels per day.
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> Commencing at Titusville in 1859, the tide of development swept over the valley of Oil creek and along the Allegheny river above and below Oil City for a considerable distance; then Cherry run, in 1864. Then came Pithole creek, Benninghoff and Pioneer run; the Woods and Stevenson farms, on Oil creek, in like succession, in 1865 and 1866; Tidioute and Triumph hill in 1867, and in the latter part of the same year came Shamburg. In 1868 the Pleasantville oil-field furnished the chief center of excitement.

While this great activity was being displayed in Pennsylvania, the old salt and petroleum region in the valley of the Muskingum, in Ohio, and on the Little Kanawha, in West Virginia, was bored for petroleum, and several wells of great productiveness were obtained. In 1860 an old brine well at Burning Springs, West Virginia, that had yielded petroleum, was cleaned out, the water tubed off, and about fifty barrels of oil per day secured. In the following winter the Llewellyn well was struck at about the depth of 100 feet, and it flowed over 1,000 barrels a day. Several other good wells were secured, when, during a confederate raid, the property was destroyed and the operators were driven away. In 1864 operations were resumed, deeper wells producing a large amount of oil, and speculation and excitement ran to a high pitch. In 1865 operations were successfully undertaken at White Oak, which resulted in developing the most extensive and best known West Virginia territory. From 1860 to 1865 wells were successfully drilled on Cow run and at other localities in Washington county, Ohio.

For more than a century bitumen had been known in southern California between Santa Barbara and Los Angeles, and had also been observed floating upon the sea in the Santa Barbara channel between the islands and the mainland. Early in 1864 this region was visited by an eminent eastern chemist, who was so far misled by false local representations and by gross deceptions practiced upon him as to induce him to make a report upon this as a petroleum-producing region of great richness. This report, and others of a similar character, led to the formation of mining companies representing stock to the value of millions of dollars, all of which, it is needless to add, was lost to the *bona fide* investors. Several hundred thousand dollars were spent in boring wells, but few of them produced sufficient petroleum even to serve as a specimen, and none, so far as I am informed, paid the cost of boring. A few years of effort found the companies with depleted treasuries and no oil, and with a large amount of land and apparatus on their hands. On one estate 5,000 barrels in shooks, shipped from New York, were rotting down in a huge pile before a drop of petroleum had been obtained from beneath its surface. While these magnificent enterprises were becoming magnificent failures, more humble efforts were achieving a measure of success in driving tunnels into the steep mountain sides upon the petroleum-bearing rock. The total production of this region, however, never reached above a few thousand barrels of inferior quality per year, and the San Francisco market continued to be supplied almost exclusively with Pennsylvania petroleum shipped around cape Horn. (*a*)

From 1870 to 1880 the region between Tidioute and Oil creek has constantly become relatively of less importance when compared with the entire area of producing territory in Pennsylvania. At the beginning of this decade the production of this region had considerably lessened, and a number of new and very successful wells farther down the Allegheny river were attracting attention in that direction. Wells had been put down near the junction of the Clarion and Allegheny rivers as early as 1863 and 1864, but very little notice had been taken of them at the time; and it was not until 1868 that a successful well on the hill above Parker's landing attracted the attention of the bolder operators and led to the development of what is termed the "lower country", lying in Butler, Armstrong, and Clarion counties. In 1867 Mr. C. D. Angell had developed a very productive oil property on Belle island, in the Allegheny river, 25 miles below Oil City. While carrying forward his work he was busily investigating the occurrence of petroleum by studying the relative position of the most productive wells. He had observed in the "upper country" that a narrow belt extending across from Scrubgrass, on the Allegheny river, to Petroleum Center, on Oil creek, included many of the best wells in that region. In the "lower country" he

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a Advices from the Pacific coast indicate that during the years 1880 and 1881 a petroleum interest that promises some local value has been developed in a portion of the state further north than that here referred to.

projected a similar belt, lying in a direction nearly parallel with the first, and extending from Saint Petersburg, in Clarion county, through Parker's landing, to Bear creek, in Butler county. A glance at the map (III) accompanying this report will show how Angell's so-called "belt theory" corresponded to the facts as shown by subsequent developments. As is usually the case, the majority of operators scoffed, while a few listened, and, after listening, went to work. The results have shown that the oil rock lies in belts or in long and narrow areas, having a general northeast and southwest extension, often not more than 30 rods in width, but several miles in length; that the sand rock is thickest and most productive along the axis of the belt, thinning out toward its borders, the upper surface being level and the under surface curved upward from the center; that the present configuration of the surface has no relation to the form, extent, or direction of the "belt". These facts established, and their successful application abundantly demonstrated by the remarkable success attending Angell's operations, have given a certain degree of accuracy to the development of oil territory that it never possessed before. On the other hand, they have led to very exaggerated views, some enthusiasts affirming their belief that the line of north 16° east, upon which Angell achieved his first success, governed the direction and extent of territory containing oil from Canada to Tennessee. I shall again refer to the facts upon which Angell's theory is based in my chapter on the "Origin of Bitumens". (*a*)

Angell kept his own counsel at first, and obtained a sufficient number of leases on favorable terms to insure his financial success; but the plan upon which he worked became apparent from the character of his operations, and others followed, or attempted to follow, his example, and wells were drilled across the country to the southwest of Parker's landing into Butler county, and often miles in advance of any territory hitherto proved profitable, until a tract was more or less clearly outlined about five miles in breadth and thirty-five miles in length, the principal axis of which lay in the general direction north 22° east. Other less extended belts lying generally parallel to this will be noticed by glancing at the map (III).

During the early years of this decade, when Angell's efforts and sagacity were being rewarded in the lower country with success in a most substantial form, other operators struck out from the "upper country" of Oil creek in a general northeast direction, some on a line north 16° east, others north 22½° east, and others on still other lines, often traced over the forest-covered hills of that region with a compass, and located their wells in the expectation of finding other sand-bars of the ancient sea from which the oil would rush to the surface. They finally reached the town of Bradford, in McKean county, a locality which some thought could never produce oil.

It was not the first attempt at well-drilling that obtained oil in the neighborhood of Bradford. In 1862 the old Bradford well, since known as the Barnsdall well, was drilled to a depth of 200 feet with a spring-pole and then abandoned. In 1866 the citizens of the village of Bradford concluded to club together and sink the Barnsdall well deeper, and it was drilled to a total depth of 875 feet, or to within 150 feet of the Bradford producing sand. In 1865 F. E. Dean and brothers drilled a well in the valley of Tuna creek, on the Shepherd farm, near the present site of Custer City, 160 feet of drive-pipe being used, and the hole being drilled to 900 feet, but it was abandoned when over 200 feet above the top of the oil-sand.

The next well was drilled by the Dean brothers on the Clark farm, at Tarport, and drilling was stopped at a depth of 605 feet, or over 400 feet above the top of the oil-sand. All of these wells were drilled with the expectation of finding the Venango county oil-sand at about the same depth below water-level as at Oil City, but they were all failures.

The first well sunk to the Bradford sand was drilled by Mr. James E. Butts and others, under the name of the Foster Oil Company, on the Gilbert farm, 2 miles northeast of Bradford. "Slush oil" was found at a depth of 751 feet, and in November, 1871, producing sand was struck at 1,110 feet. The daily production was 10 barrels, and from the time this well was struck to December, 1874, no wells were drilled to amount to anything. On December 6, 1874, Messrs. Butts and Foster struck the oil-sand on the Archy Buchanan farm, 2½ miles northeast of Bradford. This well started off with a daily production of 70 barrels, and was really the first that attracted attention to the possibility of finding a profitable oil district in the county. In December, 1878, four years from the completion of the Butts well, the average daily production of crude oil was 23,700 barrels, or about four-sevenths of the total daily production of the state of Pennsylvania, while in December, 1880, two years later, and six years from the completion of the first well, out of a total average daily production for the Pennsylvania oil-fields of 72,214 barrels, 63,000 barrels were yielded by the Bradford field alone.

During the year 1879 there were 475 wells drilled to the Venango sands in the counties of Warren, Venango, Clarion, and Butler. Of this number 122 were dry holes, or produced no oil, being 25.7 per cent.

In the Bradford or northern district there were during the same year 2,536 wells drilled to the Bradford oil-sand, of which number but 76 were dry holes, or only 3 per cent., being nearly 23 per cent. less than in the Venango or western district.

The average daily production for the first month of the wells drilled in the Bradford sand was about 20 barrels, while for the wells in the Venango sands it did not attain that amount. Some of the wells drilled to the Venango third-oil sand have produced from 2,000 to 3,000 barrels of oil per day, while the largest well ever found in the

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a See page 70.

Bradford district has not exceeded as many hundred. The largest individual wells have been located in the western district; the largest average wells in the northern district. Since the beginning of the year 1875, when the Bradford oil horizon was discovered, there have been 6,249 wells drilled in the district, of which 236 were dry holes, or 3.77 per cent. From the most authentic statistics which I can gather in the western district, about one-fourth of the wells that have been drilled in the Venango sands, since their discovery in 1859, have proved dry. When we take these facts into consideration, we can readily understand why there should have been 2,536 wells drilled in the northern district to only 475 in the western in 1879. (*a*)

During 1880, as undrilled territory became more scarce in the Bradford field, what are termed "wild-cat" or test wells were drilled both to the northeast and to the southwest of Bradford, and the result has determined two areas, one near the city of Warren, and another around Stoneham, both in Warren county, Pennsylvania. To the northeast an area not yet outlined has been determined around Richburg, Cattaraugus county, New York.

Forty-five years ago M. C. Read, esq., now of Hudson, Ohio, lived in Mecca, on the east side of Mosquito creek. It had been observed for a long time that petroleum gushed out when stones were removed from their places along the bank of the creek, and as it frequently appeared in wells it was considered a nuisance. In the spring of 1860, when there was great excitement in eastern Ohio over the oil in Pennsylvania, Mr. Read mentioned to some persons what he knew about the oil-springs in Mecca, and it was only a few days thereafter before property was being leased in that place on a royalty of from one-tenth to one-quarter, and in a year all available property on the west side of the creek and some on the east side had been taken up.

Wells were bored rapidly, yielding from 10 to 20 barrels, and in some cases were so near together that one sucked air from the other when pumped. Thousands of barrels of oil were taken out yearly for a few years, when a large part of the wells became exhausted, many of them were abandoned, and the excitement subsided. In 1864 it was renewed for a short time, and Pennsylvania parties bought up all the land on the east side of the creek and obtained a few good wells, but they soon failed. Since that time a few persons have been engaged in drilling new wells and pumping the old ones, for the most part spending what they got on good wells in drilling others which produced nothing. In the opinion of those best qualified to judge, Mecca oil operations have netted nothing, or more probably have resulted in a loss. The operators now make a living, all money earned over and above being spent in putting down new wells.

Near Power's Corners there was in early times an old shaft which tradition credited as the work of a prehistoric race. Such an origin is not probable.

At Belden, in Lorain county, Ohio, it is reported that one Reuben Ingersoll sunk a well for salt in 1818 or 1819 on the Root farm, but so much oil came with the brine that the well was soon abandoned. The oil for a long time was skimmed off and sold as a medicine. Many years afterward, in sinking a hole for the post for a flood-gate to a mill, petroleum appeared at the bottom, and occasionally it appeared in other excavations.

It is claimed that the first well was bored here for oil in 1858, but on what authority I do not know. It is said to have been bored 500 feet deep by a Mr. Harper and to have struck oil at 50 feet. In 1860 a Mr. Gardener sunk Harper's well to 1,200 feet and abandoned it.

Other wells were put down soon after, and one of them—the old Crittenden well—in 1862 pumped by hand, wind-mill, and steam-power 65 barrels. A few wells at Liverpool have a similar history.

A Mr. Thoms in 1850 gathered oil from holes dug in the sand on a bar of the Ohio river near the mouth of Little Beaver creek, Beaver county. The first well was the Fenton well, drilled in 1860, close to the mouth of Dry run. This well was 170 feet deep, and yielded 14 or 15 barrels of heavy lubricating oil. They then went down along the river 575 feet and on Island run 600 feet, and reached a fine, close sand. Some wells were carried down 1,100 or 1,200 feet to the second sand, yielding a little oil. Wells in this section have never been drilled 1,500 to 1,600 feet to the third sand. This territory is between three and four miles square. Some oil has also been obtained at Beaver creek and Rochester, in the same county; but the principal development in this section is confined to a small territory immediately north of Smith's ferry, and has occurred since 1878.

SECTION 6.—HISTORICAL NOTICE OF THE RUSSIAN PETROLEUM INDUSTRY.

There are five foreign oil-fields that have attracted attention and that have produced more or less oil in commercially valuable quantities. They are the region of the Caucasus, Galicia, Canada, Japan, and Peru. Of these, the first mentioned is altogether the most important so far as present information indicates. Next may be placed Canada; but as regards the relative importance of the others it would be difficult to decide.

The Russian fields lie in two districts, one at either extremity of the Caucasus. The western, on the Black sea, is the Kouban, on a river of the same name; the eastern is the Baku district, on the peninsula of Apscheron, extending into the Caspian sea, and on which the city of Baku stands.

The Kouban district is situated on the northwestern slope of mount Oshten, which is the most western peak of the Caucasus, 9,000 feet in height. Its area is about 250 square miles. Operations were commenced here in 1864

a I am indebted for the major portion of this statement in reference to the Bradford field to two papers by Charles A. Ashburner, esq.—the first read at the Baltimore meeting of the American Institute of Mining Engineers, February, 1879; the second read before the American Philosophical Society, March 5, 1880. P. A. P. S., xviii, 419; T. A. I. M. E., 1879; P. A. P. S., 1880.

by the Russian colonel Novosiltsoff, who had a monopoly of the petroleum industry of that region for more than twelve years. He sunk his first well at Peklo, near the coast of the Black sea, and after many borings, with varying success, in different parts of the district, he became so heavily involved that to save him from bankruptcy the government placed the petroleum interests under a curatorship.

From these exploitations of varying depth, large quantities of excellent petroleum of specific gravity from 38° to 48° Baumé have been obtained.

The most remarkable well was obtained at Kandako in 1866. At a depth of only 40 feet from 10 to 12 barrels of oil per day were yielded. At a depth of 123½ feet the first flow of oil appeared and yielded 125 barrels of oil per day, throwing it 14 feet high. The well was mismanaged and choked, and when finally reopened and sunk to 182 feet, a flow of oil rose to 40 feet high, and gave 250 barrels per day. It was again choked and finally deepened to 242 feet, when the oil again flowed with great power and violence, yielding several thousand barrels per day, and continued its spontaneous action for eighteen months. (*a*)

This management came to an end in 1877, on the breaking out of the last Russo-Turkish war, when the whole district of the Kouban was abandoned. In 1879 the larger portion of the district, amounting to 1,500,000 acres, was leased to Dr. H. W. C. Tweddle, with private estates amounting to 90,000 acres additional. During the years 1879 and 1880 great activity has prevailed in preparation for an extensive development of oil with all of the appliances in use in Pennsylvania for obtaining, handling, and refining petroleum.

Concerning the history of petroleum production at Baku, Consul Dyer wrote, on August 10, 1880, as follows:

From time immemorial oil has been known to exist at Baku, and for generations the natives have taken it for greasing their vehicles, preparing skins for wine, etc., and for use in the southern countries for embalming the dead, and even in some cases for illuminating purposes. Their wants were, however, small, and the surface production was sufficient.

The wells were rather receptacles for the surface oil than otherwise, as they were simply holes dug a few feet deep in the earth.

From the time of the Russian occupation of the country in 1723 down to 1825 this industry remained almost neglected. From 1813 something was done, but nothing of importance, and the total revenue to the government arising from it was less than $40,000 per year. From time to time private persons took the privilege, and at times the crown worked them to some extent. The price charged for the oil was as high as 4 rubles per pood, and thus the industry was destroyed. (*b*)

It was about 1832 that the industry began to assume anything like business proportions; but even then it was managed so badly that it remained very insignificant. A few wells were dug (as wells for water are dug), and the government even refused permission for an enterprising lessee to work with any kind of boring tools, the officer replying that such things had been tried, but that they had not succeeded, and consequently could not be tried again at Baku.

In 1850 the government gave a monopoly and limited the selling price of crude oil to 45 kopecks the pood, and received the sum of 200,000 rubles for the privilege. This monopoly was farmed out every four years to the best * * * bidder. In 1868 a commission was formed to take into consideration the industry. In 1872, in pursuance of its recommendations, the territory upon which there were surface indications was divided into plats of 25 acres each, and sold to the highest bidder by sealed proposals. By this time the field had attracted much attention, and the parcels were disposed of in some instances for enormous prices. In most cases, purchases were made by persons who had not the means to work their possessions, nor the experience had they possessed the capital. They, however, held on to their lands, and capital and experience were thus kept away, and the industry was worked in the most crude and unsatisfactory manner.

The product of the refineries was so bad, and the market so small, that there was not energy enough engaged to bring on a crisis in the industry. The government had placed an excise tax, which, under the circumstances, was unbearable, and for a time previous to 1878 the operators were upon the verge of ruin. No work was done except to fill contracts previously made. At Nishni-Novgorod there was in store more than one and a half millions of poods, almost 200,000 barrels, unsold, and the price had gone down from 3.50 to 1.30 rubles per pood. The government then removed the excise tax, and now there remains only a small tax collected by the town of Baku.

The real birth of the industry may be said to be the year 1872, when the lands passed into private hands. There have been since that time great but insufficient energy and activity displayed. The operators have no relations with each other. * * * Many small owners, for want of means to work their property, have been obliged to sell, and some capitalists have entered simply as refiners, buying the crude oil for that purpose. Some of these refineries have grown to large proportions, and the principal ones are now making such improvements and changes as to make them first-class establishments, capable of enormous and thorough work.

He states further, as follows:

The territory now worked does not exceed six square miles. The principal field is at Balaxame, 9½ miles northeast of Baku, covering a territory of, say, 3½ by 1½ miles. Two miles south of Baku is a small field at Bēbēābat, on which there are some 25 wells. This is a very small territory, say three-fourths of a mile square. Ten miles southeast from Baku is an island. It is certain that oil exists there, but in what quantities is not known. Within a radius of 50 miles there are constant surface indications, and even some small wells.

In 1850 there were in all 136 wells. In 1862 there were 220, and in 1872 there were 415. These were wells dug as water wells are. In 1871 the first well was *bored*. In 1872 there was 1; in 1874, 50; in 1876, 101; in 1879, 301 bored wells in the district. The other wells had entirely ceased to be worked. During the year 1879, and so far in 1880 (August), there has been very much work done, but the exact figures are not attainable. The business is in a most confused condition now, in consequence of the changes that are being made. Many new wells have been commenced, and a very large number of those previously worked are being drilled deeper. If the figures given may be relied upon, that is, 301 wells up to 1879, it may now, perhaps, be said that on the 1st of July, 1880, about 500 wells had been commenced. Many of them are not completed, and some have been abandoned.

I have purposely omitted reference to the more or less highly colored accounts of the Baku "field of fire" and the "Persian fire-worshipers and their temples". The "field of fire" is described by Gruner (*c*) "as a broad expanse filled with fissures, from some of which inflammable gas escapes, and from others naphtha". Another speaks of it as a "wonderful sight; of green fields and waving corn, in the midst of which the removal of a foot or two of earth will reveal a jet of gas that will raise an enormous blaze if set on fire". (*d*)

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a Consular Reports No. 1, October, 1880.
b Ruble, $0.56; pood, 36 pounds.
c *Ann. Génie Civil*, iv, 845.
d Churchill, British consul to Resht, Persia.

Section 7.—HISTORICAL NOTICE OF THE PETROLEUM INDUSTRY OF GALICIA.

The petroleum fields of Wallachia, Moldavia, and Galicia lie upon the southern, eastern, and northern flanks of the mountain system that incloses Hungary from Russia and the plains of the Danube. This system embraces the Transylvanian Alps, the Siebenbürgen, and the Carpathians.

Oil springs have flowed in this region from time immemorial, and the oil has been collected and used by the inhabitants of the country and devoted to many of the rude and uncultivated wants of a people remote from the centers of civilization. In 1810 Josef Hecker and Johann Mitis obtained petroleum in Drohobycz district, and made a trial of the distilled and crude oil, which was obtained from dug wells and afterward treated in stills; but having worn out their still in 1818, their works were closed. In 1840, in the Stanislow district, there were 75 dug wells and 6 establishments for the manufacture of wagon-grease. In 1853–'64 Schreiner boiled down petroleum and made a very superior article of grease, and his successor condensed the distillate and used it for illuminating purposes. The industry since that time, although conducted in a small way, had steadily increased until 1860–'65. (*a*)

Since 1860 a great deal has been written on the Galician oil-fields, and several spasmodic attempts have been made to find remunerative employment for capital in their development. This was especially the case in 1865, when the expansion of the production of Pennsylvania led to so many enterprises of a more or less experimental nature all over the world.

There are three localities particularly noted for their petroleum product. These are the neighborhood of Sandecer, in west Galicia; that of Bōbrka, near Dukla, Sanoker, and Samborer, in middle Galicia; and Boryslav, in east Galicia. The latter locality is also celebrated for its production of ozokerite. The localities in Roumania that are now principally associated with petroleum are Sarrata, Bacan, Dimbovitsa, Prahova, Burzen, Moniezta, Plojezti, and Baikoi.

The oil was originally collected, as in other localities, from the water of the springs, with which it flowed from the crevices in rocks. It was afterward obtained from wells or shafts that were dug, and in Galicia and Roumania it is at present obtained in that primitive manner. Later the shafts were connected by galleries, forming what are called "complex mines" (complex Gruben) in Galicia.

The exploitations for oil at Mraznica consist of about 70 shafts in the upper part of the valley of Tiesmienka, the lowest row of shafts lying on both sides of the declivity of the Bachspiegels, with a second and a third row above them. They consist of the "old" complex mines, consisting of about 40 shafts, and the "new" complex mines, consisting of about 30 shafts. The older "complex mine" is going on 12 years old, having originated when the oil fever agitated Galicia. The first shafts were sunk by a Jewish company near an oil-spring to a depth of 100 meters (328 feet) with very satisfactory results, in consequence of which, and in order to control the production, they sunk many other shafts in the immediate neighborhood as soon as possible, and thus copied the Boryslav method of operation in the most destructive manner. The consequence was that they finally obtained from about 40 shafts the same quantity of oil that they could have had from 10 exploitations. A second oil-level, not yet reached, is supposed to exist, but the shafts have only penetrated 100 to 150 meters (328 to 492 feet). The largest yield from a single shaft is said to have amounted to 40 barrels of crude oil per week. Through ten years the most of the shafts have had an average flow of about 4 barrels per week; yet a single shaft is said to have yielded a net profit of 200,000 gulden ($100,000), and has yielded petroleum for ten years up to 1878.

After a period of ten years the yield of oil decreased to such an extent that the enterprise became unprofitable. This caused the projector of the Jewish enterprise to attach the new "Gruben complex", consisting of 30 new-dug shafts, which likewise lay near each other in a compact mass, to the immediate upper half of the old shafts. In November, 1878, these shafts were sunk 20 to 50 meters (65 to 164 feet); yet they yielded no traces of petroleum particularly worthy of note. The extensive development of gas of the "old complex" was also entirely wanting. This failure is explained by assuming that the new shafts happened to lie within the circle already exhausted by the "old complex". Hence the petroleum industry in Mraznica must come to an end; yet, toward the close of 1878, 5 shafts still yielded about 14 barrels weekly. The long duration of the flow from these shafts is remarkable (ten years), while other springs in Galicia only flow an average of five years. (*b*)

Mraznica is in east Galicia. The facts set forth by Herr Walter explain why Consul-General Weaver reports December 30, 1880, that, of the yearly product of 100,000 barrels, produced in Galicia, two-thirds are at present obtained in west Galicia, in the vicinity of Grybow, where, during the census year, Mr. James Corrigan succeeded in establishing an American refinery. In a letter dated October 9, 1881, Mr. Corrigan states that a new well, yielding 75 barrels daily, had been struck at Slaboda, near the boundary of Bukowina (east Galicia), and that consequently great excitement prevailed.

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a Ost. Zeit. f. Berg- und Hüttenwesen.

b Abstract of a portion of an article by Bruno Walter on "The chances of a petroleum production in Bukowina". J. K. K. G. R., xxx, 115 (1880).

SECTION 8.—HISTORICAL NOTICE OF THE PETROLEUM INDUSTRY OF CANADA.

The productive oil-fields of Canada lie in the county of Lamberton, in the western part of the province of Ontario, and principally in the township of Enniskillen. From the earliest settlement of the region "a dark oily substance had been observed floating on the surface of the water in the creeks and swamps. No matter how deep the wells were dug, the water was brackish and ill-smelling, and in some localities totally unfit for use; while a surface of black, oily slime frequently arose an inch thick, as cream rises on new milk. Here and there in the forest the ground consisted of a gummy, odoriferous tar-colored mud, of the consistence of putty. These places were known by the name of 'gum-beds', and in two or three instances were of considerable extent". (Henry's *Early and Later History of Petroleum*, p. 130.)

Operations were commenced there as early as 1857 by one Shaw, who dug an ordinary well, as for water, and after several days of digging struck a tremendous flow of oil, which ran in a stream into the creek. The usual phenomena attending such a discovery followed; land was bought and leased, more wells were dug, and oil flowed; they gathered what they could and wasted the remainder; fortunes were made and lost, and after a time, in 1864, the town of Oil Springs contained 3,000 inhabitants.

Flowing wells were struck here in 1862, and some of them proved the most prolific on record, rivaling those of the region around Baku. These great wells were exceptional, and the average yield has been comparatively small. The region over which borings have proved the existence of oil in paying quantities is about 50 miles north and south by 100 miles east and west, and within this range Petrolia, Bothwell, and Oil Springs have produced nearly all of the oil. The latter had the largest wells, though the former now produces more than nine-tenths of the amount at present obtained. Petrolia is about 16 miles southeast of the outlet of lake Huron, Oil Springs 7 miles south of Petrolia, and Bothwell about 35 miles from Oil Springs.

The petroleum of Canada contains sulphur and is difficult to refine, but its production has been fostered, and it supplies a large demand throughout the British provinces.

SECTION 9.—HISTORICAL NOTICE OF THE JAPANESE PETROLEUM INDUSTRY.

The knowledge of rock-oil in Japan is of great antiquity. In B. S. Lyman's reports (1877) appears the following:

It is said in the Japanese history called Kokushiriyaku (I am told) that rock-oil (or "burning water") was found in Echigo (in Niphon) in the reign of Tenjitenno, which was 1,260 years ago, or about A. D. 615; and that was probably at Kusôdzu, where there are very old natural exposures as well as dug wells. The name of the place, Kusôdzu, is the name given in the country to rock-oil, and means stinking water; and the very fact that the word is by contraction so much changed from its original form, Kusai midra, shows of itself considerable antiquity.

In the Miyôhôji and Kusôdzu oil region there are (beside a much larger number of old, abandoned wells) about 178 productive wells, which altogether yield about 4⅔ barrels a day, making an average of about 1 gallon a day for each well. The best well is at Machikata, and yields about half a barrel a day. The best of the former wells was at Kitakata, and for fourteen days (in 1871) it yielded a daily average of 19 barrels, but after that only about 8 barrels a day. The deepest productive well of the region is 122 fathoms deep.

Reviewing all the Echigo oil-fields, we find that there are in all 522 productive wells, of which the deepest is 122 fathoms (732 feet) deep, the greatest yield is about 1.2 barrels a day, and the total yield about 26 barrels a day, giving an average of about 2 gallons a day for each well. Such a yield, if kept up through the whole year, summer and winter, would amount for all the wells together to 9,500 barrels a year, worth, at 12 gallons to the dollar, $31,650.

At Shinano, on the other hand, the yield is far smaller. There are in that province, in spite of the numerous traces of oil and gas, only 22 productive wells, of which the deepest is 57 fathoms (342 feet) deep, and the best has a yield of 2¼ barrels a day; and the total yield is a little over 5 barrels a day, or an average of 9½ gallons a day to each well; or, in a year, 1,900 barrels altogether, worth about $6,250.

The whole yield of the two provinces, then, is about equal to that of two average Pennsylvania oil-wells. Yet two or three cases have occurred in Echigo of a yield of 15 to 19 barrels a day for a few days when the wells were new. At Miyôhôji they talk of having had a profit of $70,000 to $80,000 from a single well; and the general estimate of the yield of that field has been high.

Such was Mr. Lyman's (geologist of Japan) estimate of the product of the most fruitful oil-fields of Japan in September, 1876. Many other localities have been explored for petroleum with similar results; but the introduction of American refined oil at present prices has nearly destroyed the domestic trade, and has completely arrested the production.

In the very elaborate report made by Consul-General Van Buren in 1880 no mention is made of any domestic production of petroleum, although Consul Stahel, of Hiogo, shows that the imports of American refined petroleum into Japan have increased from about 1,000,000 gallons in 1872 to nearly 18,000,000 gallons in 1880. Hiogo has been one of the most important centers of the native petroleum trade, it having had a refinery.

SECTION 10.—HISTORICAL NOTICE OF THE PERUVIAN PETROLEUM INDUSTRY.

Previous to the outbreak of the war between Chili and Peru the prospect of a large development of petroleum in Peru was very flattering. The following statement of operations there has been widely copied, but I cannot vouch for its accuracy, as I have not been able to verify it:

Mr. Prentice, the Pennsylvania oil operator, in 1867, paid Peru a visit. A well was put down near Zorritos. At the depth of 146 feet a volcanic formation was reached by the drill, and oil was found. The well pumped 60 barrels a day. A second well was put down. Oil was reached at a depth of 220 feet. The yield rapidly declined from 12 barrels to 7 barrels a day. Mr. Prentice was satisfied that the region would prove productive, but he held his own counsel. In 1876 he succeeded in securing the control of the entire estate for the purpose of producing oil. In that year the second well mentioned above was drilled to the depth of nearly 500 feet. The tools struck a vein of oil-bearing sandstone, and immediately sank 10 feet. This was the first finding of the sandstone. The strike was followed by a column of oil that filled the 6-inch casing and was thrown 70 feet in the air. In attempting to control the great flow by insertiug tubing in the well the inexperienced employés let the tubing drop to the bottom. The side caved in soon afterward and stopped the flow. The well is still plugged. Mr. Prentice says its capacity will be 1,000 barrels a day. Another well of his near the above has been in use for three years. It has never yet been torpedoed or recupped. It yields 600 barrels a day. Mr. Prentice's experiments have proved that the deeper the wells are sunk the larger the yield is. At 600 feet he declares that a well in his Peruvian regions will pump 5,000 barrels a day. Back in the mountains some of his men have struck a vein of petroleum by merely digging a pit 28 feet deep. Several of these pits have been dug. Oil accumulates in them in paying qnantities. Mr. Prentice has a refinery at Zorritos. Its capacity is 200 barrels; this he is now enlarging. There were shipped from the Pennsylvania oil regions in 1870, 1,085,615 gallons of oil to Peru, Chili, and Ecuador. Refined oil brings 25 cents a gallon in Peru and its neighboring states.

I have been informed that since the outbreak of the war nothing has been done in reference to this industry.

Section 11.—HISTORICAL NOTICE OF THE ITALIAN AND OTHER PETROLEUM INDUSTRIES.

I am indebted to Professor P. E. DeFerrari, C. E., of Genoa, for the following statement concerning the petroleum interests of Italy. His letter was dated Iglesias, Sardinia, December 22, 1881, and in it he says:

There are in Italy two large districts with petroleum-bearing strata: one in the north, on the southern borders of the Po valley; the other in the south of Italy. Unfortunately, in spite of extensive workings and a considerable amount of money employed in searching for mineral oil, no satisfactory result was obtained.

The chief localities where petroleum and its allied products are met with are—Po valley: Rivanazzano, province of Voghera; Riglio, province of Piacenza; Miano, in the Caro valley of Parma; Sapuolo, in the Secchia valley of Modena. South Italy: San Giovanni Incarico of Caserta; Coco, in the Pescara valley of Chieti.

In the first district the oil is of a very good quality, very pure, largely diffused in the rock, but occurs in strata chiefly of clay and argillaceous sand, which, because of their little permeability, do not permit the free exit of the oil when wells are dug in the ground. The geological range of the strata is the Miocene and Pliocene periods. Some geologists believe that below the above-mentioned strata there may be other strata which would yield large quantities of petroleum when pierced through with wells. It must be stated that these strata have not been found, even in those places where borings of 250 and even 400 meters have been opened (820 to 1,312 feet).

Six different societies have worked the petroleum springs of North Italy from the year 1866 to 1874, but without success. Several wells reached the depth of 200 meters (656 feet), but no large veins of petroleum were met with, and the works were abandoned. In the valley of Pescara, South Italy, there are also petroleum springs, with bituminous products. At Coco borings of great depth have shown the existence of some oil veins, but of little importance. At San Giovauni Incarico several veins of some hundred liters every twenty-four hours were found, but they have no industrial importance. Lately an Italian and French society, with large capital, and Canadian workmen and machinery, explored the ground at Rivanazzano and at Coco. They opened four wells 200 meters deep in the north; one 400 meters in the south (Coco); but the working was given up for deficiency of money. The whole product of petroleum in Italy does not exceed 300 tons a year, and it is chiefly collected in large and shallow wells by the country people, and used on the spot. No machinery worth mentioning, but small pumps, are used, and in most places the work is done simply by hand.

At Sapuolo and Salsomaggiori the gas which comes from crevices in the ground is collected and burned for industrial purposes. In the south of Italy bituminous clay is distilled and petroleum condensed in small quantity. The annual importation of petroleum into Italy is 50,000 tons, and its value is 14,500,000 francs.

This letter states the condition of the petroleum industry as related to modern methods of exploitation, and prices as governed by the enormous supply furnished at present by the United States; but petroleum has long been known in the valley of the Po, and many of its smaller towns have been lighted by it. The exceptionally fine quality of the petroleum of that region made it possible to use it without refining.

The earliest mention of petroleum from this region is by François Arioste, who cured men and animals afflicted with itch with petroleum which he had discovered in 1460 at Mont-Libio, in the duchy of Modena. (*a*) Agricola also mentions it in the middle of the sixteenth century. (*b*)

Many other localities will be enumerated in the succeeding chapter as furnishing petroleum, but those mentioned are the only ones that have furnished petroleum to the commerce of civilized nations.

The historical development of the petroleum industry may be summed up as follows: In many regions, and for immemorial periods, petroleum gathered from natural springs and dug wells has been used in medicine, and in a rude way as an illuminating agent. In China artesian wells have been bored for brine and for natural gas, and the latter was used to boil brine for centuries before the Christian era. In the United States artesian borings made for brine had furnished petroleum in enormous quantities thirty or forty years before any use was known for such a supply. The development of the coal-oil industry between 1850 and 1860 led to experiments upon petroleum as a substitute for the crude oil obtained from coal, and with the success of those experiments (1859) came a demand for petroleum that led to Drake's attempt to procure the oil directly by boring.

The success attending the oil industry in Pennsylvania during the first four years of its existence led to the organization of companies all over the world for the purpose of drilling test-wells wherever springs of petroleum were accessible. In some localities they were successful; in others only partially so; while in the majority of instances they were failures, or were found inferior to the primitive dug wells. The continuously increasing and enormous production of the United States, and the consequent depreciation in value of all the products manufactured from petroleum, has led to the almost complete control of that trade by American manufacturers, Galicia and the Caucasus at the present time being their only competitors, and they only to quite a limited extent.

a His book was published in 1690 by Jacob Oliger; *Comptes-Rendus*, ix, 217.

b *Comptes-Rendus*, ix, 217.

CHAPTER II.—THE GEOGRAPHICAL DISTRIBUTION OF PETROLEUM AND OTHER FORMS OF BITUMEN.

SECTION 1.—THE OCCURRENCE OF BITUMEN IN THE UNITED STATES.

The following chapter has been prepared for the purpose of showing the localities upon the earth's surface at which bitumen occurs, and great care has been taken to secure the most accurate information regarding the United States. For this purpose letters of inquiry have been addressed to the state geologists of all the states with which I am not personally acquainted, and to the geologist in charge of the geological survey of the United States. To these official sources of information has been added a large amount of personal inquiry and correspondence.

The map of the world (I) has been prepared to show the location of the areas producing bitumen. These areas are unavoidably exaggerated in size, and many localities of minor importance are omitted.

The map of the United States (II) shows the localities within the United States that have produced bitumen of any kind. Many of these areas are also unavoidably exaggerated in size.

The large map (III) shows the areas in Pennsylvania and New York that have proved commercially valuable. This map has been prepared from actual surveys, many of which were undertaken expressly for parties engaged in producing oil. The areas tinted yellow are believed to be substantially correct as regards both location and outlines. The streams were plotted with every attention to accuracy, and are believed to indicate the water-shed and lines of greatest elevation. The dates beneath the names of towns indicate the period at which the locality was yielding its maximum production. The red lines indicate the main pipe lines, and the broken blue lines indicate in a general way the outline of territory over which wells or natural springs have yielded petroleum or gas, but in most instances not a sufficient amount of petroleum to be profitable.

Map IV represents the areas at the White Oak district, West Virginia, drawn from actual surveys.

Map V shows the location of oil-wells in the valley of the Cumberland river in Kentucky and Tennessee, drawn from actual surveys.

Map VI represents in a general manner the localities in southern Ohio, West Virginia, and Kentucky that have produced bitumen.

Map VII represents in a general manner the localities in Louisiana and Texas that have produced bitumen.

Map VIII represents the localities in Michigan and Canada that have produced bitumen.

STATES AND TERRITORIES FROM WHICH NO BITUMEN HAS BEEN REPORTED.

Maine.	Maryland.	Mississippi.	Montana.
New Hampshire.	Virginia.	Arkansas.	Idaho.
Vermont.	North Carolina.	Iowa.	Washington.
Massachusetts.	South Carolina.	Wisconsin.	Oregon.
Rhode Island.	Georgia.	Minnesota.	Nevada.
Delaware.			

STATES AND TERRITORIES IN WHICH SOLID BITUMENS OCCUR.

CONNECTICUT.—In the valley of the Connecticut river solid bitumens have been observed filling thin seams and veins in eruptive rocks. (*a*)

NEW YORK.—In the eastern portion of the state, in the region of eruptive and metamorphic rocks, veins occur similar to those reported from Connecticut. (*b*) In some of the cavities of the New York limestones the crystals which line them are covered with a substance, black and shining, with the fracture and appearance of anthracite.

NEW JERSEY.—Veins are reported in the trap of New Jersey filled with a bituminous mineral. (*c*)

WEST VIRGINIA.—In Ritchie county, West Virginia, on McFarland's run, a small tributary of the south fork of Hughes' river, which enters the Little Kanawha, is found a vein of bituminous material, called asphaltum, which is without doubt closely related to petroleum and other forms of bitumen, but in precisely what manner has been a subject of much controversy. This vein cuts the nearly horizontal sandstone almost at right angles and stands vertical to the horizon. Very extensive mining operations were commenced upon the vein, but the mass was soon worked down to the lower level of the sandstones, and was found to pinch out in the shales beneath. It presented all of the appearances of an eruptive mass. The material was found to be exceedingly

a J. C. Percival on "Indurated Bitumen", *Geol. of Conn.*, A. J. S. (3), xvi, 130.
b L. C. Beck, A. J. S. (I), xlv, 335.
c J. C. Russell, A. J. S. (3), xvi, 112.

valuable for enriching gas, for which it was chiefly used; but a thickness of several hundred feet of shale, in which it was almost entirely wanting, prevented continuous working. Other smaller but otherwise similar veins occur in the neighborhood. (*a*)

TEXAS.—Near the mouth of the Brazos river and in other parts of Texas beds of asphaltum occur, evidently resulting from the decomposition of petroleum; but so far as I have been able to learn they have no commercial value.

NEW MEXICO AND ARIZONA.—In these territories beds of asphaltum are reported. They have no other than a local value.

UTAH.—In this territory, in the Sanpete valley, southeast of Salt lake, is said to be a deposit containing ozokerite similar to that found in Galicia. Also on the banks of the Green river veins are said to occur resembling the grahamite found in West Virginia. Although I have seen specimens which were said to have come from both of these localities, I have never met any detailed description of them. Neither deposit has yet any commercial value.

CALIFORNIA.—This state includes a large area which furnishes asphaltum, much the larger proportion being the product of the decomposition of petroleum, while the remainder occurs in veins that are evidently eruptive, (*b*) the former occurring in beds of greater or less extent on hillsides or gulch slopes below springs of more fluid bitumen. These deposits are scattered over the country between the bay of Monterey and San Diego, but are chiefly observed west and south of the coast ranges between Santa Barbara and the Soledad pass. In the aggregate there are thousands of tons of asphaltum scattered over this region of every possible degree of purity; but it is so difficult to handle, and so little is concentrated in one place, that little use has thus far been made of it.

The case is quite different, however, with the deposit at Hill's ranch, on the coast above Santa Barbara. Here eruptive masses that have been very fully described by Professor J. D. Whitney and myself (see note *b*) occur in such quantity that it has been obtained in cargoes for use in San Francisco. The asphaltum of this locality is solid and homogeneous in appearance, but it really contains 50 per cent. of sand, so fine and in such complete admixture as to make the material superior for pavement to any artificial mixture that can be produced. I have never been able to obtain even an approximate estimate of the quantity that this locality has furnished.

KENTUCKY.—Asphaltum is reported in Johnson county, on the tributaries of the Big Sandy river. I have never seen any of this asphalt, but I am inclined to think it is also more closely related to the gum beds of Canada, above mentioned.

TENNESSEE.—Asphaltum is reported in cavities and prisms in the Trenton limestone in middle Tennessee in small veins rarely an inch in thickness. The amount is insignificant.

OTHER LOCALITIES.—Asphaltum is also reported from other localities, in Missouri and Kentucky, but I have never seen any of the material, and from all that I have been able to learn regarding the deposits they resemble the so-called gum beds of Canada, which really consist of a mass of mud or soil saturated with petroleum, rather than of pure and solid asphaltum. Such mixtures of oil and mud are often met around oil-wells in any of the productive districts where the waste oil has soaked the ground about the derricks.

STATES AND TERRITORIES IN WHICH SEMI-SOLID BITUMEN (MALTHA) OCCURS.

This material issues from so-called tar-springs, and is found almost or quite exclusively within the southwestern portion of the country. I have seen but a single specimen from one of the interior counties of Texas. A letter of inquiry, addressed to the secretary of state of Texas, was referred to Mr. N. A. Taylor, who replied:

> The tar-springs in Burnet county discharge a good deal of petroleum. The wagoners gather it to grease their wagon wheels. It is probable that borings there would get a good supply of oil. It appears on the surface of nearly all the springs at Sour lake. In days past it has evidently exuded from the ground at that place in great quantity, for there are some acres just below the lake almost completely covered with the consolidated stuff, or asphalt, the thickness of which I don't recollect, but no doubt it is very thick in some places. An attempt was made there to bore for the oil, but after penetrating the ground to some distance a great explosion occurred, and the fellow was afraid to try it again. I think some borings have also been made in Nacogdoches county. There is also a small lake in Marion county, where oil covers the water, and where there is also a good deal of asphalt. These counties are in northeast Texas. Burnet county is in the southern central portion of the state.

These tar-springs, which yield a semi-fluid maltha, are often called oil or petroleum springs by those who do not understand the difference in the value of these different although in some respects similar substances.

In New Mexico, not far from Albuquerque, tar-springs are reported; also in Arizona and southern Utah; but the exact localities I have been unable to learn or verify.

In southern California, throughout the same region in which asphalt is found, maltha occurs in great abundance, oozing from springs on the hillsides and in the beds of water-courses in cañons, and after exposure to the elements becoming hardened into asphaltum. In consistence it passes by insensible gradations from a material scarcely to be distinguished from heavy petroleum to solid asphalt. It varies in specific gravity from 0.9906 to 1.100, the heavier material, though heavier than water, still remaining plastic like mortar. Springs near the old stage-road between

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a Lesley, J. P., P. A. P. S., ix, 183; A. J. S. (2), xli, 139; H. Wurtz: Report, 1865; S. F. Peckham, A. J. S. (2), xlviii, 362, Nov., 1869; A. G. J., xi, 164.

b J. D. Whitney: *Geology of California*. Geology, I, 132; S. F. Peckham, A. J. S. (2), xlviii, 368.

the Gaviota pass and the old mission of San Miguel (if my memory is correct) yield a quicksand cemented by maltha that oozes out and accumulates in great masses upon the side of the hill, becoming rigid as the maltha changes to asphalt. At Rincon point, about half way from Santa Barbara to San Buenaventura, a bed of sand overlying the shales, which there stand at a high angle, is saturated with maltha for about 20 feet in thickness over many hundreds of acres. The formation is exposed in the ocean bluff for at least a mile. Fig. 1 shows the manner in which the sand overlies the shale. (*a*)

Early in 1866, when trial-borings for petroleum were being conducted upon the San Francisco ranch, in the Santa Clara valley, Ventura county, maltha was found at a depth of 117 feet too dense to pump and without sufficient tenacity to admit of being drawn up with grappling hooks, yet sufficiently firm to clasp the tools and prevent further operations. On the plains northwest of Los Angeles an artesian boring that penetrated sandstones interstratified with shale to a depth of 460 feet yielded maltha.

In this region there are vast quantities of this material, which has not hitherto been found valuable, but which will no doubt at some future day be found useful in the arts. (*b*)

Maltha is also reported at the Shoshone springs, in Wyoming territory, and in cavities in the limestones of middle Tennessee. In the latter locality it occurs in small quantities, and has no commercial value.

STATES AND TERRITORIES IN WHICH LIQUID OR GASEOUS BITUMEN OCCURS.

NEW YORK.—In 1865 Jonathan Watson drilled a well in Ontario county, 5 miles east of Canandaigua lake, and found there a good oil-rock, plenty of gas, and a production of about 5 barrels of oil daily. A line drawn from this point west to lake Erie, and another south to the Pennsylvania line, would include all of the territory in the state of New York over which oil or gas has been obtained by boring (see map III), and along the shores of lake Erie, from the state line to Buffalo, at almost any point natural gas may be obtained from artesian borings. Fredonia, in Chautauqua county, a few miles south of Dunkirk, has been lighted by natural gas for more than forty years.

A great many wells have been bored along the lake shore and for some distance inland, and at a number of localities in Chautauqua and Erie counties they are reported to have produced small quantities of oil. In the southeastern portion of Chautauqua county, and that portion of Cattaraugus county north and west of Salamanca, the indications of a productive oil territory become more pronounced, but I have not been able to learn definitely that any wells in that region have yielded oil enough to pay their cost. The larger number of these wells were drilled many years ago, and detailed statements concerning their exact locality and the results afforded by them are now very difficult to obtain.

South and east of Salamanca the Bradford oil-field of Pennsylvania extends into New York, and has proved a very certain and valuable territory. The statements that are made in this report respecting the Bradford field apply equally to that portion lying in New York and in Pennsylvania. The field in New York lies south of the Allegheny river. (See map III.)

The next county east of Cattaraugus is Allegany, and at Cuba, in the southwestern part of that county, is the oil-spring described in 1833 by Professor Benjamin Silliman, sr. (*c*) Through the southern townships of this county the Richburg field has been recently opened with much promise. A few wells have been drilled in the southwestern part of Steuben county, but with what promise of commercial success has not yet been determined.

The wells in this region are from 1,600 to 2,000 feet in depth; the oil is of a dark amber color and of a specific gravity of 44° Baumé, very closely resembling that of the Bradford field.

PENNSYLVANIA.—A number of test wells have been drilled in the western part of Potter county, Pennsylvania, contiguous to Allegany county, New York, and some are reported to have yielded oil in small quantity, but most of them are understood to have been entirely unproductive.

The next county west is McKean county, and the greater portion of the Bradford field occupies that portion of the county embraced in about one-half the townships lying west and north of Smethport. As may be seen from the map (III) accompanying this report, the outline is irregular, with a small but detached portion lying to the southwest of the main body. This field has been developed since 1874, and while it has been very completely outlined by dry holes and wells of small production, there are many wells in different portions of the county outside the field that have yielded more or less oil. At Smethport a well yielded a "small quantity" of very dense amber-colored oil, while at Kane, in the southwestern part of the county, on the Pittsburgh and Erie railroad, is one of the most remarkable gas-wells on record. (*d*) The wells here are from 1,600 to 2,000 feet deep.

The next county west of McKean is Warren, and in it there are two well-defined productive fields of small extent. These are the Warren field, lying around the town of Warren, and the Clarendon and Stoneham field, lying to the south a short distance, yet entirely distinct from the former. These fields yield an amber oil of a specific gravity of 48° Baumé. The wells are from 800 to 1,100 feet deep.

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a *Report of Geological Survey of California*: Geology, II. Appendix, p. 51, Fig. 2.

b S. F. Peckham, A. J. S. (2), xlviii, 370; Am. C., iv, 6.

c A. J. S., (1) xxiii, 97.

d C. A. Ashburner, J. F. I., cviii, 347; P. A. P. S., xviii, 9, 419; T. A. I. M. E., 1879, 1878, 316; A. J. S. (3), xvi, 393, xvii, 69, xix, 168; J. F. Carll, P. A. P. S., xvi, 346.

In the central, southern, and southwestern portions of Warren county, from Tidioute, on the Allegheny river, southwest into Venango county, the territory known as Triumph hill was opened in 1868. Some wells were bored in 1860 by the Economites in the river opposite Tidioute, and later upon the high land on the south side of the river. But this territory is small. On the north and west side of the river (which makes a bend just below Tidioute) a narrow belt of territory that has been very productive extends across the hills into Venango county. Northwest of this belt, in the southwestern corner of the county, a small territory around Enterprise proved very productive. Other noted localities in this section are Fagundus, southeast of Tidioute, and New London and Colorado, southwest of the same place.

The wells in the Warren and Stoneham fields are in a horizon which lies in depth between the Bradford and Venango county fields. Those on the island in the Allegheny river, first drilled by the Economites in 1860, were 120 feet deep; on the hills they are from 560 to 570 feet deep. The oil produced here is dark green by reflected light and of the color of brandy by transmitted light, resembling in this respect the oil of the so-called Oil creek. At Sheffield, in the southeastern part of this county, is another remarkable gas-well.

Erie and Crawford counties lie west of Warren county, and have both been pretty well drilled over. At Erie, on the lake shore, a number of gas-wells has for many years furnished gas to dwellings and manufacturing establishments, and a few wells sunk 600 to 700 feet in the shale have yielded a few barrels of heavy green oil, suitable for lubricating machinery. The most successful of these wells (the Demming) did not, so far as I could learn, pay the cost of drilling. The oil has a specific gravity of 26° Baumé. At Union City, in the southeastern part of Erie county, wells have also been drilled in shale which yielded a small quantity of very dense oil for a very long time. The first well was drilled in 1859, soon after Drake struck oil, to a depth of 52 feet, and has yielded a small quantity of oil ever since. Several other wells have been drilled here, but none of them, so far as I could learn, have ever proved profitable.

Mr. J. P. Stranahan, of Union, informed me that he and his brothers dug out an oil spring thirty-five years ago at Oxbow hill, a few miles northeast of Union, and that it had flowed oil ever since. The boys set the gas from the spring on fire and boiled eggs in the flame.

In 1879 a well was drilled 2½ miles west of Union, that struck oil in "paying quantities" at 18 feet. In going deeper to get more oil the well was spoiled, and was afterward abandoned; but I conclude that at better prices Erie county can be made to produce a considerable amount of heavy oil. At Girard and other points near the lake shore gas-wells are productive.

Crawford county, excepting in the southeast corner, along the valley of Oil creek, has about the same record as Erie county. Along the valley of French creek and its tributaries, above and below Meadville, many wells have been bored, some of which produced oil, but none in quantities that proved remunerative.

Titusville is near the line of Venango county, in the southern part of Crawford county, and north of Titusville is Church run, a locality that for a time proved very productive. This neighborhood has yielded oil from the date of Drake's well (1859) up to the present time. Drake's well was 69½ feet deep, and penetrated only to the first stratum of sandstone yielding oil; but after the wells were drilled deeper a second and a third sandstone were reached, and a much greater yield was obtained. The valley of Oil creek has been drilled all over, and nearly everywhere south from Church run it has proved productive. The portion, however, that lies in Crawford county is comparatively small.

South of Crawford county lie Mercer and Venango counties. Mercer county has been well drilled over with test wells, particularly the eastern portion, but without developing any territory of value. Venango county has proved one of the four most productive counties in the state, and if complete statistics from 1859 were to be had it would probably head the list. Oil creek enters near the middle of its northern boundary and runs a little east of south until it enters the Allegheny river near the center of the county, at Oil City. The Allegheny river enters the county near the middle of its eastern boundary, receives Oil creek at Oil City, and, flowing southwest, receives French creek at Franklin, from which point it flows southeast, and leaves the county at its southeast corner. The valley of Oil creek, the triangle between that creek and the Allegheny river, and the region below Franklin, on the same river, is crossed at intervals by long and narrow belts of territory, often from an eighth to a quarter of a mile wide and several miles in length, which have produced and are still producing oil in enormous quantities. These belts occupy long troughs or depressions, level on their upper surface, and curved upward from the center on the under surface from side to side. In a few instances the productive territories have been found to resemble pools in their outline and dimensions, but the major portion of this whole county is crossed by a great number of these belts which have yielded enormously productive wells in the center and less productive ones on parallel lines along the sides, until at a distance in some instances of 20 rods on either side the drill failed to reveal the presence of either sand or oil. The oil of this section has been quite uniform in character, excepting that produced in the neighborhood of Franklin, a small territory in the angle formed by French creek and the Allegheny river. In color it is for the most part green, although a considerable quantity has been obtained that is decidedly black. The specific gravity has varied from 42° to 48° Baumé.

The Franklin district has furnished a lubricating oil of very superior quality from shallow wells. These wells are almost all in Cherrytree township, Venango county; but a few are in Franklin on the high bluffs south of the city.

Forest county lies east of Venango county. Here several belts extend from one into the other, and several independent areas of small extent have been developed within its limits. West Hickory, Foxburg, and Balltown have been the principal centers, but the county, on the whole, has not proved to be very important for oil production.

The next county east is Elk, but as an oil-field is of less importance than Forest. A few wells have been drilled in its northwest corner, and others in the neighborhood of Wilcox have produced oil; but the production, as a whole, is unimportant. Near Wilcox is a noted gas-well.

Jefferson county, lying south of both Elk and Forest, has received some attention, but is without reputation. I have not learned that any of the wells reported to have been drilled there have yielded oil; they certainly have not in valuable quantity.

A glance at map III, accompanying this report, will show a large belt of oil territory having a general northeast and southwest direction lying in Clarion, Armstrong, and Butler counties. This belt begins in the southwest corner of Clarion county, passes through the northern part of Armstrong county, and extends nearly to the center of Butler county. The wells are from 900 to 1,300 feet in depth, becoming deeper as they approach the southwest extremity of the belt. This belt has been exceedingly productive throughout its entire area, and furnished the bulk of the oil production of Pennsylvania from 1869 to 1877. Small areas in each of the three counties have been developed outside the principal belt that have yielded in the aggregate a large amount of oil, but their importance has been so overshadowed by the main Butler and Clarion fields that they have been but little noticed. At Petrolia, in Armstrong county, gas-wells have proved very productive, and at Leechburg, on the Kiskiminitas, this gas has been used for manufacturing iron.

In the lower part of Armstrong county petroleum was obtained in 1839 in salt-wells, and was used for derrick lights.

West of Butler county, in Lawrence county, many wells have been drilled, with varying success. In the southeast corner of this county, on Slippery Rock creek, a belt has been developed that has been moderately prolific; but outside of this small area the county may be said to possess but little value for oil purposes.

South of Lawrence county, in Beaver county, a very valuable field has been opened up in the neighborhood of Smith's Ferry, on the north side of the Ohio river. This territory is between 3 and 4 miles square, and the oil is uniformly different from that produced in other portions of Pennsylvania and the adjoining states of Ohio and West Virginia. Being of a light amber color, resembling pale sherry wine, though not transparent, and having a specific gravity of 50° Baumé, it will burn in a lamp in hot weather without refining. This oil is much more valuable than the average of Pennsylvania oils.

Allegheny county lies east of Beaver, and near its center is the city of Pittsburgh. Along the Allegheny river above Pittsburgh, particularly near Tarentum, in the northeast part of the county, petroleum has been observed for 40 or 50 years, and it was here that Mr. Kier obtained the first oil that he refined at Pittsburgh. This county has never been regarded as valuable for oil purposes.

Oil suitable for lubrication has been obtained at Greensburg, in Westmoreland county, and many wells have been drilled in Washington county; but the production of oil has been practically nothing. In the southeast corner of Greene county, which is the southwest county of the state, an area on Dunkard's creek has produced a few thousand barrels yearly for several years, but the territory is small, and has been comparatively unimportant.

Ohio and West Virginia.—There are three localities in Ohio that have yielded petroleum from an early date. These are the neighborhood of Mecca, in Trumbull county, the neighborhood of Belden, in Lorain county, and Washington county.

Mecca is near the center of Trumbull county, which lies directly west of Mercer county, Pennsylvania. The oil produced here is from shallow wells, less than 100 feet in depth, is of a specific gravity of 26° Baumé, and of very superior quality as a lubricator. The territory is about 4 miles in length, north and south, by 2½ miles wide, and lies upon the west bank of Mosquito creek, with the village of Power's Corners near its center. Large sums of money have been expended in boring for oil in the valley of the Cuyahoga, where there are numerous springs; but none of the wells proved profitable, although a small quantity of oil was obtained in nearly all of them.

The Belden district, in the southeast part of Lorain county, is of about the same dimensions (4 by 2½ miles), but lies with its longer axis east and west. Several varieties of oil are produced here from wells of different depths. The more dense is black, and has a specific gravity of from 26° to 28° Baumé, while the lighter is green, and has a specific gravity of from 28° to 36° Baumé. It is supposed that this territory is larger than present developments would indicate, as wells have produced oil at Liverpool and at Medina, in Medina county, both of which are several miles east and southeast of Belden.

In the southeast portion of Columbiana county, a short distance west of the Smith's Ferry district, in Pennsylvania, many wells have yielded in the aggregate quite a large quantity of petroleum, although, as compared with other localities, the yield is unimportant.

The Washington county district extends into Noble, Morgan, and Athens counties, and for the most part lies in the valley of the Muskingum and its tributaries. Petroleum was obtained here in brine wells as early as 1814, and was noticed by Dr. Hildreth, of Marietta, in 1833, and again in 1836. (*a*)

The white oak anticlinal, or so-called "oil-break" of West Virginia, extends from Newell's run, a tributary of the Little Muskingum river, in Newport township, Washington county, Ohio, to Roane county, West Virginia, passing through Pleasants, Ritchie, Wood, and Wirt counties, of the latter state, reaching its highest point at Sand Hill, where the axis crosses Walker's creek, the rocks here being raised about 1,500 feet above their normal level. The crest is about one mile wide from side to side (east to west), in which the rocks are practically level, the stratification being as uniform as in the rocks outside of the anticlinal; but along its axis it is not level, forming there undulations, in which the whole depth of the formation shares. This brings the entire series in three elevations: the first one north at Horse Neck, in Pleasants county; the second at White Oak, in Wood county; and the third at Burning Springs, in Ritchie county. Oil is found under these three elevations, and consequently there are in West Virginia three contiguous districts that yield oil. (*b*) A few wells have yielded oil at the northern extremity of the uplift on Newell's run, in Ohio.

The territory of "Cow run" is situated in Lawrence township, Washington county, Ohio, about 3 miles west of the northern extremity of the white oak anticlinal. Here the rocks for about three-quarters of a mile square are raised 350 feet above their normal level, dipping off gradually on all sides.

The Macksburg territory is of limited extent, and is situated in Aurelius township, in the extreme northern part of Washington county.

At Olive, in Noble county, where the brine well of 1814 was located, petroleum has been obtained, and also in the Scioto valley, but not in paying quantities. (See Map VI.)

At Blue Rock, southeast of Zanesville, in Muskingum county, Buck run, in Morgan county, and Federal creek, in Athens county, a few wells have proved profitable. At Rutland, near Pomeroy, in Meigs county, near Gallipolis, in Gallia county, and on Tug fork of the Big Sandy river, in Wayne county, West Virginia, oil-springs have been observed. These localities lie in an almost direct line from Blue Rock to Tug fork, and are supposed to indicate a line along which wells will ultimately prove profitable.

There are several horizons in this region lying at different depths that yield oil of different specific gravities. The facts relating to this subject will be elucidated in Chapter III. (*c*)

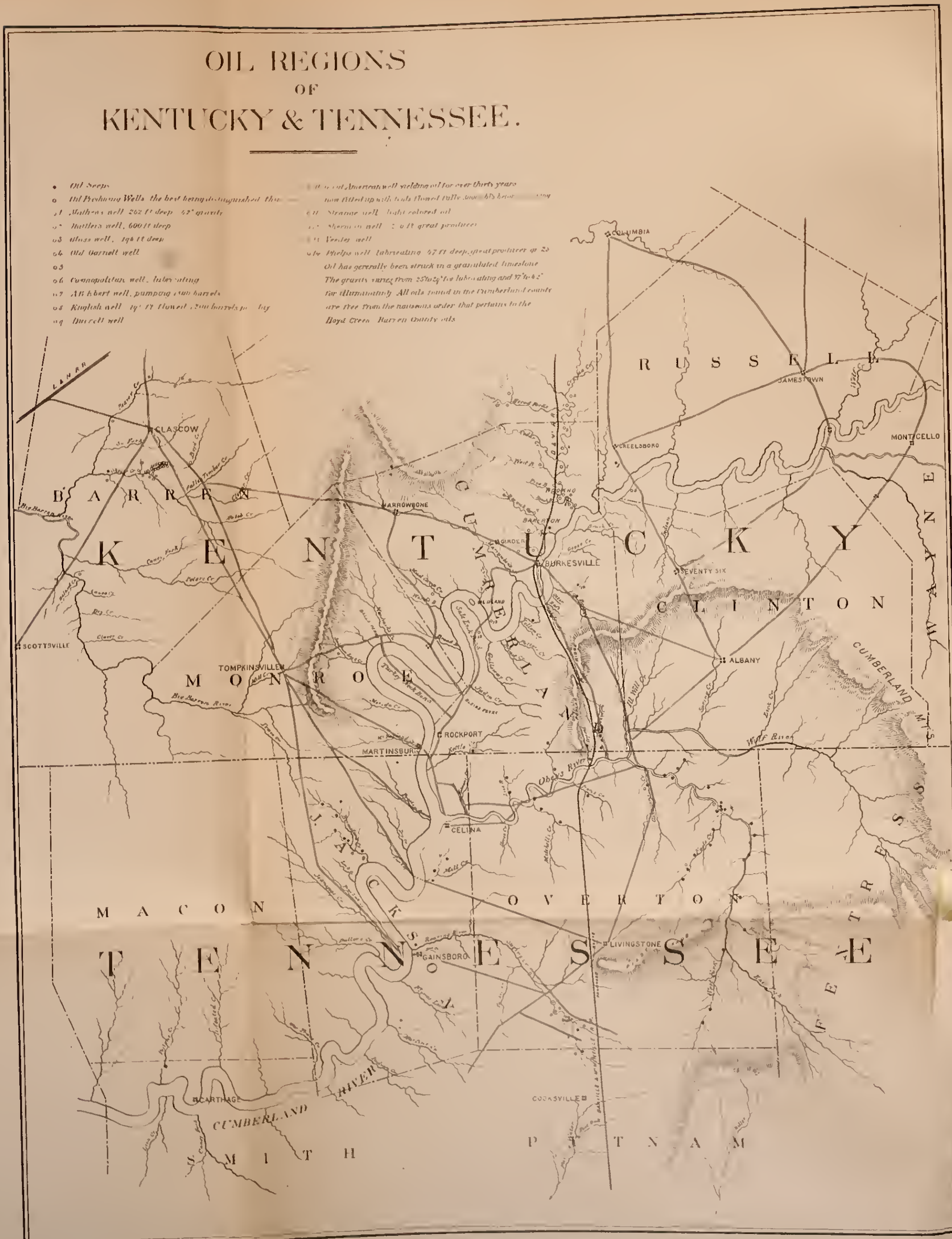
Along the lake shore, at Ashtabula, Painesville, Cleveland, Rocky river, and other localities, gas-wells have yielded profitable supplies for heating and lighting dwellings. (*d*) At Liverpool, Columbiana county, Ohio, and across the river, at New Cumberland, Hancock county, West Virginia, gas-wells have yielded very large amounts for a long time, (*e*) the gas from which is used for lighting dwellings and factories and for the manufacture of lampblack. In Knox county some of the most remarkable gas-wells on record have been discovered in boring for oil. This gas is also used for the manufacture of lampblack. A further description of these wells will be given in the chapter devoted to natural gas. (*f*) At Burning Springs, Ritchie county, West Virginia, the escape of natural gas was noticed by the earliest settlers. (*g*)

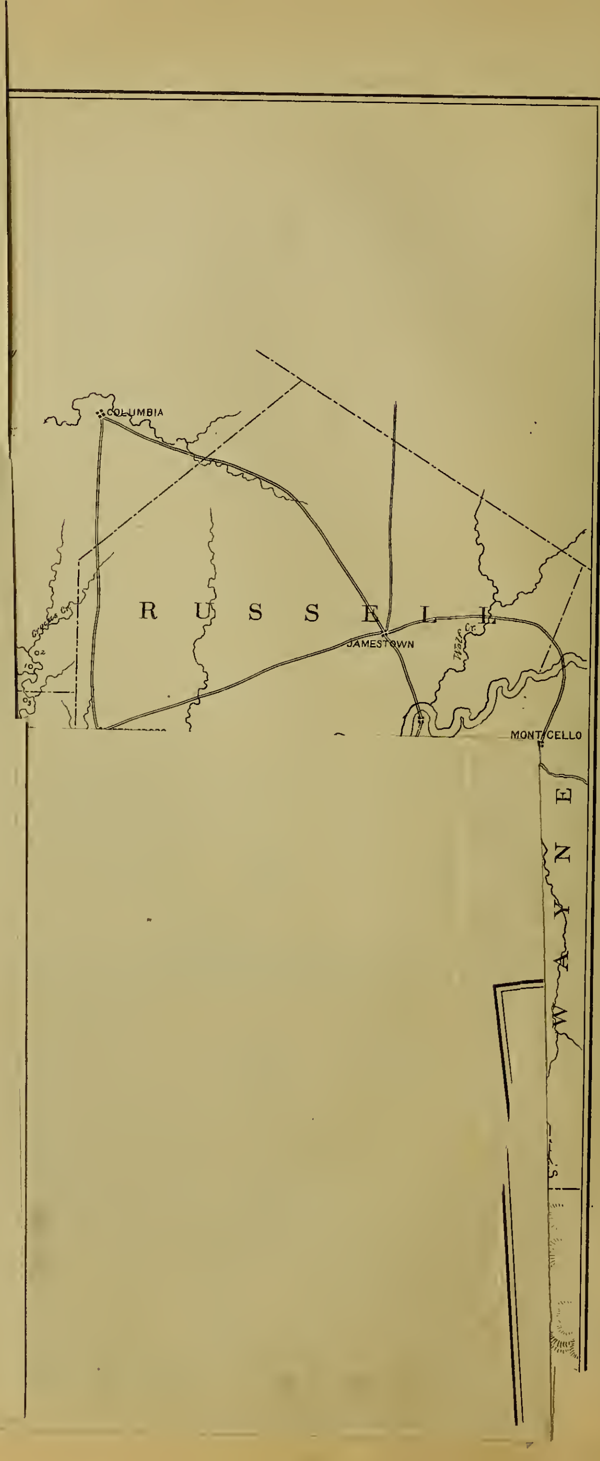
At the salines, in the valley of the Great Kanawha, above and below Charleston, petroleum has been observed for at least fifty years, and for a time the natural gas which arose with the brine in nearly all of the wells was largely used for evaporating purposes; but while the aggregate production of this locality has no doubt been many thousands of barrels, it was for the most part obtained before petroleum became an article of large demand, and much of it was doubtless wasted. (See Map VI.)

KENTUCKY AND TENNESSEE.—The oil and burning springs that mark the line from Blue Rock, in Ohio, to the Tug fork of the Sandy river, in West Virginia, is continued in outcrops on Paint creek, Johnson county, Kentucky. This creek is a tributary of the west fork of the Big Sandy, and has been described by J. P. Lesley in his report published in 1865. (*h*) Springs are also met with near Saylersville, in Magoffin county. In Lincoln, Rockcastle, Pulaski, Casey, Green, Adair, Russell, and Metcalfe counties oil-springs are found, and oil-wells have been drilled at different times. Some of these wells in Lincoln and Casey counties are old salt-wells, drilled fifty or sixty years ago; others are oil-wells drilled during the excitement of 1865 and 1878. The oil sand in Lincoln county lies at a depth of about 300 feet. A number of wells have been drilled in this county in the neighborhood of Stanford, all of which are reported to have reached oil, but the wells have not been piped or pumped, and none of the oil has been put upon the market. In Wayne county the oldest well in the country is still flowing oil. It was drilled for brine on the little south fork of the Cumberland river, in the southeast corner of the county, in 1818. The oil is heavy, black lubricating oil. Wells have been drilled near Monticello since 1865 that yield a heavy oil of a dark-green color, specific gravity 25° Baumé, that has a high reputation as a lubricator. In Clinton county oil was obtained in 1866; in Cumberland county the old American well was bored for brine in 1829 and flowed oil till 1860; and in 1865 a large number of wells were drilled along the Cumberland river and the creeks flowing into it, and they probably gave the most

a A. J. S. (1), xxiv, 63; xxix, 87.
b See sections, Plates III and IV.
c For many of the facts stated in this report respecting this region I am indebted to F. W. Minshall, esq., of Parkersburg, West Virginia.
d J. S. Newberry, Geo. Ohio, i, 161.
e *Ibid.*, iii, 118.
f Geo. Ohio, 44.
g S. P. Hildreth, A. J. S. (1), xxix, 87, 121.
h P. A. P. S., x, 33.


MUSKINGUM
NOBLE
MARSHALL
GREENE
P E N N.
PERRY
FAIRFIELD
PICKAWAY
MONROE
MORGAN
MONONGALIA
WETZEL
MARION
HOCKING
WASHINGTON
TYLER
ATHENS
ROSS
VINTON
PLEASANTS
BALTIMORE & OHIO R.R.
TAYLOR
HARRISON
DODDRIDGE
WOOD
RITCHIE
MEIGS
JACKSON
PIKE
BARBOUR
WIRT
GILMER
LEWIS
JACKSON
CALHOUN
UPSHUR
GALLIA
MASON
ROANE
BRAXTON
SCIOTO
LAWRENCE
RANDOLPH
PUTNAM
CLAY
WEBSTER
CABELL
CHESAPEAKE & OHIO R.R.
LOYO
POCAHONTAS
KANAWHA
NICHOLAS
LINCOLN
LAWRENCE
WAYNE
FAYETTE
JOHNSON
BOONE
GREENBRIER
ALLEGHANY
MARTIN
LOGAN
Ohio
82°30′
82°
81°30′
81°
80°30′
80°
39°
38°
Scale.
50
25 20 15 10 5 0
50
100 MILES [STAT.]


OIL REGIONS
OF
KENTUCKY & TENNESSEE.
Oil Seeps
Mathews well 262 ft deep
Old Garnett well
Cosmopolitan well
Durrell well
Oil has generally been struck in a granulated limestone
Boyd Creek Barren County oils
RUSSELL
COLUMBIA
JAMESTOWN
CREELSBORO
MONTICELLO
GLASGOW
BARREN
KENTUCKY
MARROWBONE
CUMBERLAND
BURKESVILLE
SEVENTY SIX
CLINTON
ALBANY
CUMBERLAND MTS.
WAYNE
SCOTTSVILLE
TOMPKINSVILLE
MONROE
ROCKPORT
MARTINSBURG
Obeys River
Wolf River
CELINA
JACKSON
MACON
OVERTON
FENTRESS
TENNESSEE
LIVINGSTONE
GAINSBORO
CARTHAGE
CUMBERLAND RIVER
COOKSVILLE
SMITH
PUTNAM


COLUMBIA
RUSSELL
JAMESTOWN
MONTICELLO
WAYNE

certain and largest yield of oil that has ever been obtained for the same cost in any locality. At the same time, probably a larger proportion of the oil produced was wasted than has been the case anywhere else in the United States, as it is supposed that 50,000 barrels from the American well ran down the Cumberland river before any attempt was made to save it. The oil near Burkesville, Cumberland county, has a peculiar, offensive odor and a specific gravity of 37° Baumé. Amber oil of a lower specific gravity was obtained from other wells in small quantity, and a larger amount was yielded by wells on Oil fork of Bear creek (east of Burkesville), which was of a black color, with a specific gravity of 26° Baumé. The oil here appears to be in a sort of marble at 90, 190, and 380 feet from the surface.

On Boyd's creek, near Glasgow, Barren county, Kentucky, oil has been obtained for several years in commercial quantities, the wells being in the bed of the creek and on the adjoining hills. A few thousand barrels per year are obtained here. Wells have also reached oil on Beaver creek north of Glasgow. A well is also reported to have yielded "considerable quantities" of oil near Bowling Green, Warren county, and another near the Mammoth cave, in Edmonson county. (See Map V.)

Directly north of these counties, on the Ohio river, wells have reached oil at Brandensburg, in Meade county, at a depth of 900 feet; but those who drilled them afterward concluded that they were not deep enough. Three wells were also drilled near Cloverport, which yielded a small quantity of oil. Another well is reported in Bourbon county, and still another at Henderson, in Henderson county. This latter well is reported to have yielded a very valuable lubricating oil. Over at least one-third of the state scattering wells have yielded petroleum, some of which have been among the most remarkable in the country.

Springs of natural gas are common throughout the region just outlined; but I have not learned that the gas is anywhere used for any purpose, or that more than one well has ever been bored for gas, that at Bristow station, Warren county. Cumberland, Clinton, and Wayne counties, Kentucky, border Clay and Fentress counties, Tennessee, which, with Overton, Jackson, and Putnam counties, are drained by the east and west forks of Obey's river and other smaller tributaries, with Eagle and Spring creeks, all of which are tributaries of the Cumberland river. Many oil springs are found in the valleys of these streams, and during 1867, 1868, and 1877 a number of wells were bored, almost uniformly producing oil, the larger part of which ran to waste for want of means of transportation. Trousdale, Macon, and Sumner counties, lying west of Jackson county and north of Nashville, also have oil-springs along some of their streams. To the west of Nashville about 40 miles another group of counties has oil-springs in the valleys of their streams, the principal field of operations being in Dickson county. Several wells drilled here from 1866–'69 to 1877 to a depth of between 400 and 600 feet yielded oil of a specific gravity of 44° Baumé.

In Hickman, Montgomery, and Maury counties there are springs, from one of which oil has been oozing since 1830, when it was opened by blasting for the foundation of a mill.

During the year 1863–'64 McMinnville, in Warren county, was the center of some activity in exploring for oil. A well sunk about forty years before for brine was sunk deeper for stronger brine. Oil flowed upon the creek, which took fire and destroyed the forests for 10 miles along its banks. Mr. M. C. Read visited this region in 1864, and found the agents of a Chicago company putting down five or six wells. These were located by witch-hazel men, at $500 each, to be paid when they struck oil. Mr. Read asserted that there were several bottomless pits of petroleum beneath an intensely hard, cherty limestone, very difficult to drill. The company spent the first assessment before they got through that stratum, when, the price of oil falling, they pulled out their tools and left. Cannon county, adjoining Warren county on the west, has been examined during the last season and many springs of heavy oil have been discovered. Oil has also been reported in a well near Chattanooga. The counties that I have enumerated cover about one-sixth the area of the state. (See Map V.)

ALABAMA.—Jonathan Watson, esq., of Titusville, Pennsylvania, drilled wells in northern Alabama in 1865 and got oil in two of them.

FLORIDA.—It is reported to me that there are no petroleum springs in Florida. A. A. Robinson, commissioner of the board of immigration, Tallahassee, Florida, in a letter, says:

> There is in the midst of an impenetrable cypress swamp near the coast, in Jefferson county, and about 35 miles southeast of Tallahassee, a mysterious column of black smoke, which has been rising for twenty years. At night it emits light, fitful and irregular, frequently lighting the sky so as to be seen miles away at sea. It is supposed to be a petroleum spring on fire. Much time, money, and enterprise has been expended to explore the swamp. No one has ever succeeded. It must be petroleum or a volcanic eruption. Some data may be found on the subject in the records of the United States coast survey.

MICHIGAN.—Oil and gas springs have been noticed on and near the shores of lake Huron and the entrance to the Saint Clair river. They are situated in several townships of Saint Clair county, not far from the city of Port Huron. A number of wells were bored near these springs in 1865, but none of the enterprises proved remunerative. (See Map VIII.)

ILLINOIS.—A well was bored at Chicago in 1865 that passed through strata that yielded petroleum both near the surface and at considerable depths. (*a*) The well was drilled for water. Recently a well has been reported as having been drilled in Montgomery county, a little north of east of Saint Louis, which yields a very heavy black oil, valuable as a lubricator.

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a A. J. S. (2), xl, 388.

INDIANA.—Wells drilled for water at Terre Haute in 1870-'71 showed petroleum, and afterward a well drilled purposely for oil yielded 25 barrels a day of a heavy green oil. In Crawford county, "during the oil excitement" from 1864 to 1868, ten wells were bored, and almost every one yielded "a show" of oil; but in no case could a yield of more than a pint a day be heard of, and in some cases only a few oily drops upon the snrface of thousands of barrels of water were found.

The oil-supply rocks of this vicinity are so limited that there is hardly a possibility of striking a paying well, and some of the white-sulphur fountains now running from wells bored for oil are more valuable than any oil-well possible in the county. More than 20 oil-springs have been noted in this county. (*a*) E. T. Cox, in the *Geological Survey of Indiana for* 1872, page 139, says:

During the great oil excitement of 1865-'66 quite a number of wells were drilled in the northern part of this (Perry) county, on the waters of Anderson and Oil creeks. These wells were generally carried to a depth of 700 feet, and in one or two of them was found a little oil and gas. Though it is extremely doubtful if oil in paying quantities can be found in the county, still I do not believe that these wells were carried to a sufficient depth to reach the corniferous and Niagara limestones, from whence the oil is obtained in the Terre Haute well.

Perry county joins Crawford county on its eastern border, and also contains oil-springs. In Lawrence county indications of petroleum have also been noted. Perry and Crawford counties, Indiana, are north of and opposite Breckinridge and Meade counties, Kentucky.

MISSOURI.—Some wells were drilled in this state about 1865-'68. A letter from Professor G. C. Swallow says:

A well was sunk on Mr. Boyd's land in Sec. 21, T. 33, R. 33, Barton county, 130 feet, without obtaining any considerable quantity of oil. Another well was sunk in Sec. 35, T. 34, R. 32, to the depth of 525 feet, principally in sandstone and shale; very little oil was found. In Barton and Bates counties oil often rises on the water of many springs in small quantities. In La Fayette county a well was sunk to a depth of some 600 feet through sandstone, shale, coal, and limestone. Very little oil was found, and none was saved. It appeared on the surface in a sandstone, and this led to the work upon the well. Another well was sunk in Ray county, from which small quantities were obtained. In Ray county oil often rises with the spring water and consolidates into asphaltum; in fact, there is no prospect of ever finding any oil in paying quantities in Missouri; though it comes to the surface in springs in hundreds of places in the region of the coal measures.

Ray and La Fayette counties are on either side of the Missouri river near the western boundary of the state; Bates and Barton counties are farther south, and are drained by the tributaries of the Osage river. Oil-springs are also reported in Cass county, north of Bates.

KANSAS.—Miami county, Kansas, is west of Bates county, Missouri, and is also drained by the tributaries or the Osage river. Oil and tar springs abound in this county, and oil was obtained in the salt-wells at Osawatomie, Paola, and other places. In 1860 a well was bored 275 feet deep on Sec. 15, T. 17, R. 23, and "they got oil all the way down". It is supposed it would yield one barrel a day. Another well was bored in 1865 on Sec. 11, T. 17, R. 24. Oil-springs are also reported in Linn county. The oils are all black and heavy, and are fit only for lubrication. (*b*)

LOUISIANA—In the low lands bordering on the Calcasieu and Sabine rivers there are numerous springs of petroleum. (*c*) (See Map VII.)

NEBRASKA.—In a communication to S. F. Peckham from Professor Samuel Aughey appears the following:

No petroleum springs, as such, are known in Nebraska. No wells have been drilled purposely for oil. In boring for coal at Ponca, Dixon county, a small amount of oil rose to the surface from a depth of 370 feet. I obtained only about a spoonful by saturating woolen cloths. Don't amount to anything. The same traces of oil have been obtained this season in boring for coal at Decatur, Burt county. I have observed genuine petroleum floating in the north Platte river above the mouth of Willow creek, in extreme western Nebraska. Thus far I have failed in my efforts to trace it to its source.

Dixon and Burt counties are on the west bank of the Missouri river, in northeast Nebraska.

MONTANA, WYOMING, DAKOTA, COLORADO, AND NEW MEXICO.—A letter addressed to the director of the United States geological survey, July 6, 1881, in which inquiries were made regarding the occurrence of petroleum in the territories, was referred to the different geologists in charge of those regions, and in reference to those named above S. F. Emmons replied as follows:

Certain horizons of the cretaceous sandstones in the Rocky mountain region are more or less impregnated with hydrocarbons, and when sufficiently and systematically examined will be very likely, in favored localities, to yield merchantable petroleum in considerable amount, if the conditions are such as to make it pay. As yet, however, but little has been done, and the returns of my experts, who were instructed to report on any petroleum wells that they could hear of, contain no schedules on this industry. The only information I can give you, therefore, is of the most general description. * * * Actual springs of petroleum I have not seen, though I have occasionally heard of a little oil on the surface of water. Considerable thickness of sandstones was observed by me on the southern slopes of the Uinta mountains, notably in Ashley creek basin, which were black with carbonaceous matter. The weathered surfaces, however, had lost all of their volatile ingredients, and doubtless suffered thereby some chemical change; so that it was more of an asphaltic material that was left. In the neighborhood of Bear River City, on the Union Pacific railroad, near the boundary of Utah and Wyoming, and also about 15 miles east of there, in the hills, wells were sunk, from which a few barrels of petroleum were obtained, but I fancy it never proved a pecuniary success. The supply was small, and the product of too little value to pay for working. This was nine or ten years since.

I heard of a man who claimed to have a petroleum well somewhere between the south end of the Wind river and the Big Horn mountains from which he was obtaining an excellent lubricating oil, and which he sold at a high price. Some excitement was spoken of in the papers a year or two since about petroleum on the west slopes of the Black hills of Dakota; and there has been talk of some out on the hills to the

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a *Geological Survey of Indiana*, 1878, p. 520.

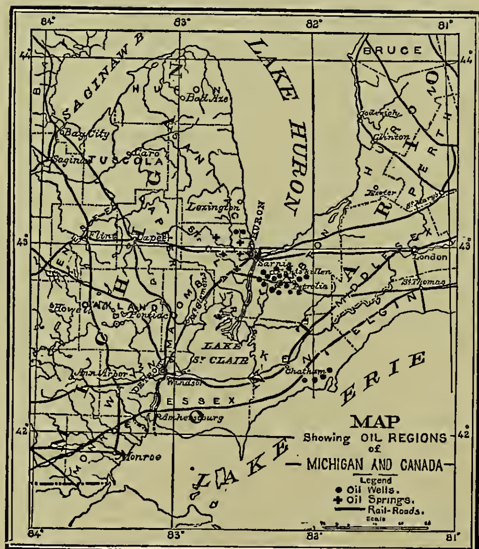
b *Report of Geological Survey of Miami county, Kansas*, by G. C. Swallow. 1865. Kansas City, Missouri.

c Prefessor William M. Carpenter, A. J. S. (1), xxxv, 345.

MAP VII.


MAP
Showing BITUMEN SPRINGS
in
TEXAS AND LOUISIANA
Legend.
Oil Springs.
Oil Wells.
Rail-Roads.
GULF OF MEXICO
TEXAS
LOUISIANA
SCALE

MAP VIII.



MAP
Showing OIL REGIONS
of
MICHIGAN AND CANADA
Legend
Oil Wells.
Oil Springs.
Rail-Roads.
LAKE HURON
LAKE ERIE
LAKE ST. CLAIR
SAGINAW B
TUSCOLA
OAKLAND
ESSEX
BRUCE
Bay City
Saginaw
Flint
Lapeer
Lexington
Sarnia
Petrolia
London
St Thomas
Chatham
Windsor
Detroit
Amherstburg
Monroe
Ann Arbor
Pontiac
Howell
Goderich
Clinton
Exeter

northeast of the same, though I hear nothing of them lately. All these points would strike the same cretaceous rocks, but are too far away from lines of communication to encourage capital to develop at present. Within the past year some coal company "struck oil" in a well on their property a few miles south of Cañon City.

In brief, then, as far as I know, there is no actual production of petroleum in my district; it exists, however, in the cretaceous rocks which extend over the greater part of it along the eastern slope of the Rocky mountains from British Columbia to Mexico and in many of the interior valleys. Blake's map, published in the Ninth Census, will give you a rough general idea of the extent of this formation. Whether the petroleum thus existing can be made to pay, whether it is concentrated in sufficient quantity, or is of good enough quality, can only be satisfactorily proved by practical experiment. I think myself it will probably do so in time, locally, at any rate; but, owing to low price, it may be some years yet before labor and other conditions favor the development.

An artesian well at Yankton, Yankton county, Dakota, 300 feet deep, is reported to have struck blue shale which is saturated with petroleum.

Returns have been made to the Census Office from two parties in Wyoming. The first is located 75 miles north of Point of Rocks station, on the Union Pacific railroad, and south of the Shoshone Indian reservation, in Sweetwater county. This property is reported to consist of ten or twelve springs and a well 60 feet deep. The oil is very heavy—19° Baumé. The second locality is southwest of the Black hills, in Laramie county, near the Dakota line, 25 miles northwest of the junction of the east and west forks of Beaver creek. This property consists of springs of water, from the surface of which the oil is collected and strained, and supplies a local market.

California.—Bitumen is distributed very generally throughout the coast ranges from San Francisco bay south to Los Angeles county, and petroleum is reported to have been obtained in a well on Tunitas creek, San Mateo county. The extensive operations of the Pacific Coast Oil Company are reported to be located in Lexington township, Santa Clara county, but I have been unable to learn any particulars in reference to the production of their wells. Tar-springs are found through Monterey, San Luis Obispo, Santa Barbara, Ventura, and Los Angeles counties. In the Santa Clara valley, in Ventura county, and in the hills on both sides of it, much money has been expended during the last seventeen years, and some oil has been obtained, the principal localities having been in the cañons of the Sulphur mountain that border the Ojai ranch on the south, at the mouth of the Sespé cañon, further east, and both east and west of Petrolia, near the upper end of the valley; but it is impossible at this distance to express an opinion respecting the real value of the operations or the product obtained. The opinion that I expressed in 1866, in a report that I at that time submitted to Professor J. D. Whitney, then state geologist, I believe has been justified in every particular, so far as the Santa Clara valley is concerned.

In the *Report of the Geological Survey of California* (Geology, II), appendix, page 73, it appears as follows:

The expectation of extraordinary results, that will admit of comparison with those that have been produced in Pennsylvania, must be set aside. The expectation of a fair return and a permanently profitable investment may be reasonably entertained; and the application of capital on this basis to this interest will make it of great importance to the state, and especially to that particular section in which the bituminous outcrops occur.

Section 2.—GEOGRAPHICAL DISTRIBUTION OF BITUMEN IN FOREIGN COUNTRIES.

The notices of bitumen in foreign countries do not admit of very exact classification, as the name petroleum has been from early times applied indiscriminately to nearly every form of bitumen by writers but little acquainted with the subject.

British America.—Bituminous minerals, often solid when they appear upon the surface, but more frequently semi-fluid or fluid, occur at many localities in British America. Petroleum has been almost without exception obtained by boring.

Bituminous schists, called petroleum schists, have been observed on the banks of the Mackenzie river; (*a*) also near fort McLeod, 260 miles north of fort Benton, Montana, and at another point 36 miles southwest of the same point, near the 114th meridian, on the Taylor farm. (*b*) In the valley of the Elk river that empties into Athabaska lake "there is a peaty bog, whose crevices are filled with petroleum, a mineral that exists in great abundance in this district. We never observed it flowing from the limestone, but always above it, and generally agglutinating the beds of sand into a kind of pitchy sandstone. Sometimes fragments of this stone contain so much petroleum as to float down the stream". (*c*) The occurrence of petroleum or bitumen on the Athabaska was recorded by Sir Alexander Mackenzie in 1789, and again by Sir John Richardson in 1851. The first-named author states, on page 87 of his narrative, alluding to the forks of the Athabaska or Elk river, that "at about 24 miles from the forks are some bituminous fountains, into which a pole 20 feet long can be inserted without the least resistance. The bitumen is in a fluid state; heated, it emits a smell like that of sea coal". Sir John Richardson says: "The whole country for many miles is so full of bitumen that it flows readily into a pit dug a few feet below the surface."

On the Abittibi river, south of Hudson's bay, petroleum is reported, occurring in strata resembling those just mentioned. (*d*)

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a E. Heibert, B. G. S. F. (3), iii, 87.

b J. C. Nelson, of the Dominion surveyor-general's office.

c Account of the route to be pursued by the Arctic Land Expedition in search of Captain Ross, by Captain Back, R. N., *Jour. Roy. Geog. Soc.*, iii, 65, 1833.

d *Descriptive Catalogue of the Minerals of Canada at the Philadelphia Exhibition*, page 63.

A number of localities are mentioned where petroleum occurs in Newfoundland, among them West bay, Port-au-Port bay, Piccadilly, and a point between Bonne bay and Saint John's island, to the north of Cow harbor. (*a*) At lake Ainslee, on Cape Breton island, petroleum springs occur, and a number of borings have been made without success. At Kempt, Nova Scotia, limestone occurs, in which petroleum is found of a honey-yellow color in small cavities which are lined with crystals of calcite. (*b*) Petroleum is also reported at Hillsborough, New Brunswick. Here also occurred the deposit of albertite which for a number of years, like the grahamite of West Virginia, was very famous. It is of eruptive origin, filling a vertical fissure in shale. It was at first extensively used for the production of coal-oils before the introduction of petroleum, and afterward, like grahamite, for enriching gas coals. The deposit is practically worked out and the mine is abandoned.

Petroleum springs were first mentioned at Gaspé, near the entrance to the gulf of Saint Lawrence on the south, in 1844, by Sir W. E. Logan. They have since been noticed in successive reports of the Canadian geological survey, and were in 1865 made the subject of a special report by Dr. T. S. Hunt, in which he mentions a number of localities in the neighborhood of Tar Point, Douglastown, and other places in the neighborhood of Gaspé bay, along a line of 20 miles, where the rocks are impregnated with solid, semi-solid, and liquid bitumens, which ooze from them at many points. Several wells were drilled here, but in none of these localities do the springs yield any large quantities of oil, nor have the borings which have been made in two places been as yet successful. (*c*)

In reply to inquiries made in June, 1881, Dr. A. R. C. Selwyn, director of the geological survey of Canada, says:

As regards Gaspé and Cape Breton, the question is easy. Petroleum has been found, but never in sufficient quantity to be commercially available.

Wells were drilled near Wequamikong, Great Manitoulin island, in lake Huron, in 1865, and oil was obtained, but not in remunerative quantities.

The productive oil-fields of Canada lie in the county of Lamberton, in the western part of the province of Ontario, and principally in the township of Enniskillen, around the village of Petrolia. In the *Descriptive Catalogue of the Minerals of Canada at the Philadelphia Exhibition*, page 61, appears the following:

The whole oil-producing region around Petrolia has an area of about 11 square miles, with its longest diameter running about north-northwest. The bluish clay of the surface has a pretty uniform depth of about 100 feet, and beneath it borings penetrate an average thickness of 380 feet of interstratified bluish-gray dolomites, shales, and marls (the last being locally known as "soapstone") to the most productive stratum, or 480 feet in all. At first many of the wells both at Oil Springs and Petrolia flowed spontaneously, but now they all require to be pumped. The oil is accompanied by sulphurous saline water, and has an offensive odor. The difficulty in getting rid of this odor at first stood much in the way of the successful competition of the Canadian petroleum with mineral oils from other countries; but since the refineries have been able to thoroughly accomplish this, it has been acknowledged to be a very superior burning oil.

Theo. D. Rand, J. F. I., LXXX, 59, says:

In 1861 numerous wells were sunk, many through the surface clay only, others one or two hundred feet in the rock, and oil was everywhere obtained in fair quantity. During the winter of 1861–'62 and the following spring the great flowing wells which have made this region so famous were struck one after another. The yield from these wells was enormous, ranging by estimate from 1,000 to 7,000 barrels a day.

MEXICO.—A vein resembling albertite is reported in the state of Guerrero, 170 miles from the city of Mexico, and petroleum of a beautiful light-straw color and a density of 32½° Baumé is reported from near the city of Mexico. (*d*) It is also reported from laguna Tampamachoco, on the north side of the Tuxpan river, on the gulf of Mexico, 20 miles from Tuxpan. Tar-springs are reported to rise in the gulf of Tampico, and their products float ashore.

About 20 miles from the bar of the river Coatzacoalcos, that rises on the isthmus of Tehuantepec and empties into the bay of Campeche, and half a mile inland, the "laguna del Alquitran", or lake of Tar, is thus described:

It is surrounded by tall grass, and measures upward of an acre in extent. The exterior crust is a compact layer, sufficiently solid to enable one to walk around its border; but the center is soft, and under the rays of a vertical sun the surface shines like polished jet. In many places there are diminutive ponds of water tinged with iridescent colors, while in others the fluid bitumen bubbles up as if in a constant state of ebullition. Sometimes these bubbles are aggregated so as to form small cones three and four feet high, which evolve vapors, burst, and overflow. As a proof that the petroleum springs of the isthmus are subterraneously connected, I may mention that whenever an ebullition or a spontaneous conflagration occurs in the lake of Tar it is at the same time repeated in all the others, although widely separated. At rare intervals, about once a year, the lake of Tar is spontaneously ignited, and the whole surface is covered with a sheet of flame, which is accompanied by volumes of dense smoke, impregnating the air with powerful bituminous odors. On the day of our visit one of these spontaneous conflagrations took place, and continued to burn until after sunset. The heat arising from the flames was very great, and the sky was darkened by clouds of black smoke that arose above the lake, recalling the descriptions given of the Caspian "field of fire". I learned that within a league and a half, in a southeasterly direction from the right bank of the Coachapa, a tributary of the Coatzacoalcos, there are six smaller lakes, clustered together within a space of 300 acres. (*e*)

Other localities less remarkable were visited in the vicinity, and immense quantities of asphaltum are said to occur along the shores of the Gulf of Mexico above and below the mouth of the river.

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a *Geological Survey of Canada*, 1877–'78, c. 24; John Milne, F. R. S., J. G. S. L., xxx, 738.
b D. Honeyman, A. J. S. (3), i, 386.
c *Geol. Canada*, 1862, pp. 788, 789.
d Am. C., ii, 290.
e *Report on Petroleum in Mexico*, by John McLeod Murphy, 1865.

THE WEST INDIES.—In 1837 Professor R. C. Taylor described a vein of solid bitumen that occurs at Casualidad, three leagues east of Havana, Cuba. He describes the mass as a wedge-shaped vein "filled with carbonaceous matter, as if injected from below". He calls the substance coal, but shows that it is very unlike ordinary coal, both in its specific characteristics and in the mode of its occurrence, and says:

In whatever way we may account for the origin of this remarkable coal deposit, we must be led to view it in some measure in connection with the petroleum which is found in the rocks of this region. The petroleum springs which rise from fissures in the Serpentine at Guanabacoa have been known for two centuries. Nearly contemporaneously with the discovery of the coal of Casualidad, it has been observed about midway between the cities of Matanzas and Havana, not far from the sea-coast. (*a*)

* * * * * * * *

The strike of the Casualidad vein is nearly north and south, conforming to the local range of stratification, although the general range is east and west, following the general direction of the island. At the outcrop the vein is scarcely a foot thick, but at the depth of 30 feet it is enlarged to 9 feet, descending nearly vertically. Other positions in the neighborhood of the principal mine of this substance show its prevalence in the country. We have examined and reported upon some excavations two leagues from Havana, on the road to Tapozte. (*b*)

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Even in the bay of Havana the shore abounds with asphalt and bituminous shales in sufficient quantity for the paying of vessels, as a substitute for tar. It is stated that in buccaneering times signals used to be made by firing masses of this chapapote, whose dense columns of smoke could be recognized at great distances. It is matter of history that Havana was originally named by the early settlers "Carine"; "for there we careened our ships, and we pitched them with the natural tar, which we found lying in abundance upon the shores of this beautiful bay." Petroleum leaks out in numberless places in this delightful island from amid the fissures of the Serpentine, and perhaps has deeply-seated sources. We are acquainted with abundant springs of petroleum between Holquin and Mayari in the eastern part of the island, and we possess notices of others in the direction of Santiago de Cuba. In fact, the entire chain of the West India and Windward islands present similar phenomena of petroleum springs. (*c*)

The reputation of Cuba asphaltum, or chapapote, is too well known to require comment, as it is exported from the island both to the United States and to Europe. Petroleum has never been found there in such quantities as to be commercially important.

Petroleum was reported as occurring in San Domingo by William M. Gabb, esq., who made a geological reconnaissance of the island in 1872. It occurs about three miles from Azna, in the southwestern part of the Dominican republic, on a stream called El Agua Hedioudo, or Stinking Water. An unsuccessful attempt was made to bore here in 1865–'66. The product of the springs is a thick maltha, of a density of 22½° Baumé = 0.945, which does not yield paraffine. (*d*)

The petroleum of Barbadoes was described in 1750 by Griffith Hughes, in a work entitled *Natural History of the Island of Barbadoes.* He says:

The most remarkable fossils of bituminous kind is green tar. It is obtained by digging holes or a trench, and it rises on the water. It issues from hills, and is gathered in the months of January, February, and March, and serves to burn in lamps. Munjack is dug out of veins. It is stated that one of these veins was fired by a negro, who built a fire on a hillside to roast potatoes, and it continued to burn for five years.

The heavy, dark-green or black petroleum was an article of commerce, under the title "Barbadoes tar", for many years prior to the introduction of petroleum for illuminating purposes.

The Pitch lake of Trinidad is the most extensive known deposit of asphaltum. It was described by Dr. Nugent in 1811, (*e*) by G. P. Wall, esq., in 1860, (*f*) and by Professor T. Rupert Jones in 1866. (*g*) The lake is about three miles in circumference, and is described as a mass of asphaltum, sloping to the northern sea-coast. Although firm enough to bear a team of horses, it is still somewhat plastic, and appears to be in motion toward several points that act as vortices, as the trunks of trees disappear and after a time emerge at some distance from the point at which they sunk. Small lakes and streams of water abounding in fish are described as distributed over the surface, with numerous islands covered with tropical verdure. The asphaltum is exported from the island to the United States and Europe, where it is used for the preparation of roofing materials and in the preparation of mastic pavements. It does not yield paraffine on distillation, and has not, therefore, been proved valuable in the arts for the purposes to which albertite, grahamite, and other similar substances are applied. In 1857–'58 an attempt was made to manufacture illuminating and other oils from the pitch, and Mr. William Atwood spent more than a year there superintending operations on the island; but that and all other attempts to use the material for such purposes have failed. It is, however, applied to other uses in the arts in enormous quantities, and the supply appears to be practically inexhaustible.

"South of cape de la Brea is a submarine volcano, which occasionally boils up and discharges a quantity of petroleum. Another occurs on the east side of the island, which throws up on the shore masses of bitumen." (*h*)

SOUTH AMERICA.—Humboldt mentions in his personal narrative the occurrence of petroleum springs in the bay of Cumana, where the oily fluid rises and spreads upon the surface of the sea. (*i*) Wall mentions the occurrence of asphaltum in the province of Maturin, on the mainland opposite Trinidad, and observes that other districts of the Llanos are generally affirmed to furnish it, although he did not examine them. (*j*) On the northern shores of the United States of Colombia and along the Magdalena river asphaltum is reported in immense quantities.

a *Philosophical Magazine*, x, 161–167.
b Taylor's *Statistics of Coal*, p. 578.
c *Ibid.*, page 579.
d E. Waller, Am. C., ii, 220.
e T. G. S. (1), i, 63.
f Q. J. G. S., xvi, 467.
g *Ibid.*, xxii, 592.
h Taylor's *Statistics of Coal*, p. 584.
i *Travels*, Bohn's ed., i, 198; iii, 113.
j Q. J. G. S., xvi, 467.

Under date of August 10, 1880, Commercial Agent Plumacher, of Maracaibo, gives a very elaborate description of the petroleum deposits of Venezuela, from which I infer that the slopes of the Cordilleras that inclose the lake of Maracaibo abound in asphaltum, maltha, and petroleum. It is difficult, however, for one locally unacquainted to eliminate reliable details from the report.

Petroleum is reported in Ecuador at Santa Elena, along the sea-shore, and Henry, in his *Early and Later History of Petroleum*, page 144, says:

Pits from 10 to 12 feet deep are dug into the sand till clay is reached, and, when the oil which oozes from all sides has filled them, it is dipped out. Near the wells are primitive furnaces, built with sun-dried clay, on which are open iron boilers. The bituminous matter is thrown into these vases and cooked until all the volatile products disappear and leave a thick pitch.

A well-known region in northern Peru near Payta, on the Pacific coast, is undoubtedly very rich in petroleum. The existence of this material was known in Peru before the conquest, as a mummy of date prior to that event in the Peabody Museum of Archæology of Harvard University has been prepared with it. The pitch was also used for coating earthenware on the inside, particularly liquor jars.

Several wells have been bored here, one of which produced several hundred barrels daily, and it is claimed by those who are conducting the operations that flowing wells may be obtained with great certainty over an area many miles in extent. A refinery has been built at Callao, but the recent war between Peru and Chili has caused a suspension of operations. The Peruvian oil does not yield any paraffine, nor a considerable amount of naphtha.

It is reported that in Bolivia the three principal springs of Cuaruzute, Plata, and Pignirainda form an oil stream 7 feet wide. (*a*) This wonderful story lacks confirmation.

ENGLAND.—In reply to a letter of inquiry in relation to the occurrence of petroleum in England, E. W. Binney, F. R. S., the distinguished geologist, wrote, November 14, 1881, as follows:

I am in receipt of yours, wherein you ask me if petroleum has been found in quantity in Great Britain. It was found about one hundred years since in making the Duke of Bridgewater's tunnel at Worsley, at Wigan and West Leigh in the Lancashire coal-fields, at Coalbrookdale and Wellington in Shropshire, and Riddings in Derbyshire, two other coal-fields; also in a peat bog at Down Holland, near Ormskirk, in Lancashire, but none to my knowledge in commercial quantities. The greatest supply that I have ever seen has not been more than 50 gallons a day, and even that soon diminished. When I went down Mr. Oakes' pit at Riddings in 1848 the petroleum came out of the black shale roof dripping, and not as a spring. The coal is a gas-coal in the lower part of the middle coal measures.

In a paper read before the Manchester Geological Society, March 30, 1843, Mr. Binney, in company with Mr. John Hawkshead Talbot, described the manner in which the petroleum occurred at Down Holland moss, northwest of Liverpool, on the north bank of the Mersey, near its mouth:

The whole of the moss is in cultivation either under the plow or in grass, and has been so for at least forty or fifty years, and all or the greater portion of it lies at a lower level than the high-water mark of the sea at Formby. On approaching the place where the peat containing petroleum occurs, from Down Holland, the authors soon became aware of its presence by an empyreumatic smell, resembling that yielded by Persian naphtha, and the water in the ditches was also coated with a thin film of an oily, iridescent fluid that floated upon its surface. In walking over some oat-stubble fields, and thrusting their heels through the black decomposed peat forming the soil, they felt a hard, pitchy mass, of 3 or 4 inches in thickness, which yields no smell unless it is burnt. On exposure to the atmosphere for a time the pitchy matter lost the greater part of its inflammability, and was finally converted into black mold. This substance also occurred under the roots of the grass in old sward fields, but it then yielded an odor similar to the petroleum that floated on the surface of the water, and pervaded the moist peat. (*b*)

I remember to have once met a lady who spent her childhood in New Hampshire, where she recollected a peat bog presenting similar phenomena to that above described.

Arthur Aiken, esq., in 1811, described the occurrence of petroleum in the great coal-field of Shropshire. He says the thirty-first and thirty-second strata are coarse-grained sandstone, entirely penetrated by petroleum; they are both together 15½ feet thick, and have a bed of sandy slate clay about 4 feet thick interposed between them. These strata are interesting as furnishing the supply of petroleum that issues from the tar-spring at Coalport. (*c*) In 1836 it was still further described by Dr. Preistwich, who says:

The well-known tar-spring at Coalport, which had its rise in one of the thick sandstones of the central series, formerly yielded nearly 1,000 gallons a week, but it now produces only a few gallons in the same time. In sinking a shaft at Priorslee the 20-yard rock was so charged with petroleum that the shaft was converted into a tar-well. It formerly yielded 2 or 3 gallons a day. In a pit at the top of the same dingle petroleum exudes in so great abundance from every crevice in the "little coal", and from the shale forming the roof, that the colliers are obliged in the latter case to have large plates of iron suspended over them. More rarely petroleum is found in cavities of the Pennystone nodules. (*d*)

Dr. Richard Bright described in 1811 a liassic limestone in the neighborhood of Bristol, containing "claws of crustaceæ, corallines, and millions of the stalks of encrinites. They were first noticed by Mr. Miller surrounding calcareous concretions in the black rock, which are penetrated with petroleum. Petroleum sometimes exudes from the rock in small quantity". (*e*) A correspondent of *Iron* describes, in 1875, the occurrence of petroleum in a coal

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a *Deutsche Industrie Zeitung*, 1868, p. 400.
b Papers read before the Manchester Geological Society in 1842–'43, p. 17.
c T. G. S. (1), i, 195.
d T. G. S. (2), v, 438.
e T. G. S. (1), ii, 199.

pit at Longton, in North Staffordshire, the first discovery being made in a seam of coal that seemed to be saturated with it. Five or six tons a week are collected : a valuable addition to the output of coal. The coal is used for the manufacture of illuminating gas, and is rich in hydrocarbons. (*a*)

France and Switzerland.—There are three sections of France from which bitumen is reported. Petroleum floats on the water of springs, and the rocks in the neighborhood are saturated with bitumen at Saint-Boëz, Basse Pyrénées; (*b*) it has not been found anywhere, however, in the Pyrenees in quantities commercially valuable. In the hills that skirt the highlands of Auvergne, at Gabian, near Béziers, petroleum is reported. At Ardèche and Autun asphalt occurs, and in the neighborhood of Alais and at Bastenne asphaltic limestones are obtained and used in large quantities in the preparation of the asphaltic pavement so largely used in Paris and other French cities. (*c*) The third district is in Savoy, and extends into Switzerland. In the Val de Travers the celebrated bituminous limestones of Pyrmont and Seyssel occur in the department of Ain. This asphaltic stone is not stratified, but is crossed with fissures in all directions, and consists of cretaceous limestone, calcareous schists, and molass, the latter a sort of asphaltic breccia. The porous limestones are saturated with bitumen, and the siliceous pebbles and fragments of the molass are cemented with the same material, as has been repeatedly proved on comparison. The limestone is quarried and pulverized and is then heated, and while hot it is thoroughly mixed with asphalt extracted from the molass by repeated boiling in water. This asphalt rises to the surface of the water and is skimmed off. The mastic thus prepared is used in enormous quantities in Paris and other French cities. A similar material is reported from the Tyrol, in eastern Switzerland.

Germany.—In Alsace, on the lower Rhine, at Schwabweiler, Pechelbronn, and Lobsan, petroleum has been obtained for many years and has been employed for local uses, but it has never been introduced into commerce. Several wells have been drilled at different points, and a small yield of oil has been obtained in some of them, but the enterprises, on the whole, were not remunerative. Petroleum is also reported near Carlsruhe, in the grand duchy of Baden, but concerning it I have no particulars. In Hanover, on the Lüneburger heath, south of Hamburg and east of Bremen, the occurrence of petroleum has been known for at least a century. Since 1863 several attempts have been made to procure petroleum near Oberg by boring, and at different times, particularly within the last two years, the reports have been such as to encourage an expectation of a production rivaling that of Pennsylvania.

In 1876 it was stated that at Oberg the source of the petroleum was supposed to lie at a depth of 700 or 800 feet, and that it had been obtained at Edemissen and Oedessen by the re-establishment of mines having but a single shaft. In Kline Eidessen the sand is permeated with petroleum to such an extent that it is found on the water that collects in foot-tracks. At the village of Weitze, in the northern part of the district, is found an extensive stratum of sand of about 1,000 meters long, 600 meters broad, and 75 meters deep, which corresponds to 45,000,000 cubic meters, the upper strata of earth containing about 10 per cent. of petroleum. The owner of this tract, which has been penetrated to 125 feet, has often bored and obtained petroleum in a very primitive way through the gushing of oil from the sand. (*d*)

In March, 1880, a company was organized in Bremen for the purpose of deep boring, with the expectation of obtaining at greater depths than had hitherto been penetrated a lighter variety of oil, that previously obtained from wells 220 feet deep having had a specific gravity of 28°, and commenced operations on the southern border of the Lüneberger heath, at a point 25 miles east of Hanover, on the railroad to Brunswick. A refinery has been established at Peine, 20 miles from Hanover, and a pipe-line, has been laid from the wells.

Mr. William C. Fox, United States consul at Brunswick, reports that traces of petroleum have been found in belts or spots commencing in the village of Klein Schoppenstate, in the duchy of Brunswick, and running west in a direct line for 40 miles to the village of Wietze, on the river Aller, a navigable tributary of the Weser. Two of these belts are at present known: the Oelheim, near Peine, and another 8 or 10 miles to the northwest. The former contains about 25,000 acres, and embraces the villages of Edemissen, Odessa, Windesse, and Steterdorf.

At present, borings are confined to about 20 acres, and there are 12 pumping wells, yielding 1,250 barrels a week. A flowing well, struck last July, caused great excitement, the petroleum having a specific gravity of 0.888, and producing, when refined, about 40 per cent. of illuminating oil of very superior quality, 40 per cent. of lubricating oil, and 5 per cent of naphtha. (*e*) For barreling, American barrels are preferred. While this field may be said to be one of the most promising fields, it cannot be said yet to promise any considerable competition with the fields of Pennsylvania.

Denmark and Sweden.—At Hölle, near Heide, in Ditmarschen, over an immense bed of petroleum, there is a layer of light diluvial sand 20 feet deep, saturated with tar, which may be cut like cheese. There is also found here an important bed of asphaltic limestone, similar to that of Seyssel. (*f*)

a San Fran. Min. and Sci. Press, xxi, 184.
b M. Thoré, L'année Sci. et Ind., 1872, p. 251.
c S. P. Pratt, Q. J. G. S., ii, 80.
d Archiv für Pharmacie, ccix, 461.
e Report, October, 1881.
f Dr. L. Meyn, J. S. A., xxi, 12.

At Nullaberg, in the northwestern district of Wermland, west Sweden, metamorphic strata of gneiss and mica-schist have been observed. Bituminous matter is distributed everywhere throughout the whole mass of these strata, so as to be present even in the smallest fragment, giving them a black color closely resembling gunpowder. (*a*)

ITALY.—Petroleum wells have been dug and bored along the southern borders of the valley of the Po, in the provinces of Voghera, Piacenza, Parma, Modena, and others, and in the provinces of Chieti, east of Rome, on the Adriatic sea, and of Caserta, on the gulf of Tarentum. Small quantities of petroleum have been obtained in these localities for centuries; also in the province of Girgenti, on the island of Sicily. Asphalt occurs at Marsiconnova and in the valley of Pescara, and asphaltic schists or bituminous clay have been observed in many places in southern Italy.

Professor Silvestri described, in 1877, paraffines and homologous hydrocarbons, which he obtained in lava about 13½ miles on a direct line from the great central cone of Etna. (*b*) The gas-springs of the Apennines have been many times noticed as of scientific interest, but have never been made of economic value.

The petroleum interests of Italy have been for many years locally valuable, but do not promise to become of greater importance.

DALMATIA AND ALBANIA.—On the island of Brazzo, on the coast of Dalmatia, and also at Ragusa, on the mainland south of Brazzo, extensive deposits of asphaltum are reported. This island is nearly opposite the valley of Pescara, on the Italian coast.

Farther down the coast of the Adriatic lies the island of Zante, where a petroleum spring occurs in a marsh near Chieri that was mentioned by Herodotus in the fifth century before Christ. One well was drilled 300 English feet, and produced about half a hogshead daily, which progressively diminished; another was drilled later that at the same depth struck a black, hard, and fetid limestone; and another was at the side of the marsh, and struck oil at 70 feet, yielding 5,000 liters in seven hours. The latter afterward became completely sterile, and was abandoned, and borings made near the spring in 1865 were not successful. (*c*) On the mainland east of Zante lies the coast of Albania. There, in the neighborhood of Selenitza, occur some of the most extensive and remarkable asphalt deposits in Europe. Strabo remarks that "in the country of the Apolloniates there is a place called Nymphæum. It is a rock which emits fire, at the foot of which flows a spring of warm bitumen, which probably proceeds from liquefied bitumen, because on a neighboring hill there is a mine of bitumen, where, as related by Posidonius, the earth, from the excavations from which the bitumen has been exhausted, converts itself into that substance". (*d*)

Vetruvius also mentions the same springs, and says: "Around Dyrrachium and around Apollonia are springs which emit great quantities of pitch with water." (*e*) Durazzo, in Albania, occupies the site of the ancient Dyrrachium, and the convent of Pollina is built upon the ruins of Apollonia, both of which are found near the emboucheur of the Vojutza (Aous of the ancients), about six hours to the northeast of Avlona. "It appears that the curious phenomena which these springs manifest to-day arrested the attention of the Greek and Roman naturalists, because they are mentioned in the works of Aristotle, Pliny, Ælian, and Dion Cassius." (*f*) Setting aside some erroneous ideas, due to the ignorance of the ancients regarding natural phenomena, recent studies of the bituminous deposits of Epirus confirm in a remarkable manner the observations made by these early writers, and the testimony of more modern authors is less abundant and exact than that furnished by the ancient historians. Recently the bitumen from this section has been employed in Trieste, Naples, and Marseilles as a substitute for rosin in calking ships.

Between Durazzo and Avlona the coast of Epirus is level, and consists of plains formed by the alluvium of the rivers Usoli Komobin (Senussus of the ancients), Beratino (Apsus), and Vojutza (Aous), which drain Albania throughout its length, and which have their sources in the high mountains of Macedonia. It is in the hills at the foot of these precipitous and almost inaccessible mountains that the deposits of asphalt occur in great variety of detail. M. Coquand, to whose elaborate article I am mainly indebted for the facts here stated, (*g*) regards the exploitation as very rude and of very great antiquity, probably extending from a period long prior to the Christian era to the present time, but destitute of any general system. This want of method, while compromising the future interests of the deposit, has opened it up at many points, and has admirably exhibited the manner in which the mineral lies in the formation. It is easy to perceive that it does not lie in regular beds or veins, but in irregular masses in the midst of sandstones and conglomerates, of the form of which no general description will give an idea, except that a sort of parallelism may be observed among them, and that each mass consists essentially of a central portion of considerable thickness, which gradually thins out in all directions to zero. In no case does the bitumen penetrate the roof above the mass, but was evidently injected from below. The following illustration (Fig. 2) shows at a glance a deposit that has furnished an enormous quantity of bitumen. A depth of 3 meters (9.84 feet) is not rare

a L. J. Englestrom: *The Geological Magazine*, iv, 160.

b Gazetta Chemica Italiana, vii, 1; B. D. C. G., 1877, 293; C. N., xxxv, 156.

c *Les Mondes*, October, 1865.

d B. S. G. F., xxv, 20. Translated from French rendering.

e *Ibid.*

f This passage and the others given above can be found in the original in *Bul. Soc. Géo. de France*, xxv, 20.

g B. S. G. F., xxv, 20.

Map showing the Distribution

' Bitumen throughout the World.

in the thickest places. The bitumen is almost always of very great purity, and generally consists of compact, very homogeneous masses, very black, brilliant, tarnished upon the surface, very friable, with a resinous fracture, softening by percussion or heat, and with a pronounced asphaltic odor.

The ancient workings have caved in, making their exploration no longer possible. It appears, to judge by tradition, and, above all, from the ancient workings, now overgrown with oaks many centuries old, that the exploitation reaches back to a time anterior to Strabo; because we read in that author that, following Posidonius, the bituminous earth, which he calls *ampelites*, was a remedy against the worms that eat the vines, the worms by this means being destroyed before they had ascended the trunk to the young sprouts. This method appears to have been practiced until lately, and perhaps it is to-day, because the greater part of the bitumen of Albania was exported to Smyrna, where it was used for the preservation of vines, and more frequently for the calking of ships.

Some of the springs of water rising from the formation containing the bitumen of Albania are accompanied with maltha, but in insignificant quantity.

ROUMANIA.—The Roumanian oil-fields lie in the northeast part of Wallachia and the southern part of Moldavia, in the valleys of the streams that drain the eastern slopes of the Siebenbürgen.

The Wallachian oil district lies on the southern slopes of the Transylvanian Alps, and is more extensive than that of Moldavia. The wells are from 6 to 12 miles north of Plojeschti, a station on the Roumanian railroad. In Bakoin the inhabitants use the inflammable gas which issues from the ground to cook their meals. The manner of obtaining the oil is very primitive, the wells being dug as for water, the landlord receiving a tenth of the net produce as rent. A part of the crude petroleum is refined at Sarati and Plojeschti, and part is sent by rail to Vienna, Pesth, and Odessa.

The Moldavian petroleum fields occupy a triangle bounded by the rivers Taslen and Trotusch, not far from Adschud station, on the Roumanian railroad. The wells near Morneschti do not exceed 120 meters (394 feet); those near Salante and Comonesti 50 to 70 meters (164 feet to 230 feet) in depth. Like the Wallachian wells, they are worked in the most primitive manner, and the proprietors here receive as rent one-third of the gross produce. The cost of the petroleum at the well's mouth does not exceed 4 francs per 100 kilograms (20 cents per 220 pounds).

The Moldavian petroleum is darker than that of Galicia, and remains fluid at a temperature of 20° Celsius—4° F.(a)

GALICIA.—Petroleum is found in many localities on the Hungarian side of the Carpathians, but its exploitation is of little or no importance. In Galicia there are three principal localities that yield petroleum and ozokerite: the region around Sandecer, in west Galicia; that around Bobrka, near Dukla, in middle Galicia; and that around Boryslaw, in east Galicia, and Basco, on the confines of Moldavia. This region is said to be in general outline 400 miles long by 40 miles wide. Although ozokerite is found associated with petroleum wherever it occurs in both Galicia and Roumania, its production is principally confined to the east Galician district, in the neighborhood of Boryslaw and Stanislow. It appears from statistics that I have met with that the fields of east Galicia were at first much the most important; but while the total production of Galicia has decreased, the relative production of west Galicia has increased. The exploitation has been conducted in a very rude manner, largely by Polish Jews, who occupy that country, and all attempts at innovation by the introduction of machinery, both for boring and for refining, have been resisted with great pertinacity.

The development of oil territory by shafts has been encouraged by the amount of ozokerite that almost everywhere accompanies the oil and that cannot be obtained by other methods of exploitation. Wells have been bored, however, which in some instances have been productive and in many others have failed. The great importance of the ozokerite industry, which will be referred to in detail in a subsequent chapter, will prevent the complete substitution of borings for shafts.

RUSSIA.—Petroleum is reported to have been observed in northern Russia, in the province of Archangel, on a streamlet that runs into the river Betchora; also at "some distance from Orenburg", on the Ural river, but the exact locality was not given.

In official reports the Russian petroleum fields are divided as follows:

Government of Tiflis.—Mirsanski, Schirorski, Eldarski.

Government of Baku.—Bakinski, Derbentski, Kaitags-Tabarsaranski.

Kuban district.—Kadygenski, Kudako.

Terek district.—Gronenski, Maïsha-Kajevski, Karabulakaki, Brajimavski, Benojevski.

Daghestan.—Berikaki, Djernikentaki, Naflutanski, Bashlinski, Tupsu-Kutanski, Ghiak-Salgav, Kukinski, Napkutanski.

A reference to map I will show that these districts are embraced in a triangle, the apex of which is at the mouth of the Kouban river, near the entrance to the sea of Azof, extending eastward to the Caspian sea, and embracing that portion of its western coast lying between the mouths of the rivers Terek and Kura, and embraces the flanks of the Caucasus and the valleys of the principal rivers that drain them. There are also indications of petroleum across the Crimea that have attracted some attention.

The Kouban oil-fields proper begin at Taman, situated on the strait which connects the Black sea with the sea of Azof, and extends along the foot-hills of the western extremity of the Caucasus mountains to the river Balah, a distance of about 250 miles.

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a Dr. H. E. Ginth, *Oester. Monatschrift f. d. Orient*, 1878; John Fretwell, jr., J. S. A., xxvi, 481.

The Apscheron oil-field as at present worked lies within a radius of 20 miles of the city of Baku; but the larger portion of the oil has been obtained at Balachany, 12 miles north of Baku, where naphtha has been produced from the most ancient times, and from Sabonntchi, which was explored in 1873. This first part contains (1880) forty-seven wells, of which twenty-eight are productive, yielding 6,192,000 pounds daily of an average specific gravity of 0.8675, while the second part yields 6,622,000 pounds per day of the specific gravity of from 0.820 to 0.860. The specific gravity is very variable in the same well, and in general diminishes with the depth, being greatest near the surface, from loss of gas. The light oil contains volatile products of a specific gravity of 0.62, of which no use is made. The illuminating oil varies from 15 to 85 per cent., the average being between 35 and 40 per cent. (*a*) On the outskirts of the field a colorless oil is obtained that can be burned without refining. This oil soon thickens and becomes asphalt.

The oil seems to lie in a sort of quicksand, irregularly interstratified with clay, as fine, loose sand rises with the oil and collects around the wells so that it has to be shoveled away. This oil has been known to spout from an 8-inch hole from 50 to 60 feet high; yet there is no regular stratum of sand yielding the oil, and no particular depth at which it may be struck. One well in the Kouban yielded oil of 46° at from 8 to 10 feet in depth. This oil does not contain paraffine.

The Bebeabat field is below Baku on the coast of the Caspian sea, and produces oil resembling that of Baku; but it deteriorates by keeping, and is often run up on a salt lake near by and set on fire. On the island of Tchillekin, or Naphtha island, on the eastern shore of the Caspian sea, a well was drilled which produced a small quantity of oil of a better quality than that of Baku, and one well at about 140 feet yielded oil, and at 200 feet yielded hot water. Ozokerite and "living earth", which is a mixture of soft asphalt and pulverized shells, abounds along this shore. (*b*)

The Caspian sea is dotted with numerous islands, which produce yearly a large quantity of naphtha (petroleum), and it has been no uncommon occurrence for fires to break out in the works and burn for many days before they could be extinguished. In July, 1869, owing to some subterranean disturbances, enormous quantities of petroleum were projected from the wells and spread over the entire surface of the water, and, becoming ignited, notwithstanding every precaution, converted the sea into the semblance of a gigantic flaming punch-bowl many thousands of square miles in extent; but the fire burnt itself out in about forty-eight hours, leaving the surface of the water strewed with the dead bodies of innumerable fishes. Herodotus mentions a tradition that the same phenomenon was once before observed by the tribes inhabiting the shores of the Caspian sea.

There is practically no limit to the amount of oil to be obtained at Baku, but with the exception of the Caucaso-Carpathian region the petroleum production of Europe is only of local importance. The production of maltha is insignificant, but the deposits of asphaltum and asphaltic limestone are of great and increasing importance. No region except the Caucasus has made any approach to rivalry in European markets with the petroleum products of the United States.

Asia Minor.—Many of the localities furnishing bitumen in Asia are extremely difficult to locate with exactness; but gas-springs are said to occur on the coast of Karamania, (*c*) which is that portion of Asia Minor bordering the northeast portion of the Mediterranean sea. Bitumen is also reported in Armenia near lake Baikal, and in southern Siberia near Derabund; (*d*) asphaltum near Iskardo (*e*) and near Cashmere; petroleum in Assam (*f*) and Pegu; (*g*) also near Kohat. (*h*) Gas-springs accompanying mud volcanoes are also reported in Kerman. (*i*) The authorities for these localities are nearly all to be found in works published in India, to which I have not had access.

"The asphalt of the Dead sea and its vicinity has been noticed by Strabo and other ancient writers, and many conjectures have been made by both ancient and modern authors respecting its origin. It seems to be a well-established fact that the asphalt rises in such large masses during or after earthquakes as to remind one of islands floating on the sea. While this asphalt, having a density of 1.1040, floats on the water of the Dead sea, which has a density of 1.1162, it would sink in the water of the ocean. The rocks in the neighborhood of the sea are often bituminous cretaceous limestones, containing a large quantity of asphaltic material. This is particularly to be observed in several of the ravines that border it, where the dolomitic limestones are highly charged with bitumen, and, being broken up and carried down into the sea by the winter torrents, the bitumen becomes disengaged, and is cast upon the shore." (*j*)

In one of these ravines, on the eastern borders of the sea, M. Lartet describes pebbles of silex cemented into a pudding-stone by bitumen and stalactites of asphalt produced by the liquid bitumen slowly dripping from the bituminous cretaceous limestones. This, too, is washed into the sea and cast on shore. The amount received by the sea in this manner, however, is not sufficient to account for the islands of bitumen seen floating on the surfact. (*k*)

On the western border of the valley of the Jordan similar deposits occur at the same level, and in many localities throughout Judea and Arabia Petræa from immemorial periods asphalt and maltha (slime) have been obtained from springs and shallow pits.

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a M. Goulichambaroff, *Jour. Rus. Phys. and Chem. Soc.*, xii, 5; *Nature*, xxiii, 42.
b Communication from J. R. Adams, of Oil City, Pennsylvania to S. F. Peckham.
c Beaufort: *Survey of the Coast of Karamania*, 1820.
d G. T. Vigne: *Rock Oil, near Derabund*, Kabul 1842.
e G. T. Vigne: *Travels in Kashmir and Little Thibet*, 1842.
f Report Geo. Surv. of India, I, pt. 2, p. 55.
g Lt. Duff: Pegu oil gas. *Jour. As. Soc. Bengal*, 1861.
h E. Thornton: Oil-spring near Kohat, *Gazetteer of India*, 1862.
i H. Pottinger: *Petroleum of Kerman*, 1840.
j Lartet, B. S. G. F., xxiv, 12.
k *Ibid.*

Deposits of bitumen have been described as occurring near Zaho, in Kurdistan, 440 miles above Bagdad, on the Tigris. From the description I should conclude that this material is asphaltum. It was used successfully in 1874–'75 on the steamer Mosul for making steam, and also for the manufacture of gas. Several other outcrops of bitumen occur nearer Bagdad, and liquid petroleum occurs at many points upon the road from Ribamich to Bagdad, and also between Bagdad and Mosul, in the valley of the Tigris. (*a*)

PERSIA.—Persia abounds in bitumen springs, which have been noticed and described by travelers and historians from Herodotus to the present time. One of the most noted springs of water yielding bitumen is situated five German miles from Suza, at Ardericca. Others are located on the plateau of Iran, near Durr, in the valley of of Jer'abi, and also at Chusistan, not far from a volcano that was active in the second century. The bitumen wells Kerkuk or Tuzkurmati, four days' march southward from Arbela, are also celebrated. They may be known at a great distance through their odor, their sulphur vapor producing headache, on which account they are unendurable in summer time. Other localities of minor importance in the mountains that separate Persia from Kurdistan and the valley of the Tigris are mentioned. The naphtha springs of Van Kalesi were inclosed in the walls of a castle, where they flowed from a niche. Another castle is described as belonging to Sassanite times, situated upon a crag above a naphtha spring that was arched over with great blocks of freestone—perhaps from very ancient times.

Bitumen in its various forms has been used in the valley of the Euphrates and adjoining regions from the earliest times. (*b*)

HINDOSTAN.—Natural gas furnishes the material burned in a number of Hindoo temples in Thibet and northern India. Petroleum wells are reported in Cashmere and Thibet, but I have been unable to learn anything concerning their exact localities. A locality occurs in the Punjab that has attracted some attention, but it has not yet been proved to be of importance. It lies in the corner between Cashmere and Cabul, and is nearly 100 miles by 90 in extent, being mostly between the Indus and Jhelum, in what is called the Sind Sagur Doab (two rivers), and is mainly in the mountainous or hilly part (Kohistan) of the Doab. The oil-springs are in the northern slopes of the Salt range that lie upon the southern border of this region, or in the Choor hills that lie upon its northern border. Oil, maltha, and asphaltum occur at these springs. Borings have been made at Gunda, and yielded at first 50 gallons a day, which gradually decreased. This oil is dark-green in color, is of a specific gravity of 25° Baumé, and has been used by the natives for burning with a simple wick, resting on the side of an open dish. (*c*)

BURMAH.—In a letter from Rev. J. N. Cushing, dated Toungoo, September 14, 1881, appears the following in relation to the wells in this country:

There are only two places in all Burmah where petroleum is produced to any extent, viz: Arracan and Yenangyoung, in upper Burmah. The production of the wells in Arracan is very small. Within a few years a company has been formed to work them as an experiment, but I have never seen any statement of the results, and think they must be inconsiderable. Yenangyoung (Earth-oil river) is a large town on the Irrawaddy about 400 miles north of Rangoon, and the oil-wells lie about 3 miles east of the town, among some low and very barren hills, the chief vegetation of the unproductive soil being several varieties of cactus. There seemed to be a good deal of light, soft, sandstone, through which here and there ran layers of a dark rock resembling granite. The roads were in some places worn into the hills to a depth of 10 feet, the fierce torrents formed during the rain washing out all loose soil.

When I visited the wells they were about 200 in number, although some were not yielding oil. These were upon ground as highly elevated as any, and occupied an area of about 100 acres. They were of various depths, the deepest being about 160 cubits (240 feet). I do not think that the number of wells has greatly increased since my visit, for before that petroleum had been found only in that locality, although search had been made for it in adjacent localities. What might be found by the skilled labor of the far West using the scientific knowledge which gives it success I do not dare to say.

CHINA.—There do not appear to be any wells in China that are made for the purpose of procuring petroleum; but from the communications made by M. Imbert to the French Academy, and also by L'Abbé Huc, it appears that petroleum is obtained in wells bored for salt, as it often is in this country, and that the oil is often accompanied by inflammable gas. The Chinese call the latter Ho-tsing (fire-wells), and use the gas for a variety of purposes, such as boiling brine and for domestic fuel, the gas being conveyed long distances in bamboo tubes, terminating in a clay or porcelain burner. In his *Travels in the Chinese Empire*, chapter vii, L'Abbé Huc says:

When a salt-well has been dug to the depth of a thousand feet, a bituminous oil is found in it that burns in water. Sometimes as many as four or five jars of 100 pounds each are collected in a day. This oil is very fœtid, but it is made use of to light the sheds in which are the wells and caldrons of salt. The mandarins, by order of the prince, sometimes buy thousands of jars of it, in order to calcine rocks under water that render navigation perilous.

Specimens of this petroleum sent to France were submitted to a committee of the French Academy for examination. (*d*)

The wells are described by L'Abbé Huc as occurring in the province of Sse-tchouen, which is the largest province of China, and borders upon Thibet. Petroleum is also reported from the northern province of Shansi.

a L. Mongel: *Ann. des Mines* (7), vii, 85; Proc. Inst. of Civil Engineers, 1875, p. 307.
b *Ritter's Erdkunde*, ix, 147, 177, 519, 555; xi, 191; x, 142.
c B. S. Lyman, Trans. Am. Phil. Soc., xv, 1.
d *Comptes-Rendus*, xxii, 667.

JAPAN.—The petroleum fields of Japan lie in the southern part of Yesso and the northwestern part of Niphon, and have already been noticed in chapter I, page 17.

JAVA.—Mineral oils are found in many of the islands of the Indian archipelago, and are there known under the name of Minjak Lantoeng at Java, or Minjak Linji at Sumatra; and as they are much used by the natives, they are regularly collected and sold in the markets of the principal villages and towns. The localities where these oils rise spontaneously in natural fissures or artificial excavations are ordinarily surrounded by warm or saline mineral springs.

A specimen of oil from Palantoengan, in the residency of Samarang, has the consistency of tar and a density of 0.955 at 16° C. A specimen from Tjiakijana, in the district of Porbolingo, in the residency of Banjoemas, is as liquid as water, with a deep green color by reflection, and has a density of 0.804 at 16° C. Spontaneous evaporation produces a mass of the consistency of yellow butter; distillation yields 40 per cent. of paraffine. (*a*)

Von Baumhauer, the distinguished chemist, examined and reported upon six specimens of petroleum from as many different localities in the Dutch East Indies: from Amönchay, in Borneo; Bodjoinegoro, in Rembang; Madjalengka, in Cheribon; in Soerabaga; Lematang-Ilir, in Palembang, Sumatra; and Iliran and Banjoesin. His examination shows that the petroleums of Rembang and Cheribon are of very excellent quality, while the others are of a viscous consistency. He remarks that petroleum in this region is very abundant, and is easily obtained at a depth of 250 meters (820 feet), and recommends boring, considering the oil as of great importance to the country. (*b*).

AUSTRALIA.—Petroleum is reported as occurring in Australia and New South Wales, and crude paraffine near Gisborne, in New Zealand.

AFRICA.—Petroleum is reported from Egypt, as examined by Frederick Weil, with a density of 0.953, but on distillation it did not yield naphtha or illuminating oil with a density of 0.800. It was considered a superior lubricator, and is especially adapted to heating marine boilers and in the manufacture of gas. (*c*) It is also reported as having been discovered in Algeria, in the Dahra-oraisaic, the region occupied by the tribe of Beni-Zarouel, in that part of the chain that overlooks the plain of Chiliff. A spring of glutinous petroleum here indicates a suitable place for exploitation, the product having the ordinary properties of maltha. (*d*) A more complete examination of Africa will doubtless reveal other localities which yield bitumen.

An examination of map I will show that bitumen occurs on the American continent along a line extending from Point Gaspé, in Canada, to Nashville, Tennessee, and in Europe-Asia along a line extending from Hanover, on the North sea, through Galicia, the Caucasus, and the Punjab. These are the principal lines. In America it also occurs on the Pacific coast from the bay of San Francisco to San Diego; again from northern Nebraska to the mouth of the Sabine river, on the Gulf of Mexico; again from Havana near the western end of Cuba, through San Domingo and the circle of the Leeward and Windward islands, to Trinidad; thence westward on the mainland to the Magdalena river, and southward from that point to cape Blanco, in Peru. In Europe-Asia bitumen occurs on the lower Rhine and in the valley of the Rhone; from northern Italy, following the Apennines, to southern Sicily; along the eastern shores of the Adriatic, through Dalmatia and Albania, into Epirus; again along the depression in which lies the Jordan and the Dead sea; again along the mountains that border the valley of the Tigris in the east; again from western China through Burmah, Pegu, Assam, Sumatra, and Java; and lastly in Japan. It will be observed that these lines are for the most part intimately connected with the principal mountain chains of the world.

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a Bleekrode, Rep. de Chem. Appl.; C. N., v, 158; *Le Technologiste*, xxiii, 402.
b Arch. Neerland, iv, 299; Mon. Sci., 1870, p. 53; W. B., 1878.
c Mon. Sci. 1877, p. 295.
d *Les Mondes*, xxxvi, 318.

Chapter III.—THE GEOLOGICAL OCCURRENCE OF BITUMENS.

Section I.—GENERAL CONSIDERATIONS.

The relation of geology to the occurrence of bitumens has been very liberally discussed during the last half century. In attempting to review the literature of this subject one is impressed with the fact that for the most part the opinions expressed may be said to be *provincial*, inasmuch as they are based on observations made over a comparatively limited area, and from these limited observations generalizations are often made to include all of the varied conditions under which bitumen occurs in different parts of the world. My intention has been to compile this chapter from the papers of professional geologists who have directed their attention to the subject, and it is while attempting this work that the provincial character of the materials that I have to compile and the great lack of uniformity of opinions among eminent geologists who have written upon the subject have been most forcibly impressed upon me. Again, when comparing the earlier and the later authors, there is a lack of uniformity in nomenclature that renders the task of one seeking information extremely difficult. Deposits of bitumen in different parts of the world have been described by persons whose knowledge of geology is often of an extremely elementary character, yet almost every author who has mentioned a tar or petroleum spring endeavors to inform his readers respecting the age of the rocks from which it issues and discusses the origin of bitumens.

A clearer comprehension of the geological occurrence of petroleum can be had without particular reference to the political divisions of the earth's surface, and I shall therefore consider the subject only with reference to geological sequence. It has been frequently remarked that petroleum occurs in all geological formations from the Silurian up to the Tertiary, and while this is true as a general statement, it is misleading, for bitumen is not uniformly distributed through all formations, but occurs principally in two epochs of geological history, the Silurian and the lower half of the Tertiary. The vast accumulations along the principal axis of occurrence in the western hemisphere are found in Silurian and Devonian rocks; but the most productive axis in the eastern hemisphere lies in the Eocene of the Carpathians and the Caucasus. An examination of the geographical occurrence of bitumen east of the Mississippi river shows that it has been reported from localities which describe an ellipse upon the border of the Cincinnati anticlinal, which is really an elevation of Silurian rocks extending from central Kentucky to lake Erie, with Cincinnati nearly in its center, and sloping beneath the newer formations in all directions. Starting with Great Manitoulin island on the north, petroleum is reported at Port Huron, Michigan; Chicago, Illinois; Terre Haute, and in Crawford county, Indiana; Henderson, Cloverport, Bowling Green, and Glasgow, Kentucky; and in the region around Nashville, Tennessee, extending southeast to Chattanooga, where the Silurian rocks again reach the surface. Turning northward, the line extends almost unbroken from Burksville through the eastern counties of Kentucky into Ohio and West Virginia, and into Pennsylvania and New York, but how far has not yet been determined. The ellipse is completed by the petroleum fields of Canada. A portion of this territory is covered with the carboniferous formation, beneath and within which petroleum has often been found.

At Great Manitoulin island petroleum was obtained in the Trenton limestone. At Chicago and at Terre Haute the drill penetrated the Niagara limestone before reaching oil. The failure of the wells to reach oil in southern Indiana is attributed by Professor E. T. Cox to the fact that they were abandoned before they reached the corniferous and the Niagara limestones. (*a*) Professor Shaler appears to regard the great Devonian black shale as the source of the oil of Kentucky. (*b*) The oil in that state is found saturating sandstone at Glasgow, and in crevices at Burksville and other points on the Cumberland, in many instances, as I am informed by those who reside in that vicinity and are familiar with the subject, beneath the black shale. In the neighborhood of Nashville, where the Lower Silurian rocks reach the surface, petroleum occurs within geodes that are inclosed within the solid mass of the blue limestone under such circumstances as to admit of no question as to whether the oil originated in the rock where found. As the occurrence of petroleum is studied in localities lying northeast of Nashville, the present location of the oil is found to be in rocks that lie in a continually ascending series. Around Burksville it is found in crevices, in a so-called marble in the Upper Silurian, immediately beneath the Devonian black slates. Further north it lies in the Devonian and subcarboniferous sandstones, and is held in the region in Johnson county partly in rocks that are now above the drainage level of the country. (*c*) In Professor J. P. Lesley's elaborate report upon this region he says: "A conglomerate age or horizon of petroleum exists; this is the main point to be stated." (*d*)

Leaving Kentucky and entering Ohio, we find the so-called oil break of West Virginia and Ohio furnishing petroleum in sandstones that lie within the coal measures. Still further to the northeast, in Pennsylvania and New York, the oil sands are all found beneath the coal measures in the Upper Devonian, and in Canada they again descend to the Lower Devonian.

a *Geological Survey of Indiana*, 1872, p. 139. *b* *Geological Survey of Kentucky*, N. S., iii, 107. *c* Lesley, P. A. P. S., x, 33. *d* *Ibid.*

At Belden, Ohio, the oil is found in crevices in the Berea grit which covers a wide expanse of country in Lorain and Medina counties.

At Mecca, in the neighborhood of Power's Corners, the oil saturates the Berea grit, which lies within 80 to 100 feet from the surface. Water is pumped from the wells, bringing the oil with it. These wells are often used for water at the same time that they yield petroleum.

The geology of the trans-Mississippi localities producing petroleum has never been studied in any comprehensive or satisfactory manner. Professor G. C. Swallow says the petroleum of western Missouri and eastern Kansas comes from the coal measures, the well in La Fayette county, Missouri, passing through "sandstone, shale, coal, and limestone", and Professor Aughey reports the oil in the well at Ponca, Dixon county, Nebraska, as coming at a depth of 570 feet from the Lower Carboniferous. "The boring passed through the Cretaceous (Dakota) group, then through the Upper Carboniferous into the Lower Carboniferous, and obtained only a very small quantity of oil." Mr. S. F. Emmons says: "It (petroleum) exists in the Cretaceous rocks which extend along the eastern slope of the Rocky mountains from British Columbia to Mexico, and in many of the interior valleys." The outcrops mentioned in the last chapter as occurring in Wyoming and Colorado arise probably from the Cretaceous. I have no information respecting the geology of the outcrops in Texas.

The bitumen of the Pacific slope of Mexico, the West Indies, and South America is doubtless Tertiary Miocene in California and Eocene in Trinidad. In England the small quantity of petroleum that has been observed has sprung from the coal measures. In the valley of the Rhone and Savoy the bitumen is in Jurassic limestones. The bitumen of the Apennines, of Dalmatia and Albania, issues from rocks that are Eocene; also that of Roumania, Galicia, and the Caucasus. But little is known respecting the geology of the bitumen of Syria, Judea, and Persia. The Punjab is Eocene, and the little that is known of the deposits yielding petroleum in Burmah and the East India islands indicates that they are of the same age.

From these statements it will be seen that there is a vast area in the valley of the Mississippi, estimated at 200,000 square miles, over which petroleum has been obtained, the formations of which are nowhere newer than the coal measures. Another vast area, extending from California through Mexico to Peru, and including the West India islands, yields petroleum from Tertiary rocks, while on the eastern continent a belt of country extends from the North sea to Java, the bitumen-bearing rocks of which, so far as is known, are Tertiary. I shall have occasion to refer to many of the details of these localities in the fifth chapter. At present the bulk of the petroleum produced issues from rocks older than the Carboniferous, while the formations in by far the greater number of localities yielding bitumen are of Eocene age.

SECTION 2.—THE GEOLOGICAL OCCURRENCE OF PETROLEUM IN EASTERN NORTH AMERICA.

The geological occurrence of petroleum in the United States has been discussed with reference to whether it has all primarily issued from the Silurian limestones and has accumulated in the crowns of anticlinals. This view has been forcibly argued by Professor T. Sterry Hunt, of Montreal. The question has also been discussed with reference to whether petroleum, having originated in deep-seated strata, has not collected in crevices which have resulted from faulting and movement of the overlying strata. The late Professor E. B. Andrews was perhaps the leading exponent of this view. Again, it has been urged that the oil, having originated in the lower rocks of deeply-seated strata, is held neither in crevices nor beneath the crowns of anticlinals but by capillary attraction in the interstices and cracks of porous sandstone. This view has been advocated by Professor J. P. Lesley. Dr. Hunt observed in Canada, Professor Andrews in West Virginia, and Professor Lesley in Pennsylvania and Kentucky, and from a careful examination of the facts to be observed in a summer's trip through the oil region from Olean, New York, to Nashville, Tennessee, and also from a careful collation of statements made by many oil producers and others, I conclude that each of these gentlemen is correct as regards his own locality. There is no question but that petroleum has originated in the Silurian rocks, and that the finding of oil in the Niagara limestone at Chicago and at Terre Haute was a strong confirmation of the opinions expressed by Dr. Hunt in his famous essay on the history of rock-oil, when he says, referring to a previous paper reported in the *Montreal Gazette:*

> I asserted that the source of the petroleum was to be sought in the bituminous Devonian and Silurian limestones. Beside the corniferous limestones (Devonian), we have shown that both the Niagara and Trenton (of Upper and Lower Silurian age) contain petroleum. (*a*)

There is no question that petroleum occurs in West Virginia along an anticlinal, as has been advocated by Professor Andrews. The hypothesis that petroleum occurs in huge fissures or cavities which have been represented by sections, in which water, oil, and gas are arranged according to their specific gravities, has not been sustained by later and more careful study of the subject. It is beyond question that the oil of Pennsylvania does not occur beneath anticlinals, nor in crevices, nor is it anywhere near the Silurian limestones; yet there is no doubt that at Gaspé and in Ontario the springs of petroleum occur along the crests of gentle anticlinals, as so carefully described by Dr. Hunt.

a C. N., vi, 5, 16, 35; C. Nat. (1), vi, 245; A. J. Ph. (3), x, 527.

In 1867 Professor C. H. Hitchcock contributed an article to *The Geological Magazine*, which has been very widely quoted, particularly as to the conclusions therein reached. These conclusions appear to have been obtained from a collation of the writings of Professors Hunt, Andrews, and Lesley; (*a*) and an address given by Dr. Hunt at a meeting of the Société Geologique de France, in which he made a general application of his views, based on his Canadian experience, to the occurrence of petroleum in the United States, appears to have been very widely quoted in Europe. (*b*)

In the article above mentioned Professor Hitchcock enumerates fourteen different formations from which petroleum has been obtained in North America (exclusive of the West Indies), and generally in commercial quantities. These are:

a. Pliocene (*c*) Tertiary of California. This has been known for a century.

b. Cretaceous in Colorado and Utah, near lignite beds. Not yet explored.

c. Trias of North Carolina and Connecticut, in small amounts. (*d*)

d. Near the top of the Carboniferous rocks in West Virginia. Most of the producing wells of this state are from this horizon.

e. Shallow wells near Wheeling, West Virginia, and Athens, Ohio, not far from the Pittsburgh coal.

f. Four hundred and twenty-five feet lower, near the Pomeroy coal-beds.

g. At the base of the coal measures, in conglomerates or millstone grit.

h. Small wells in the Archimedes limestone (Lower Carboniferous) of Kentucky.

i. Chemung and Portage groups—certainly three different levels—in western Pennsylvania and northern Ohio.

j. Black slate of Ohio, Kentucky, and Tennessee, or the representatives of the New York formation from the Genesee to the Marcellus slates. This is near the middle of the Devonian.

k. Corniferous limestone and the overlying Hamilton group in Canada West, extending to Michigan. This is largely productive.

l. Lower Helderberg limestone at Gaspé, Canada East. This is Upper Silurian.

m. Niagara limestone near Chicago, and awaits development. (*e*)

n. In the equivalents of the Lorraine and Utica slate and Trenton limestone of the Lower Silurian in Kentucky and Tennessee. One well in Kentucky in these rocks was estimated to have yielded 50,000 barrels. (*f*)

Developments since 1867 have added little, if anything, to the above as a general statement. With particular reference to the three localities in Canada, Pennsylvania, and West Virginia, which practically yield the petroleum product of North America, I shall endeavor to show the manner in which nature has stored and yields such vast accumulations of material, and to present the ascertained facts without bias for any theory. Dr. Hunt has been a frequent contributor to the literature of this subject during the last twenty years, and from his articles in the *American Journal of Science* for March, 1863, (*g*) and November, 1868, (*h*) I make the following extracts, which embody his views upon the geological occurrence of petroleum in Canada:

The natural oil-springs which occur in various parts of western Canada are upon the outcrop of the corniferous limestone or of the overlying Hamilton shales, and are along the line of a broad and low anticlinal, which runs nearly east and west through the district. In the township of Dercham, where small quantities of oil rise to the surface in several places, the corniferous formation is overlaid by about 40 feet of clay and sand, after sinking through which the limestone was bored to the depth of 36 feet. From this opening a few barrels of petroleum were obtained. Oil-springs abound for several miles along the Thames about 60 miles to the westward of Dercham, and borings into the limestone beneath have furnished considerable quantities of oil, although not sufficient, perhaps, to be of great economic importance. The principal oil-wells of Canada occur in Enniskillen, about 20 miles to the northward of the last. Here numerous oil-springs are found, and the thickened petroleum, mixed with earthy and vegetable matters, forms layers of considerable extent at the surface of the ground and around the roots of growing forest trees. Two of these layers have together an area of more than two acres, and a thickness which varies from a few inches to 2 feet. They are locally known as gum beds. In sinking a well in the vicinity of an oil-spring in this region there was found beneath a depth of 10 feet of clay and reposing upon 4 feet of gravel a layer of bituminous matter like that just described from 2 to 4 inches in thickness. It is easily separable into thin laminæ, which are so soft as to be flexible, and show upon their surfaces the remains of leaves and of insects which have become imbedded during the slow accumulation and solidification of the bitumen. This little deposit, which is mingled with a considerable proportion of earthy matter, is instructive as showing the manner in which beds of bituminous rock may sometimes be produced from previously-formed sources of petroleum.

The corniferous limestone in Enniskillen is overlaid by about 200 feet of marls and soft shales, abounding in the characteristic fossils of the Hamilton formation. To this succeed from 40 to 60 feet of Quaternary clays and sands of fresh-water origin, through which the scanty natural oil-springs rise. On sinking wells there is generally found reposing immediately upon the shales a layer of coarse gravel holding large quantities of petroleum, which is the oil of the so-called surface wells, and has accumulated beneath the clays. It is darker and thicker than that obtained directly from the rock below, on boring which fissures or seams are met with, from which petroleum issues in abundance, and often with great force, sometimes attaining the surface and often rising above it, constituting the flowing wells. These oil-bearing veins are met with at depths varying from 40 to 100 and 200 feet in the rock, and in borings near together the oil is often met with at very unequal depths. Adjacent borings sometimes appear to be connected with the same vein and to affect each other's supply. The deepest well in this region was estimated to yield, when first opened, 2,000 gallons in twenty-four hours, and, at present, where it is allowed to flow for some time, the supply in many of the neighboring shallower wells is found to fail. The facts observed in this region seem to show that these veins are fissures running obliquely downward to the great reservoir of petroleum, which is probably in the underlying corniferous limestone. The oil-wells in this township are confined to two districts, the more abundant one being about 6 miles south of the other. From the results of an unsuccessful boring made on an intermediate point, it appears that these two districts are on two slight anticlinals subordinate to the great axis already mentioned. This anticlinal structure appears to be a necessary condition of the occurrence of abundant oil-wells; the petroleum, being lighter than water, accumulates in porous strata, or in fissures in the higher part of the anticlinal, and, in obedience to a hydrostratic law, rises through openings to heights considerably above

a C. N., 6, 5, 16, 35; C. Nat. (1), 6, 245; A. J. Ph. (3), 10, 527.

b B. S. G. F., xxiv, 570.

c Since determined to be Miocene.

d Professor Kerr, state geologist of North Carolina, reported that no petroleum was known in that state.

e Since shown in Niagara limestone at Terre Haute, Indiana.

f *The Geol. Mag.*, iv, 34.

g A. J. S. (2), xxxv, 169.

h *Ibid* (2), xlvi, 356.

the water level of the region. Large quantities of light carburetted hydrogen gas are found in the palæozoic rocks of the vicinity, and seem to be in many cases accumulated in the subterranean anticlinal reservoirs, since borings sometimes yield both gas and oil, or gas alone. Water sometimes, but not always, more or less saline often accompanies the petroleum, and frequently replaces the latter in wells that have been for some time wrought. I do not conceive that the gas has any necessary connection with the oil, since large quantities of it are found in rocks which underlie the corniferous limestone. If, however, as is not improbable, portions of it were generated and now exist in a condensed state in the oil-bearing strata, its elasticity would help to raise the petroleum to the surface.

The accumulation of the petroleum along lines of uplift, and its escape through the fissures accompanying this disturbance, must evidently date from a remote geological epoch. Porous beds, like the Devonian sandstones or the Quaternary gravels, have, however, served as reservoirs in which the oil has accumulated, while argillaceous and nearly impervious strata, like the marls of the Hamilton group and the fresh-water clays which overlie the gravels in western Canada, have in a great measure prevented its escape.

Hence it would appear that the Devonian sandstones of Pennsylvania and northeastern Ohio are filled with oil which has risen from the limestone beneath, while over a great portion of western Canada this limestone was ages ago denuded, and has lost the greater part of its petroleum. (*a*)

* * * * * * * *

There exists in southwestern Ontario, along the river Saint Clair, an area of several hundred square miles underlaid by black shales in the counties of Lambton and Kent, of which only the lower part belongs to the Hamilton group. These strata are exposed in very few localities, but the lower beds are seen in Warwick, where they were many years since examined by Mr. Hall, in company with Mr. Alexander Murray, of the geological survey of Canada, and were by the former identified with the Genesee slate forming the summit of the Hamilton group. They are in this place, however, overlaid by more arenaceous beds, in which Professor Hall at the same time detected the fish remains of the Portage formation. The thickness of these black strata, as appears from a boring in the immediate vicinity, is 50 feet, beneath which are met the gray Hamilton shales. * * * * The Hamilton shale, which in some parts of New York attains a thickness of 1,000 feet, but is reduced to 200 feet in the western part of the state, consists in Ontario chiefly of soft, gray marls, called soapstone by the well-borers, but includes at its base a few feet of black beds, probably representing the Marcellus shale. It contains, moreover, in some parts beds of from 2 to 5 feet of solid gray limestone holding silicified fossils, and in one instance impregnated with petroleum, characters which, but for the nature of the organic remains and the underlying marls, would lead to the conclusion that the Lower Devonian had been reached. The thickness of the Hamilton shale varies in different parts of the region under consideration.

From the record of numerous wells in the southeastern portion it appears that the entire thickness of soft strata between the corniferous limestone below and the black shale above varies from 275 to 230 feet, while along the shore of lake Erie it is not more than 200 feet. Further north, in Bosanquet, beneath the black shale, 350 feet of soft gray shale were traversed in boring without reaching the hard rock beneath, while in the adjacent township of Warwick, in a similar boring, the underlying limestone was attained at 396 feet from the base of the black shales. It thus appears that the Hamilton shale (including the insignificant representative of the Marcellus shale at its base) augments in volume from 200 feet on lake Erie to about 400 feet near to lake Huron. Such a change in an essentially calcareous formation is in accordance with the thickening of the corniferous limestone in the same direction.

The Lower Devonian in Ontario is represented by the corniferous limestone, for the so-called Onondaga limestone has not been recognized, and the Oriskany sandstone, always thin, is in some places entirely wanting. The thickness of the corniferous in western New York is about 90 feet, and in southeastern Michigan it is said to be not more than 60 feet, although it increases in going northward, and attains 275 feet at Mackinac. In the townships of Woodhouse and Townsend, about 70 miles west from Buffalo, its thickness has been found to be 160 feet; but for a great portion of the region in Ontario underlaid by this formation it is so much concealed that it is not easy to determine its thickness. In the numerous borings which have been sunk through this limestone there is met with nothing distinctive to mark the separation between it and the limestone beds which form the upper part of the Onondaga salt group or Salina formation of Dana, which consists of dolomites, alternating with beds of a pure limestone, like that of the corniferous formation. The saliferous and gypsiferous magnesian marls, which form the lower part of the Salina formation, are, however, at once recognized by the borers, and lead to important conclusions regarding this formation in Ontario. In Wayne county, New York, the Salina formation has a thickness of from 700 to 1,000 feet, which, to the westward, is believed to be reduced to less than 300 feet, where the outcrop of this formation, crossing the Niagara river, enters Ontario. * * * *

Apart from the chemical objections to the view which supposes the oil to be derived from the pyroschists above the corniferous limestone, it is to be remarked that all the oil-wells of Ontario have been sunk along denuded anticlinals, where, with the exception of the thin black band sometimes met with at the base of the Hamilton formation, these so-called bituminous shales are entirely wanting. The Hamilton formation, moreover, is never oleiferous, except in the case of the rare limestone beds already referred to, which are occasionally interstratified. Reservoirs of petroleum are met with both in the overlying Quaternary gravels and in the fissures and cavities of the Hamilton shales, but in some cases the borings are carried entirely through these strata into the corniferous limestone before getting oil. Among other instances cited in my geological report for 1866 may be mentioned a well at Oil Springs, in Enniskillen, which was sunk to a depth of 456 feet from the surface, and 70 feet in the solid limestone beneath the Hamilton shales, before meeting oil, while in adjacent wells supplies of petroleum are generally met with at varying depths in the shales.

In a well at Bothwell oil was first met with at 420 feet from the surface and 120 feet in the corniferous limestone, while a boring at Thamesville was carried 332 feet, of which the last 32 feet were in the corniferous limestone. This well yielded no oil until, at a depth of 16 feet in this rock, a fissure was encountered, from which at the time of my visit 30 barrels of petroleum had been extracted. At Chatham, in like manner, after sinking through 294 feet of shales, oil was met with at a depth of 58 feet in the underlying corniferous limestone.

We also find oil-producing wells sunk in districts where the Hamilton shale is entirely wanting, as in Maidstone, on the shore of lake Saint Clair, where, beneath 109 feet of clay, a boring was carried through 209 feet of limestone, of which the greater part consisted of the water-lime beds of the Salina formation, overlaid by a portion of the corniferous. At a distance of 6 feet in the rock a fissure was struck, yielding several barrels of petroleum. Again, at Tilsonburg, where the corniferous limestone is covered only by Quaternary clays, natural oil-springs are frequent, and by boring fissures yielding petroleum were found at various depths in the limestone down to 100 feet, at which point a flowing well was obtained, yielding an abundance of water, with some 40 gallons of oil daily.

The supplies of oil from wells in the corniferous limestone are less abundant than those in the overlying shales and even in the Quaternary gravels, for the obvious reason that both of these offer conditions favorable to the retention and accumulation of the petroleum escaping from the limestones beneath.

* * * * The conditions under which oil occurs in these limestones in Ontario are worthy of notice, inasmuch as they present grave difficulties to those who maintain that petroleum has been generated by an unexplained process of distillation going on in some

a A. J. S. (2), xxxv, 169.

underlying hydrocarbonaceous rock. Numerous borings in search of oil on Manitoulin island have been carried down through the Utica and Lorraine shales, but petroleum has been found only in fissures at considerable depths in the underlying limestones of the Trenton group. The supplies from this region have not hitherto been abundant, yet from one of the wells just mentioned 120 barrels of petroleum were obtained. The limestone here rests on the white, unfossiliferous, chazy sandstone, beneath which are found only ancient crystalline rocks, so that it is difficult to avoid the conclusion that this limestone of the Trenton group is, like those of the Upper Silurian and Devonian age already noticed, a true oil-bearing rock. (*a*)

Although the discussion of the subject as presented in these two extracts proceeds in a somewhat disconnected manner, the opinions held by Dr. Hunt are plain, viz: that the oil comes from the limestones at the base of the Devonian formation, that it is indigenous in those rocks, and has accumulated under the crowns of anticlinals.

According to the latest published researches, I conclude that the geological formations in western Pennsylvania from which petroleum has been obtained belong to the Chemung and perhaps later groups of the Upper Devonian, and consist of shales and marls, interstratified with sandstones. The sandstone varies in character from a coarse-grained, uncemented sandstone to a pebble conglomerate, composed of worn pebbles of white or slightly-colored opaque quartz overlaid by marls and slates, often highly silicated, forming very hard and impervious crusts. This pebble conglomerate consists of two varieties, occupying separate horizons, in one of which the pebbles are nearly spherical, and in the other flattened. Between these beds of sandstone or conglomerate that contain the oil are beds of shale, often of great thickness, with which are thin beds of sand and "shells". The latter are thus described by Professor J. P. Lesley:

The hard "shells" or crusts of white flint found at different depths in this and many other wells, and broken with the auger-bits only with extreme difficulty, are deserving of particular investigation. They seem to form impervious sheets of precipitated silica effectual barriers against any general movement, upward or downward, of the underground drainage. (*b*)

The sandstones and conglomerates are of quite uniform structure over wide areas; for instance, the Venango third sand consists of smooth, rounded pebbles, while the Bradford third sand is a porous sandstone. The latter has been examined microscopically by Professor C. W. Hall, of the University of Minnesota, who, in a private communication, says:

The sandstone in the flame turned to a light gray, almost white, color through the burning out of the bituminous matter. Thin sections disclose the presence of numerous fluid cavities in some of the grains. Small as these grains are, they protected intact the fluid contents of the cavities from the penetrating effects of the petroleum which had percolated through the mass of the sandstone.

A bed of shale several hundred feet in thickness and very rich in remains of fucoids outcrops along the shores of lake Erie through Erie county, Pennsylvania, and Chautauqua county, New York, and wells drilled at Erie, Pennsylvania, to a depth of over 600 feet in this shale have yielded petroleum, but have failed to reach the underlying formation. These shales dip toward the southwest.

At Union City, in the southern part of Erie county, sandstone overlies the shale in the summits of the hills and furnishes the quarry rock for the valley of French creek. This sandstone often exhibits traces of bitumen, and when freshly quarried and exposed to the sun becomes covered with an exudation of thick oil. Farther south and east the rocks alternate between shales, sandstones, and pebble conglomerate, each of which dips south and west, and disappears under newer and higher members that succeed them on the surface. In the neighborhood of Titusville, Crawford county, the shales of Erie county have passed far below the surface, and new sandstones have appeared on the hills which border the deep and narrow valleys through which the Allegheny and its tributaries flow.

No clearer statement has been made of the relations of these rocks than that given by Mr. J. F. Carll in his reports to the geologist in charge of the second geological survey of Pennsylvania. He says:

In the first oil development by artesian wells nothing was known about the sands. Wells were drilled until indications of oil appeared, without regard to the character of the strata pierced. But experience soon proved the sand rocks to be its source, and then commenced deeper drilling for other sands, which, in the valley of Oil creek, resulted in the discovery and classification of "three sands"—these being all the oil-bearing sands found in that locality, even after several wells had been sunk much deeper in quest of others.

In the progress of development locations for wells were selected on higher ground. The drill passed now through four or five other and higher definite sand rocks before reaching the geological horizon of the *first sand* of Oil creek, and when this fact was made clear it became customary among drillers to throw out these *upper* sands from their well records. They were called the "mountain sands", and were also numbered 1, 2, 3, etc. The drillers commenced their count of the oil-rocks with that one which they found at the depth at which they supposed the first sand of Oil creek to lie; but in so doing many errors occurred, resulting from a want of accurate observation, first, as to the surface elevation of the wells drilled on high ground, and, second, as to the dip of the oil-bearing strata, which materially affected the comparison of elevations, even when these were accurately known. A third source of error may be found in the fact that a thick stratum of sand lying single and solid in one place is often split into two, or, in other words, is represented by an equivalent of two sands with shales intervening in another place, perhaps only a short distance from the first.

For several years after the discovery of oil the drilling of wells was almost exclusively confined to the "flats" bordering the principal streams. The impression prevailed that there was some connection, some parallelism, between the streams on the surface and the "oil veins" beneath; but many failures to strike oil along the streams gradually led to locations on higher ground and upon lines between good wells. This method has been pursued so long and so thoroughly that we can now affirm that the drill has traced the great oil leads of the country from point to point *regardless of any and all topographical features of the surface.* (c) * * *

We use the word "belt", not as employed by some to designate a narrow, continuous line of sand rock, which may be unerringly traced for miles with an instrument on a certain degree of the compass circle, but only as a convenient term for expressing the general trend of the oil-bearing rocks from point to point, even although interrupted by "dry" and unproductive intervals.

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a A. J. S. (2), xlvi, 356, *et seq.* *b* P. A. P. S., x, 68. c Report I, p. 10.

The base-line run from Pleasantville to Tidioute—from the commencement of the Colorado district to the Allegheny river—passes through what has been one of the best and most continuous oil-producing belts of the region. Along and contiguous to this line, and to the north of it, the deeply-eroded valleys of Pine creek and Dennis run expose the basset edges of the whole series of slightly-inclined rocks (uplifted toward the north) underlying the Great Conglomerate (No. XII, the base of the productive coal measures) to a (geological) depth of 850 feet, bringing us down to within about 100 feet of the third or lowest oil-bearing sands. (*a*)

This exposure (along Pine creek and Dennis run), taken in connection with the well records along the route, enables us to form a tolerably correct idea of the stratification of the rocks to that depth. The whole series is found to consist of bands of sandstones and conglomerates and sandy and muddy shales and slates, varying locally in character, composition, and relative order, when studied in detail, but, as a whole, lying one above another in nearly horizontal parallel planes. The local variability of stratification is particularly noticeable (at least in the southeastern part of the district) in the strata next beneath the Conglomerate No. XII, and to a relative depth of from 600 to 650 feet. These strata have never produced oil in Venango county. We may therefore call them the "barren oil-measures" of Venango, or the "mountain-sand group".

Beneath the division of mountain sands another series, with a thickness of from 350 to 400 feet, and similar to the above in structure, but rather more regular in stratification, will include the three sands of Oil creek; and, as we believe it can be shown that no oil has ever been obtained in the district except from rocks of this series, it may properly be called the "petroleum measures" of Venango, or "division of the three sands".

Some of the first wells drilled evidently obtained their oil above the first sand, and the old oil-pits of French and Oil creeks and Hosmer run were above it also. But the oil, without doubt, came really from the first sand, its close proximity to the surface in these places having admitted of the percolation of surface water into its crevices, which, by hydraulic pressure, forced the oil upward.

It is a noticeable fact that any first sand below the surface is generally full of water veins, whether it be an oil-bearing or a mountain sand. If the oil sands lie deep, they seldom (especially in new territory, before the water is let down by the drill) contain much water.

In the shallow wells at Tidioute, along the Allegheny river, and on French and some parts of Oil creek, considerable water was always pumped with the oil; but in the deep wells at Pleasantville there was not found at first one per cent. of water, and that, being salt, must have come commonly from the second sand. As the oil was exhausted the water increased. (*b*)

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A comparison of records of wells on Oil creek, where the three leading sands of the petroleum measures lie with considerable regularity, both as to their thickness and the intervening distances between them, results in an average record about as follows:

First sand, 40 feet thick; interval, 105 feet. Second sand, 25 feet thick; interval, 110 feet. Third sand, 35 feet thick. Total, 315 feet.

In addition to these three regular sands, there is found in many of the wells a fine-grained, muddy, gray sand, known among drillers as the "stray third". This lies from 15 to 20 feet above the regular third, and is from 12 to 25 feet thick. In some localities this rock assumes a pebbly character, and produces oil which is always darker than the third-sand oil, sometimes being nearly black.

At different points on Oil creek—at East Shamburg and other places—wells in close proximity to each other have produced, some of them black oil, some green, and some a mixture of both.

The "black oil" of the Pleasantville district has all been derived from the "stray third", which, in this district, is universally called the fourth, or "black-oil sand". But here the character and composition of the two sands (third and stray) are reversed. The stray is a coarse pebble or conglomerate; the third, a fine, micaceous, muddy, gray sand, only 15 to 20 feet in thickness, but always showing traces of green oil, and sometimes furnishing an abundance of gas.

We believe it can be shown also that Pithole, Cashup, and Fagundus, although producing an oil of a lighter color than Pleasantville, drew their supply from the same stray sand, and the proof will be offered farther on.

A noticeable peculiarity of these two sands (stray and third) is that on the northwestern outline of the oil-field, where the third shows itself in greatest force, the stray is seldom an oil-producing rock. As we proceed southeastward the stray begins to get its pebbly constitution and to yield oil over broader areas than the third, the latter becoming more fine and compact and gradually thinning away.

A marked difference will be noted also on comparison of specimens of the two sands. In the oil-producing stray the pebbles are of a yellowish-brown color, and in shape generally spheroidal. In the third the pebbles are white, often brilliant, and in shape lenticular. These distinguishing characteristics, we believe, hold good universally.

On the northwesterly line above mentioned the second sand lies in a massive stratum, 30 feet or more in thickness. Toward the southeast, as in a part of the Pleasantville district, at Bean farm, Pithole, Cashup, and Fagundus, it is split into two well-defined sands, with from 15 to 30 feet of slates or shales intervening. It is this that has given rise to the erroneous appellation of fourth-sand oil at Pleasantville. The drillers began to number rightly on the first; and called the split (second) sand next below it second and third, and then called the stray the fourth. This, of course, made the third sand of the Oil creek wells, which was still lower, fifth in the series.

In some localities they went still farther in their zeal to prove their territory better than Oil creek, by showing a greater number of sands. Finding the stray and third in three divisions, instead of two, they announced at once the discovery of a sixth sand.

The first sand, as far as we have examined it, appears to lie with more uniformity than the second, but further investigation may show changes of character and of level similar to the others.

Little oil has been produced from the first and second sands in the particular field under review. Their best development as oil-bearing rocks is along the Allegheny river from West Hickory to the Cochran farm, and on French creek and Two-mile run, near Franklin, to which our detailed survey of 1874 did not reach. We speak of them above as they are found on the green-oil range, and without a closer knowledge of the peculiar structural differences which they may be found to exhibit in the places above named on the Allegheny river and French creek.

Assuming, then, that all the oil from this country has been deduced from the "group of the three oil sands", consisting of the first, second, stray, and third, with their intervening slates, shales, and mud rocks, and that the trend of the oil-producing belt is marked by no surface indications to point out its direction or drift, we will proceed, on the principle of a general parallelism of strata, to trace the sands by means of the levels run, combined with the records of wells, through some of the main oil centers of the district, with a view of ascertaining the direction of the dip of the series and the fall, in feet, per mile.

The Venango petroleum district, or "upper oil belt", as it is now generally called, in contradistinction to the Butler county district, may be said to commence a short distance east of Tidioute. From thence southwestward it is marked by an almost unbroken band of wells through Dennis run, Triumph, the Clapp farms, New London, the Ware farm, and Colorado, a distance of about 9 miles.

Between this, its southwest end, and the commencement of the Shamburg district, near the National wells, no paying third-sand wells are found, except, perhaps, within a limited area on the Benedict farm, west of Enterprise, the exact geological relations of which to the Colorado "lead" has not been fully determined.

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a Report I, p. 11. *b* *Ibid.*, p. 13.

Beneath this unproductive district the third sand is found in all the wells drilled, having a thickness of from 30 to 45 feet, but apparently too fine-grained and closely compacted with mud to produce oil.

Between Shamburg and Petroleum Centre, on Oil creek, occurs another unproductive interval; but from Petroleum Centre the oil-belt has been traced with considerable continuity, crossing the Allegheny river at Reno, again at Foster's, and terminating at Scrubgrass.

This line of development, it will be noted, leaves Tidioute in a direction of about south 80° west, gradually sweeping around toward the south, and ending with a bearing of only about south 20° west.

The belt above described, it should be understood, is the green-oil or third-sand belt. It appears to be much narrower and more sharply defined than others. At many places a distance from the center line toward the north or toward the south of merely a few rods suffices to guarantee a "dry hole".

From levels taken along the surface line above described, combined with such records of wells as were obtained, the elevation of the top of the third sand in the several localities named is ascertained to be as follows:

	Feet above tide.
At Tidioute	995
At Colorado	840
At Pleasantville	755
At Shamburg	710
At Petroleum Centre	640
At Rouseville	545

Distance from Rouseville to Tidioute, 20.7 miles; difference in elevations, 450 feet; dip per mile, 21.7 feet. (*a*)

In the report made subsequently, and published in 1880, Mr. Carll continues the discussion of this subject. Want of space forbids my quoting more liberally from this report, but the following extracts present the relation and stratigraphy of these formations:

The designations first, second, and third mountain sands, used provisionally in 1874, answered very well for the purposes of that local report; but to adhere to the use of these ordinal numbers still, after the comparison of oil-well and surface sections has been extended southwestward to the very borders of the state of Ohio and northeastward into the southern counties of the state of New York, would only perpetuate confusion in our geological nomenclature.

The first mountain sand appears to occupy the horizon of the Connoquenessing sandstone of Butler county and the Kenzua creek sandstone of McKean county, and may as well be spoken of when occasion requires under one of those two names.

In the *Reports of the Pennsylvania Survey*, vol. III, page 83, appears the following in relation to this subject:

The second mountain sand cannot, indeed, be robbed entirely of its name; but whenever it is thus spoken of the name must be accounted as a mere synonym for the Garland conglomerate, and not at all as an index to the numerical position of the rock in relation to other sands in the series. But it will always be the Garland-Olean-Sharon-Ohio conglomerate.

The third mountain sand will receive in this report a new name, the Pithole grit. This rock was first recognized as a persistent sandstone in the Pithole oil-wells, being well developed in all that country, and making conspicuous outcrops along the Allegheny river on the south, and along Oil creek on the west. The term *grit* sufficiently designates it as a sandstone; but, what is more important, will serve to associate it in the reader's mind with the Berea grit of Ohio, which seems to have been a contemporaneous formation, although the two rocks have not been traced across the country toward each other to a common place of actual meeting.

Neglecting for the present the mountain sands as separate numbers of a small series, and grouping them and their intervals together as a whole, I must now show that they constitute one (and the upper) member of a larger series. The vertical section of rocks in the oil belt, as exhibited by the well records, show these characteristic subdivisions:

1. Mountain sands, so called by the oil-well drillers.
2. Crawford shales, a group of shales and mud rocks, in the midst of which is the Pithole grit.
3. Venango oil-sands, a group of sandstones and shales interleaved.

These names will be useful in defining those features of hardness and softness by which the driller classifies the rocks through which his well passes downward; but they must not be taken by the geologist to signify formations of these successive and distinct ages, plainly and absolutely separated from each other; for such dividing planes cannot be satisfactorily established from the imperfect records of oil-wells alone.

It is important to state the fact clearly at the outset that throughout the whole area which has afforded the Venango oil—that is, along the entire length of the oil-producing belt (or belts) of country—the structure of the oil-sand group is virtually the same. On the other hand, the moment we leave the oil-producing area to the right or to the left the internal constitution of the oil-sand group becomes quite different. All the wells that pierce the oil-producing belts exhibit remarkably the same group of oil sands. All wells put down outside of these belts exhibit quite a different kind of deposits when they reach the plane of the oil sands. (*b*)

From data too voluminous to quote here, Mr. Carll concludes that "the Venango oil sands as a group not only thin away, but disappear, and are wanting in the Slippery Rock country". Farther to the southwest, in Beaver county, he concludes that "not only is the oil group cut out, and also the red rock over it, but the sandstone deposit occupying the horizon of the Pithole grit is enlarged; the shaly interval above the sandstone becomes sandy; and thus the true base of the mountain-sand series becomes somewhat obscure". He further concludes:

It follows from this study of our sections that the Ohioville (Smith's ferry) amber oil must be derived from the horizon of the Pithole grit, which also furnishes *amber oil* in small quantities on Slippery Rock creek. It follows as logically, also, that the Slippery Rock heavy oil is found in one of the lower members of the mountain-sand series, an horizon which also produces heavy oil in many wells at Smith's ferry. (*c*)

Continuing the discussion, Mr. Carll states:

No direct connection has yet been discovered between the upper or Tidioute-Bullion oil belt and the lower or Clarion-Butler oil belt. The present southern termination of the line of productive wells on the upper belt is near Clintonville, in Venango county. This is about 12 miles northwest of Columbia hill, in Butler county, which is the nearest point of development in the lower belt. The lower belt

a *Report Second Geological Survey Pennsylvania*, I. 1874, p. 18. *b* *Ibid.*, III, p. 83. *c* Reports, III, p. 90.

is known to extend south-southwesterly from Columbia hill into Summit township, Butler county, some 20 miles, and northeasterly into Elk township, Clarion county, some 15 miles. The area of country between the belts has been tested in hundreds of places with results in most cases quite unsatisfactory. Nevertheless several good pools of oil have been discovered. These, however, do not establish a connection between the belts, for the stratification is somewhat irregular throughout all this district as far as is known, and the continuity of the oil-producing rocks seems to be here interrupted. We cannot, therefore, speak of the upper belt as being directly connected by a line of paying wells with the lower; yet the main structural features of the group in the upper belt are observable across the interval and the rocks themselves reappear with their characteristic aspect as soon as the lower belt is reached.

That the deposits of the lower belt have been subjected to more vicissitudes of water level than those of the upper belt, resulting in a greater number of alternating bands of sandstone and shale within the vertical limits of the group, seems evident; yet it cannot be doubted that the deposit in the two belts were being laid down at one and the same time. They occupy the same geological horizon; they are associated with similar strata; and they exhibit a like parallelism of structure. Geologically, therefore, the two belts may be viewed as one, and may be studied and described accordingly. (*a*)

Concerning the geological age of the oil-sand group, Mr. Carll remarks:

Previous to our present survey the Venango oil-sands were universally regarded as of Chemung age. In the summer of 1875 evidences began to accumulate pointing strongly toward the probability that they were of more recent date; but the idea seemed then so heterodox, and the facts to support it were at first so meager and questionable, that no definite conclusion on the subject could be immediately arrived at. Even now their relative place in the paleozoic column of eastern Pennsylvania cannot be precisely and positively indicated. We can only say there are reasonable grounds for inferring that they do not belong to the Chemung formation, as represented in New York state and eastern Pennsylvania. (*b*)

A comparison of the structure and depth of sediment belonging to the Catskill, the Pocono, and the Mauch Chunk periods in eastern Pennsylvania with those of the same ages in western Pennsylvania leaves little room to doubt that the former represent deposits in a much broader and deeper sea than the latter: a sea perhaps whose bottom was undergoing a steady depression in the east while it was alternating between depression and elevation and gradually shallowing in the west. An elevation of the ocean bottom near the close of the Chemung period seems to me to have thrown off the waters from a large portion of its former bed in the west, leaving submerged in that direction only a narrow arm of the sea, representing perhaps some old submarine valley. This comparatively contracted and shallow basin must necessarily, from the very nature of the case, have been the repository of immense deposits of reworked Chemung sediments, rapidly brought into it from the newly emerged mud-land, to be interbedded with the Catskill reds, which were intermittently swept in from the east to greater or less distances as circumstances directed. We might then expect to find in this basin precisely what the drill discloses: alternations of Catskill red and Chemung gray argillaceous shales occupying the deepest part of it, and more sandy deposits lying around its edges. (*c*)

Concerning the structure of the oil-sand group, Mr. Carll insists that the integrity of the Venango oil-sand group must be kept in clear view, as it is a group in the strictest sense of the term, and has a well-defined top and bottom. (*d*) The sandy layers at the top of the Crawford shale are of no moment in the present discussion. The sole fact here insisted on is this:

1. That over the oil-sand group lies a distinct soft formation, 300 or 400 feet thick, in all parts of the oil regions of western Pennsylvania, which, for the present, we call the Crawford shale, in the middle of which appears, in some parts of the region, a massive sand deposit, called in this report the Pithole grit.

2. That the well-sinker will find an abrupt change of character when he gets through this soft formation and strikes the top of the oil-sand group. The transition from the soft Crawford shales or slates to the first oil sand is sharply defined, and the geologist is obliged to see here the close of one period of deposits of one kind and the beginning of another period of deposits of a very different kind. (*e*)

Mr. Carll continues:

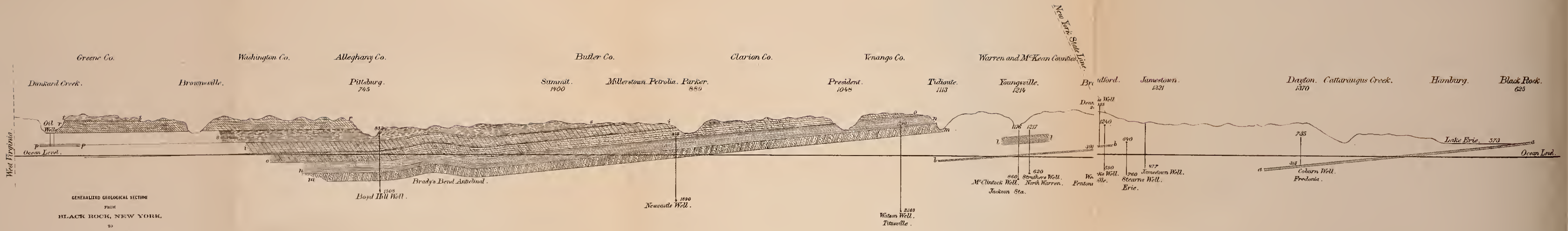
Under the oil-sand group again lies a perfectly well-marked different formation. The driller having gone through the Venango oil sands and their separating shales and reached the base of the group, suddenly, by as abrupt a transition as that he encountered at its top, enters a different set of rocks. Wherever the group is normally developed the drill passes at once from sandstone into shale, and continues from that point in the well to go steadily down through shales for hundreds of feet without encountering any sandstone layers like those above.

A large majority of oil-wells were never drilled below the third sand or base of the group, for experience had convinced operators that it was useless to expect another sand layer below that horizon along the whole line of the Venango and Butler belts. Several hundred wells, however, were put down to depths of from 100 to 500 feet beneath the lowest Venango oil sand. Their numbers, and the extent of ground over which they lie scattered, afford conclusive evidence that the measures beneath the oil-sand group have everywhere the same clay characters. The universal testimony of their records is, soft drilling and no coarse, massive sand rock after leaving the productive oil measures. Occasionally, indeed, a "sand" has been reported, and some fine-grained sandstone layers were to be expected, for they are not unknown in the Chemung series; but it is now conceded that such layers do not resemble the oil sands, and that they occurred so rarely, and the reports of them are so vague and questionable, that we are warranted in treating them as mere local variations of some of the beds of the Chemung shales. (*f*)

The Venango oil-sand group itself is a mass of sandstone deposits from 300 to 380 feet thick, with layers of pebbles and many local partings of shale and slate. These figures may be varied somewhat, but it will be found as a general rule that a thickness of 350 feet will, in nearly every case, embrace all the sands belonging to the Venango group, even the fourth, fifth, and sixth sands, as the lower members of the group in some localities have been called. It is wonderful how the group maintains its total thickness with such uniformity for a distance of 62 miles in a straight line from Tidioute, in Warren county, to Herman station, in Butler county. The top sand is sometimes 10 feet thick, and sometimes 85 feet; the bottom sand may be 5 feet thick, or it may be 120 feet; and so either one of these members may individually vary in thickness about as much as the whole group is found to vary. (*g*)

a Reports, III, p. 100.
b *Ibid.*, p. 119, § 297.
c *Ibid.* p. 122, § 302.
d *Ibid.*, p. 128, § 315.
e *Ibid.*, p. 130, § 318.
f *Ibid.*, p. 132, § 320.
g *Ibid.*, p. 136, § 323.

Plate VII.



GENERALIZED GEOLOGICAL SECTION
FROM
BLACK ROCK, NEW YORK
TO
DUNKARD CREEK, PA.,
Showing the various oil horizons of
CANADA, NEW YORK AND PENNSYLVANIA,
AND THEIR RELATIVE POSITIONS IN THE
PALŒOZOIC SYSTEM.
COMPILED BY
JOHN F. CARLL,
FOR THE
Second Geological Survey of Pennsylvania.
DRAWN BY
LAURA LINTON.

Note.

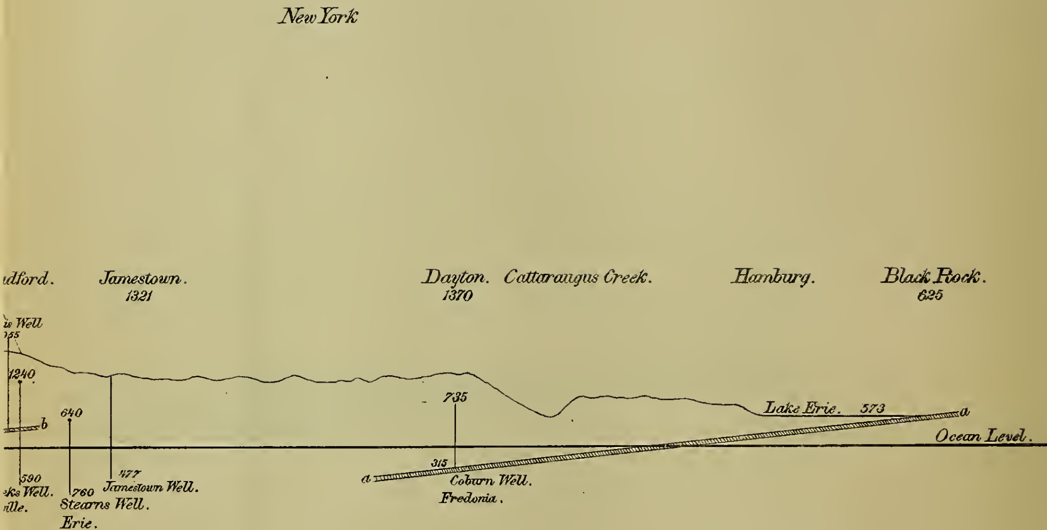
Figures under names of towns denote elevation of R.R. Depots.
Figures above wells, denote elevation of Well Mouths.
Figures below wells, denote depth below ocean level.
The top and bottom figures added, give depth of Well.

Formations.

a. Corniferous Limestone.
b. Bradford 3rd Sand.
l. Warren Oil Group.
m. Venango Group including Butler, Clarion and Venango Oil Sands.
n. Crawford Shales.
o. Conglomerate Measures including Oil on Slippery Rock and Mountain Sands.
ι. Lower Productive Coal Measures.
s. Lower Barren Coal Measures.
r. Upper Coal Measures including "Pittsburg Coal Bed."
t. Upper Barren.
p. Mahoning Sandstone

Alignment of Section.

From Black Rock, Erie Co., N.Y. to Pittsburg Pa., 175 Miles S. 20° W.
From Pittsburg to Dunkard Creek, Greene Co., Pa., 50 Miles S. 3° E.
Horizonontal 7 6/10 Miles to 1 inch = 40560 ft.
Scale: Vertical 2000 ft. to 1 inch.
Ratio, Horizontal to Vertical, about 20/1.



Alignment of Section.

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From Pittsburg to Dunkard Creek, Greene Co., Pa., 50 Miles S. 3° E.
Horizonontal 7 9/10 Miles to 1 inch = 40560 ft.
Scale: Vertical 2000 ft. to 1 inch.
Ratio, Horizontal to Vertical, about 20/1.

The following table, compiled from those prepared by Mr. Carll, shows the elevation above tide-level, the fall, distance, and rate of fall per mile of the top of the third oil-sand in Warren, Venango, Clarion, and Butler counties. Dogtown is at the same level above tide-water as Clintonville, one mile northeast of Turkey City (see map III):

Above tide.		Course.	Fall.	Miles.	Rate.
Feet.			*Feet.*		*Feet.*
	Along axis of Venango belt:				
1,008	Tidioute to—				
230	Clintonville along line of development		778	42.23	18.42
	Ditto, bee-line	S. 39° W.		39.50	19.70
	Along axis of Butler-Clarion belt:				
230	Dogtown to—				
−418	Herman station along line of development		648	29.83	21.72
	Ditto, bee-line	S. 27° W.		28.25	22.94
370	Shippenville to—				
−418	Herman station—				
1,008	Tidioute to		788	37.49	21.02
−418	Herman station (*)	S. 21° W.	1,426	62.00	23.00

* Reports, III, p. 144.

These figures show that the top of the third Venango oil-sand dips to the southwest in the 62 miles between Tidioute, in Warren county, and Herman station, in Butler county, at the average rate of 23 feet to the mile.

The first paying oil-well on the Butler-Clarion belt was obtained on the Allegheny river at Parker's landing in the fall of 1868, and operations spread out but a short distance from that point during the years 1869 and 1870.

In 1871 the somewhat unexpected measure of success attending the test wells, which were advancing toward the northeast into Clarion county, and also those toward the southwest into Butler county, led to developments in both these directions which resulted in pretty thoroughly outlining within the next three years the main or central belt.

Subsequently side lines of development were run, and the district was found to widen out in many places and to contain side belts and pools, with oil sometimes in the fourth sand, sometimes in the third, and in some localities even in rocks above the third sand, all of which aided very materially in augmenting the production. * * *

In 1874 the maximum development of this district was reached during the great fourth sand or "cross-belt" excitement. (*a*)

* * * * * * * *

At Parker's landing the oil came from the lowest member of the oil group, the representative of the Oil creek third sand, and so the rock was very properly called, not the fourth sand, but the third. In Clarion county, however, and likewise in Butler, the oil first obtained came from a rock higher in the series. But the drillers of the early wells did not notice the change from one horizon to another, and consequently supposed that they were still getting the oil from the Parker third sand. After the development had reached Modoc and Petrolia, it began to be suspected that there might be two oil horizons, instead of only one, and then commenced the experiment of deeper drilling at Petrolia and elsewhere, which finally resulted in the development of the "cross-belt", which was also called the "fourth-sand belt". (*b*)

* * * * * * * *

When Bradford first began to give signs of promise as an oil-field, the map of western Pennsylvania being consulted, the embryo development was found to be on a nearly direct continuation of the Clarion county oil belt. Immediately several transit lines were started by different parties and run through from the old to the new ground. Each surveyor had his own particular angle of deviation from the meridian to run by; and each one, as far as possible, carefully kept the exact bearing and location of his line a secret.

A statement was published at that time and much quoted as a proof of the unerring exactness of this method of tracing an oil belt, provided the bearing of the "lead" had been properly calculated. As the story went, a "belt-line expert" ran one of these lines 65 miles through an almost unbroken forest, employing an engineer who had never been over the country before, and who knew absolutely nothing about the work beyond the bald fact that he was traveling by a designated degree of the compass. Nevertheless the line thus run conducted its fortunate projector out of the woods, down the mountain side, into the valley of Tunangwant creek, to a station within a few feet of the largest well at that time known in the Bradford district. And this termination of the line was considered by many as a conclusive proof that all the lands through which that line passed were "on the oil belt".

The profile section (Plate VII) and the vertical section (Plate VIII) have been prepared for the purpose of exhibiting the fallacy of such views, and to enable the reader to see at a glance what some of the fundamental features of the sedimentary structure of the oil region especially are.

The profile section (Plate VII) follows a line upon the map drawn from Black Rock, on the Niagara river, in Erie county, New York, to Pittsburgh, and thence to Dunkard creek oil-field, in Dunkard township, Greene county, Pennsylvania, close to the West Virginia state line. From Black Rock to Pittsburgh the bearing of this line is S. 20° W.—distance about 175 miles. From Pittsburgh to Dunkard creek its bearing is S. 3° E.—distance 50 miles.

Starting at Black Rock, the line crosses the foot of lake Erie and strikes the southeasterly shore at Lakeview, in Erie county, New York. Thence it runs through, or very near to, the following places: Jamestown, New York; Youngsville, on Broken Straw creek, in Warren county, Pennsylvania; Tidioute, on the Allegheny river, in Warren county; President, on the Allegheny river, in Venango county; Foxburg, on the Allegheny, in Clarion county; Parker's Landing, on the Allegheny, in Armstrong county; and Petrolia, Millerstown, and Great Belt City (or Summit), in Butler county. Thus it may be said to follow the Butler oil belt very nearly along its line of best development.

It is evident that, as this alignment of the profile section coincides geographically so nearly with the trend of the Butler and Venango oil-sands, there can be no trouble in properly locating upon it the Venango oil-sand group.

The Warren oil development, however, lies some 8 miles to the east-southeast of our line, and the Bradford oil development some 30 miles from it, in the same direction.

a Reports, III, p. 146, § 336 and 337. *b* *Ibid.*, p. 147, § 340.

Now, it is a remarkable and important fact that in no boring in Pennsylvania has the Warren group of oil-rocks (unmistakably developed) been seen directly beneath the Venango group. It is equally a fact that in no boring has the Bradford "third" sand been seen directly below the Warren group. In other words, we have not a single direct oil-well measurement between these several groups, and therefore we must trust to some pretty nice and difficult calculations when we try to determine the thickness of these intervals; that is, when we attempt to place the Warren and the Bradford oil-rocks in their proper places in our profile section. But whatever inaccuracies of detail may thus creep into the section, it will still suffice to show the relative positions of such oil horizons as have been profitably worked in different parts of the country. It will certainly demonstrate the folly of drilling on so-called belt lines, run from one producing district to another, regardless of the age or equivalence of the rocks to be connected.

* * * * * * * *

The lowest horizon in our country from which oil in paying quantities has been obtained is that of the corniferous limestone formation, the home of the Canadian oil.

This rock can be unmistakably identified at Black Rock, in New York; and therefore Black Rock has been selected as the northern end of our profile section (Plate VII). The next and only other point at which the elevation of the corniferous limestone can be fixed is in the Coburn gas-well, at Fredonia, Chautauqua county, New York, for in our own state, as far as is known, it has never been reached by the deepest borings.

The average pitch of the corniferous limestone toward the southwest can be calculated from its elevation at Black Rock and at Fredonia, allowing us to judge approximately of the thickness of the measures between it and the Venango oil group. At Black Rock, as shown by the quotations below, the exact thickness of the rock is not known. We have assumed the top to lie about 52 feet above the surface of lake Erie, or 625 feet above ocean level, which cannot be far wrong. In the Coburn well at Fredonia it is said to have been struck at a depth of 1,050 feet, which (the elevation of the well mouth being 735 feet) puts it 315 feet below ocean level at that place. The distance from Black Rock to Fredonia is about 38 miles in a direction S. 35° W., and this gives an average slope or dip of about 25 feet per mile. But along our section line (S. 20° W.) the average dip of the limestone ought to be stronger than 25 feet per mile, because the line runs more nearly in the direction of the line of greatest dip, as calculated from other strata which admit of more accurate tracing; and this inference is strengthened by the fact that no limestone is reported in Jonathan Watson's deep well near Titusville.

The distance from Black Rock to Watson's well is about 100 miles; direction, S. 26° W.; elevation of well mouth, 1,290 feet above ocean; depth of well, 3,553 feet. On an average slope of 25 feet per mile the limestone should have been found at 1,875 feet below ocean level, or 3,165 feet from the surface; but as no limestone was seen in the well, we must conclude either that it is absent in that locality (which is hardly probable), or that it has a greater average dip slope than 25 feet per mile in that direction. As the well stopped at 2,263 feet below ocean level, an average of 29 feet per mile would put the limestone at 2,275 feet, or 12 feet beneath the well. A hard rock was reported, however, just as the utmost limit of drilling cable forced a suspension of the work at a depth of 3,553 feet from the surface. A number of other deep wells are shown on the profile, but it will be seen that none of them have gone deep enough to reach the corniferous limestone. The Watson well is not only the deepest boring ever made in western Pennsylvania, but it is also deeper geologically than any other. It is greatly to be regretted, therefore, that so little can be known of its history.

A person unacquainted with the laws of sedimentary deposition and with the methods of preparing a profile section might inadvertently be led to suppose, from an examination of the profile section (Plate VII), that the different strata represented there spread out continuously and universally in every direction under the oil regions; that a well failing to produce oil in the Venango group might be put down 400 or 500 feet deeper and pump oil from the Warren group, and then 500 feet deeper and renew itself in the Bradford "third" sand; but such has not been the experience of oil producers. The several groups of oil-producing rocks are locally well defined under certain areas; but they have their geographical as well as their geological limits, and as far as at present known the geographical limit of one group never overlaps that of another. If we take a map and outline upon it the limits of the Smith's Ferry and Slippery Rock oil-producing district, and then the Butler, Clarion, and Venango, and then the Warren, and then the Bradford, we shall see that each has its own particular locus, and that the different districts are separated from one another by areas (of greater or less extent) which have been pretty thoroughly tested by the drill and proven to be unproductive. It must have been true in all ages that every deposit of sandstone in one locality must have been represented by contemporaneous deposits of shales in other localities. Hence it happens that in tracing rocks long distances the sandstones disappear and shales come in at the same geological horizon. It may not then be presumed that each particular sandstone, or its oil, will be found in every locality where its horizon can be pierced by the drill, or that a measured section of the rocks in one place can be precisely duplicated in detail in another. The vertical section (Plate VIII) is intended to show that oil has been produced from ten or twelve different geological horizons in the earth's crust, ranging through a thickness of about 4,500 feet of sedimentary strata; and the most skillful oil producer, the most expert geologist, cannot tell how many other oil horizons may exist at intermediate depths beneath the surface (*i. e.*, in the scale of the formations), but which, being good only within certain geographical limits, have as yet escaped the oil-miner's drill (see Plate V).

VERTICAL SECTION.

SUMMARY SKETCH OF THE FORMATIONS EXHIBITED IN THE VERTICAL SECTION (Plate VIII).—This generalized section extends from the surface rocks in the upper barren coal series of Greene county, Pennsylvania, down to the corniferous limestone, the Canadian oil-rock, and will enable any one to distinguish and locate the several oil horizons thus far discovered and profitably worked in these measures. It is in fact an enlarged representation of the features presented in the profile section. (Plate VII.)

GROUP No. 1.

UPPER BARREN COAL MEASURES B.—"Greene county group;" thickness, 600 feet.

VERTICAL RANGE.—From surface to top of Washington upper limestone.

COMPOSITION.—Shales, sandstones, thin beds of limestone, and coal.

EXPOSURES.—The highlands of central and southwestern Greene county, Pennsylvania.

AUTHORITY.—Professors J. J. Stevenson, Report K, p. 35, and White and Fontaine, Report PP, Pennsylvania Survey.

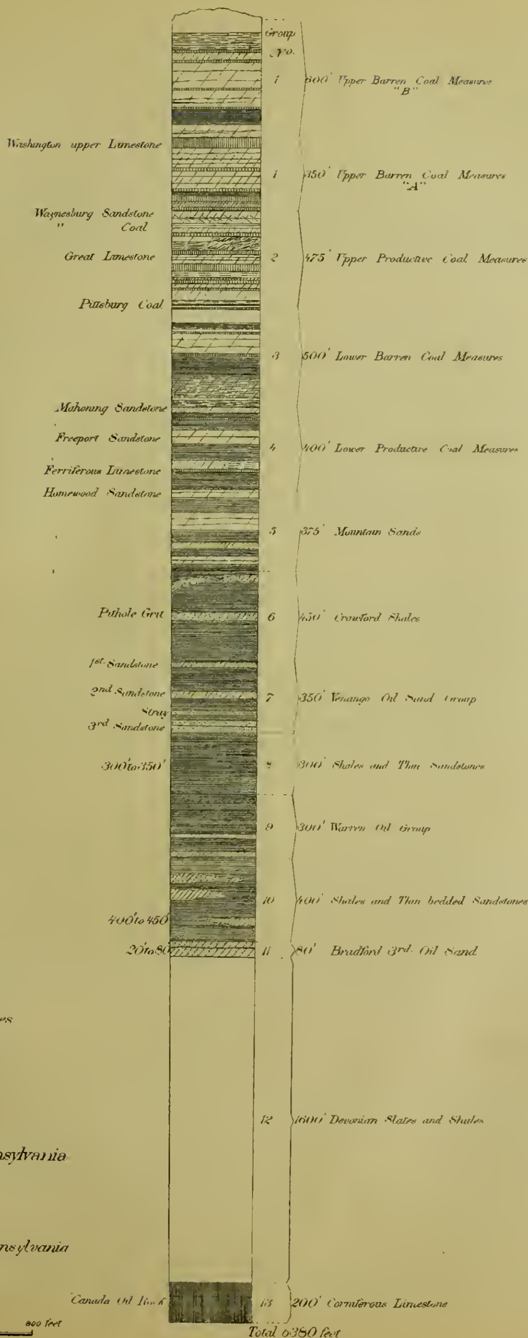
UPPER BARREN COAL MEASURES A.—"Washington county group;" thickness, 350 feet.

VERTICAL RANGE.—From top of Washington upper limestone to top of Waynesburg sandstone.

COMPOSITION.—Shales, sandstones, limestones, and thin beds of coal; but carrying also the "Washington coal-bed", from 7 to 10 feet thick. In Washington county six beds of limestone compose about one-third of the mass, but in Greene the limestones are thin and less frequent.

EXPOSURES.—In the highlands of Washington and Greene counties (see Report K, p. 44, Pennsylvania Survey).

Plate VIII.



Generalized Vertical Section
from the top of the
Upper Barren Coal Measures
down to the
Corniferous Limestone
to show the various
Oil Horizons
of
Canada, New York and Pennsylvania
Compiled by
J. F. Carl
for the
Second Geological Survey of Pennsylvania
drawn by
Laura Linton
Scale

400 300 200 100 0 400 800 feet

GROUP No. 2.

UPPER PRODUCTIVE COAL MEASURES.—Thickness, 475 feet.

VERTICAL RANGE.—From top of Waynesburg sandstone to base of Pittsburgh coal.

COMPOSITION.—Shales and sandstones, with three thick bands of limestone and several thick coal-beds, of which the Waynesburg and the Pittsburgh are the most important.

EXPOSURES.—Throughout Washington, Greene, and Allegheny counties (see detailed section in Professor Stevenson's Report K, p. 57).

GROUP No. 3.

LOWER BARREN COAL MEASURES.—Thickness, 500 feet.

VERTICAL RANGE.—From base of Pittsburgh coal to top of Mahoning sandstone.

COMPOSITION.—Shales and sandstones, with some thin beds of limestone and coal.

EXPOSURES.—Partially seen in Washington and Allegheny counties and in the highlands of southern Butler, but better developed in Beaver county, where Mr. White's detailed section of these measures was taken (see Report K, pp. 75, 76).

GROUP No. 4.

LOWER PRODUCTIVE COAL MEASURES.—Thickness, 400 feet.

VERTICAL RANGE.—From top of Mahoning sandstone to top of conglomerate No. XII.

COMPOSITION.—Sandstones and shales, with several good and persistent coal seams and two important beds of limestone—the "Freeport" and the "Ferriferous".

EXPOSURES.—This series is exposed over a large extent of country in Butler, Armstrong, Clarion, Beaver, Lawrence, and Venango counties (see Mr. Chance's detailed section, Report V, p. 16).

Professor Stevenson states (Report K, p. 392) that the Mahoning sandstone, the top member of this group, is the central and principal oil-bearing rock of the three sands found in oil-wells on Dunkard creek, Greene county. It also appears to be an oil-producing rock in Westmoreland county, where a number of oil- and salt-wells have been sunk through it.

The Ferriferous limestone of this group is the great limestone of Butler, Armstrong, and Clarion counties, and the oil-miner's "key-rock" in sinking oil-wells in these sections. It is from 5 to 25 feet in thickness, and lies from 30 to 80 feet above the Homewood sandstone, the top member of conglomerate No. XII.

GROUP No. 5.

MOUNTAIN SAND SERIES, including the Pottsville conglomerate No. XII, and probably in some localities some of the sandstones belonging to the Upper Pocono sandstone No. X (No. XI being either thin or wanting); thickness from 350 to 425 feet, say 375 feet.

VERTICAL RANGE.—From top of Homewood sandstone to the base of the Olean-Garland-Ohio conglomerate, or second-mountain sand of the Venango oil-wells.

COMPOSITION.—A group of variable conglomerates and sandstones interstratified with shales and inclosing sporadic beds of iron-ore and coal, two of the coal-beds, the Mercer and Sharon, being of great importance. It also carries in some localities two thin bands of limestone (the Mercer Upper and Lower).

EXPOSURES.—In the highlands of Mercer, southern Crawford, Venango, Forest, Warren, and McKean counties. The lower members of this group produce heavy oil at Smith's Ferry, in Beaver county, and on Slippery Rock creek, in Lawrence county, and the upper conglomerate is said to be the source of some oil in Kentucky (also in Johnson county, Kentucky).

GROUP No. 6.

CRAWFORD SHALES.—Thickness, from 400 to 500 feet, say 450 feet.

VERTICAL RANGE.—From the base of the mountain-sand series to the top of the Venango oil group.

COMPOSITION.—Shales and slates, inclosing the Pithole grit, near the center of the mass. In some localities 100 feet or more of the lower part is composed of red shale; in others no red appears. The upper part in some sections contains quite important beds of sandstone.

EXPOSURES.—Only favorably seen in cliffs bordering the streams in parts of Forest, Venango, Mercer, Crawford, Warren, and McKean counties, its northern outcrop being always obscured by drift.

The horizon of the Pithole grit appears to furnish the light-gravity amber oil at Smith's Ferry and Ohioville, in Beaver county, with traces of the same on Slippery Rock creek, in Lawrence county. It also probably yields the heavy lubricating oil of the Mecca district, in Trumbull county, Ohio.

GROUP No. 7.

VENANGO OIL GROUP.—Thickness, from 300 to 375 feet, say 350 feet.

VERTICAL RANGE.—From the top of the first oil-sand (the "second sand" of the driller in Butler county) to the bottom of the third oil-sand (called the "fourth sand" in Butler, Armstrong, and Clarion, and the "fifth sand" in some parts of Venango county).

COMPOSITION.—A group of variable sandstones, in some places conglomeritic, and locally divided into several members by irregular beds of slates and shales, some of which are red.

EXPOSURES.—These rocks, as a group, lie with a remarkable uniformity of slope and general structure in a comparatively narrow belt, from Herman station, in Butler county, to Tidioute, in Warren county. They make no conspicuous outcrops to the northwest, but appear to lose their sandy characteristics before reaching the surface.

At Tidioute the deep gorges of Dennis run and the Allegheny river expose the *first and second oil-sands*, and as far up as Warren it is quite probable that we see the upper portion of the group exposed in the river hills. These are the only localities where a portion of the group in even an approximately normal condition may be seen above water-level. Its horizon is cut through by many of the ravines of McKean county, but it has there become so changed in its physical aspects that it disappears or becomes unrecognizable when the proper range for its outcrop is reached. These are the oil-sands of Tidioute and Colorado, Warren county; Fagundus, Forest county; Church run and Titusville, Crawford county; and of all the well-known oil centers in Venango, Clarion, Armstrong, and Butler counties. They produce oil in different localities from the members of the group, ranging from 30° to 52° in gravity, and varying greatly in color:

green oil from the third sand on Oil creek; black oil from the stray sand at Pleasantville; amber oil from the second sand in many places; and dark, heavy gravity oil from the first sand at Franklin. There are also occasional local deposits of oil, shading from a light straw color to almost a jet black.

GROUP No. 8.

INTERVAL BETWEEN THE VENANGO AND THE WARREN OIL GROUP.—Thickness, 300+ feet.

VERTICAL RANGE.—From the base of the Venango third oil-sand to the top of the Warren oil group.

COMPOSITION.—Soft shale of a bluish-gray color, but containing some beds of green, purple, and red, with irregular bands of thin-bedded bluish-gray sandstones.

The wells at Warren, even when favorably located, do not pass through the Venango group in its normal condition, nor do the wells on the Venango belt, when sunk to the proper depth, as many of them have been, find the Warren oil shales and sands with oil; consequently no direct measurement of this interval can be made in oil-wells. In the section we have assigned a thickness to the mass which places the Venango and Warren oil groups as near as may be in their proper relative positions vertically at Warren.

GROUP No. 9.

WARREN OIL GROUP.—Thickness, about 300 feet.

VERTICAL RANGE AND COMPOSITION.—This group may be viewed as including the so-called second, third, and fourth sands of Warren; but its composition is so variable in different parts of the district that it does not afford any persistent bands of sandstone by which to define either its upper or its lower limit. At North Warren the upper part is shaly, and the largest wells, it is claimed, flowed from these shales, while others got their oil from the "third sand". At Warren the "second sand" is fairly developed, but the oil generally comes in the "third sand". At Stoneham a lower sand, the "fourth", produces the oil. Thus the North Warren shales are represented at Stoneham by more sandy measures which contain no oil, and the Stoneham "fourth sand" is poorly developed at North Warren, and is unproductive. The group, then, may be said to extend from the top of the North Warren shales to the bottom of the Stoneham sandstone, covering an interval, as nearly as may be calculated, of about 300 feet.

GROUP No. 10.

INTERVAL BETWEEN THE WARREN OIL GROUP AND THE BRADFORD "THIRD SAND".—Thickness, from 400 to 450 feet, say 400 feet.

VERTICAL RANGE.—From the Stoneham oil-sand to the Bradford oil-sand ("third").

COMPOSITION.—Slates and shales, generally of a bluish color, but sometimes inclined to red or brown, interstratified with thin bands of bluish-gray micaceous flaggy sandstones. The sand pumpings show this interval to be very fossiliferous.

Similar difficulties are encountered in estimating the thickness of this group to those mentioned in No. 8. A large number of wells have been sunk between Bradford and Warren, but the rocks are so variable in composition and the well records have been so imperfectly kept that no completely satisfactory identification of the rocks of the Warren oil group, with their equivalents at Bradford, or of the Bradford "third sand", with its corresponding stratum at Warren, can yet be made. The interval between the two oil horizons, however, appears to be in the neighborhood of 400 feet, as above given. This interval holds the Bradford "second sand", which has yielded oil in many of the McKean county wells, and also the sandy shale horizon producing "slush oil" along the Tuna valley.

GROUP No. 11.

BRADFORD THIRD SAND.—Thickness, from 20 to 80 feet.

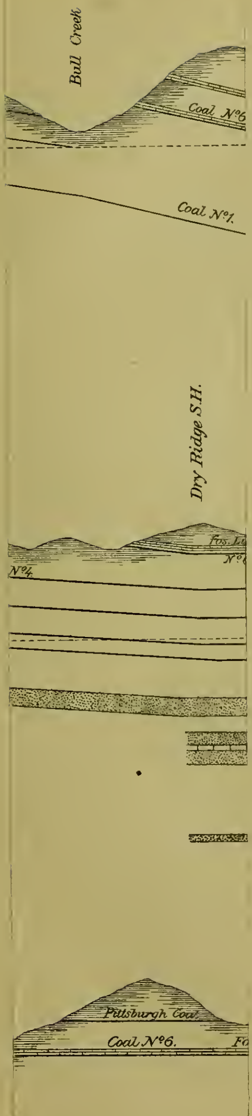
COMPOSITION.—A fine-grained, light to dark brown sandstone, containing pebbles the size of pin-heads in some localities, while in others it is little more than a sandy shale. It appears to be rather thin and irregularly bedded, is frequently interstratified with thin layers of gray, slaty sandstone, and contains many fossil shells and fish bones. The constitutional peculiarities of the rock, its color, its composition, and its structure, insure its ready recognition by the driller in any locality where he may find it in even an approximately normal condition. But this rock, like all others, has its geographical limits, outside of which its geological horizon can only be traced by the exercise of the greatest of care and the best of judgment in keeping and studying the well records.

It is seldom, however, that good records of wells on debatable territory are kept. The well-owner always starts the drill on the presumption that the oil-rock will be found. He calculates in his own way its approximate depth from the surface, and makes a contract to drill so many feet. Confident of success, he urges on the drill, making no particular note of the character of the upper rocks; but when the supposed horizon of the sand is reached, and the evidences of its presence do not appear as anticipated, he discovers, too late, that he has nothing to check by to ascertain whether the oil-rock is actually wanting or only so changed in character as to be scarcely recognizable, or whether there may not have been some mistake in calculating its position in the well. Thus it often happens that wells of this class are abandoned after drilling in doubt for a few days without having been sunk to the proper depth, while others are carried on down many feet below the horizon of the sand they are in quest of, and much valuable information is lost which a little prudent foresight might have secured.

The Bradford "third sand" may be satisfactorily located in the Wilcox wells, near the southerly line of McKean county. At Tidioute, in Warren county, 35 miles nearly due west from these wells, the base of the Venango group is well defined. Between these two points, the nearest geographical approximation that can at present be made, both groups evidently undergo rapid and radical changes in composition, and the well records are vague and unreliable; hence no absolute determination of the thickness of the mass of shales lying between the two groups can here be made.

Somewhat better facilities are afforded for a study of these measures by carefully tracing the rocks from Tidioute to Warren (15 miles), and then from Warren to Bradford (25 miles); but even along these lines the structure is so obscure that mistaken identifications are quite likely to be made.

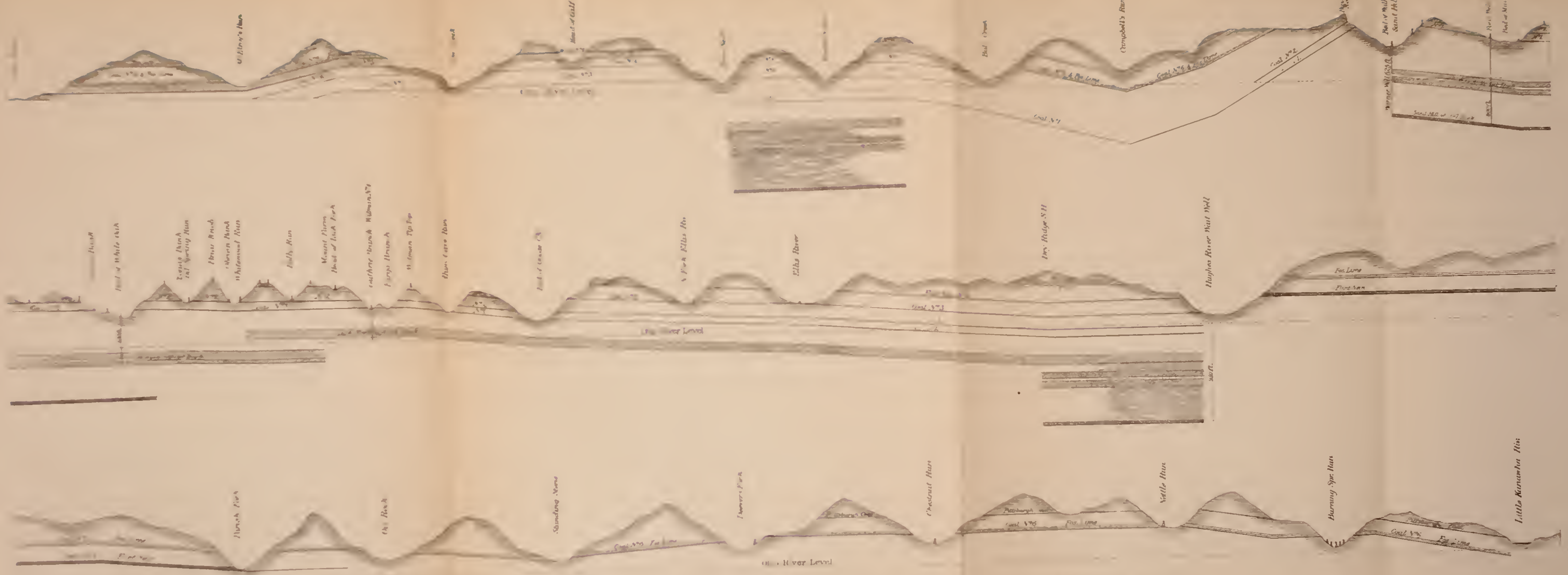
These facts are stated to explain why there is yet some uncertainty regarding the thickness of the vertical interval between the Venango oil group and Bradford "third sand". The figures cannot differ materially, however, from those given in the vertical section, Plate VIII.



LITTLE KAN

nch.

Plate III.



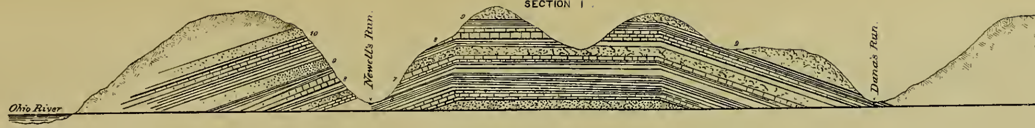
Profile through AXIS of W.Va. ANTICLINAL from OHIO RIVER to LITTLE KANAWHA RIVER.

By W. F. Minshall.

Horizontal Scale 1 mile to 2 inches. Vertical Scale 600 ft. to 1 inch.

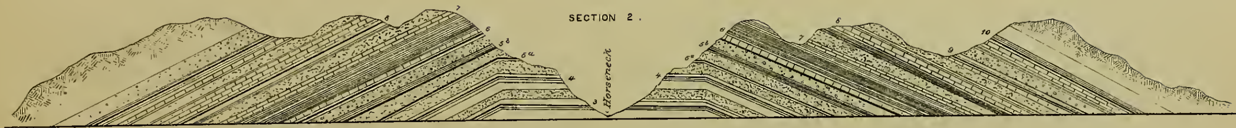
Plate IV.

SECTION I.



SECTION ON THE OHIO RIVER ABOVE MARIETTA.

SECTION 2.



SECTION AT HORSE-NECK, WEST VIRGINIA.

SECTION 3.

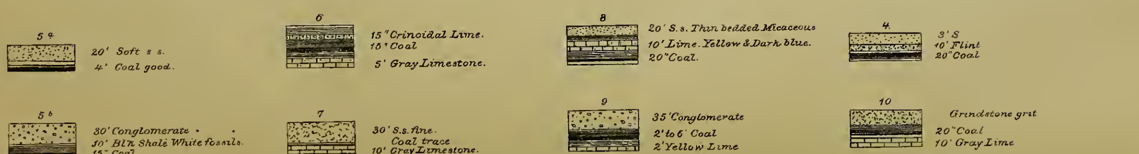
SECTION BETWEEN LAUREL FORK JUNCTION AND PETROLEUM,

WEST VIRGINIA.

ON THE BALTIMORE & OHIO R R

No.1 to No.5 inclusive, Lower Coal Measures
No.6, Crinoidal Lime, Middle Barren Measures
No.7, Pomeroy. Pittsburg. Upper Measures

No. 8, Great Limestone.
No.9, Macksburg. Waynesbury.
No 10, Gray Lime and Thin Coal. Upper Barren Meas.
No 11, Constitution Stone, Grindstone grit etc.



GROUP No. 12.

INTERVAL BETWEEN THE BRADFORD "THIRD SAND" AND THE CORNIFEROUS LIMESTONE, commencing in the Chemung and including the Portage and Hamilton groups of the New York geological survey. Thickness, 1,600+ feet.

COMPOSITION.—In the imperfect records of wells that have been sunk into these measures in various parts of the country we simply find recorded "shales, slates, and soapstone, with occasional sand shells". The upper part for 200 or 300 feet appears to contain considerable sandy material, and some of these sand-beds produce oil along the Tuna valley, in the vicinity of Limestone, Cattaraugus county, New York. Below this the drillings show principally slate and soft-mud rocks. No important bands of sandstone and no oil have been reported.

The thickness of this interval must be left questionable for reasons previously stated. We have no means of tracing the corniferous limestone south of Fredonia, New York, except approximately by its slope.

The distance from Fredonia to Bradford is about 48 miles; direction about south 45° east. A dip of 20 feet to the mile would be required to place the limestone at Bradford as shown in our section.

GROUP No. 13.

THE CORNIFEROUS LIMESTONE, probably shown in the vertical section, Plate VIII, in conjunction with the ONONDAGA LIMESTONE.—The composition of this group has already been referred to in the quotations given from *Geology of New York*. It is the oil-producing rock of the Canadian oil regions, but at Fredonia, New York, yields neither oil nor gas. We may not presume, therefore, that it will ever be found to be an important oil horizon in Pennsylvania, and even if it should prove to be productive here the great depth at which it lies beneath the surface must be a very serious obstacle in the way of its development. (a)

An illustration of the persistence of the Venango oil group as a geological formation is found in the circumstances attending the drilling of well No. 1 by the Brady's Bend Iron Works Company in 1865. Professor J. P. Lesley was asked to give an opinion upon the probable depth at which oil would be reached on their property, and as he was familiar with the rocks of that locality, and had made a careful study of their dip and superposition, he readily made the computation and reported that "if the Venango sand extended under ground as far as Brady's bend it ought to lie at 1,100 feet beneath water-level". The well was drilled and struck the oil stratum at 1,120 feet.

During 1877 the so-called grasshopper excitement occurred near Titusville, occasioned by the discovery of oil in a layer of superficial gravel beneath a sheet of clay. The wells were simple pits or shafts, from which the oil and water were pumped. The area was comprised within a few acres, but was quite productive for a time, yielding several hundred barrels of oil. The oil evidently arose from deeper sources with water, and accumulated in the gravel beneath the impervious crust of clay.

The geology of the "West Virginia Oil Break" has been recently subjected to a very careful study by F. W. Minshall, esq., of Parkersburg, West Virginia. Mr. Minshall has been connected with the petroleum industry of this region for many years, and has carefully collated the records of many wells located along the line of development in Ohio and West Virginia. His sections are considered accurate by those most familiar with the facts and best qualified to judge of their value, and are found to conform strictly to such observations as I was able to make during a hurried trip through the region. I introduce here in illustration a series of sections compiled and drawn by Mr. Minshall and generously placed at my disposal for use in this report. The section on Plate iii extends along the axis of the anticlinal from the Ohio river opposite Newport, in Washington county, Ohio, to the Little Kanawha river, in Wirt county, West Virginia. Section 1 on Plate IV crosses section on Plate III at a point on or near the Ohio river in Washington county, Ohio. Section 2, Plate IV, crosses section on Plate III at Horseneck, Pleasants county, West Virginia. Section 3, Plate IV, crosses section on Plate III on the line of the Baltimore and Ohio railroad from Laurel Fork Junction to Petroleum, Wood county, West Virginia. Plate V is a vertical section of the rocks yielding petroleum along the anticlinal. Map IV shows the territory that has produced oil in the White Oak district which lies along the anticlinal between Goose creek and Walker's creek, Wood county, West Virginia.

The following description of the occurrence of the formations along the line of the White Oak anticlinal is taken from a series of articles published by Mr. Minshall in the summer of 1881 in the *State Journal* at Parkersburg, West Virginia:

In Wood, Pleasants, Ritchie, and Wirt counties the rocks, from the river level to the tops of the hills, belong to the upper barren measures, excepting only the line of territory known as the "oil break", which passes through these counties. Although we are very nearly in the center of the great Allegheny coal basin, we have no workable veins of coal above drainage in the above-named counties. The Allegheny basin is a veritable basin in form, which not only contains many valuable veins of coal, ore, and potter's clay, but also vast quantities of natural gas, petroleum, and brine.

On account of our situation near the center of the Allegheny basin, all the mineral wealth of its rocks is sunk beneath the river level. Here at Parkersburg, barely above the river, may be seen a thin vein of coal with an underlying vein of gray limestone. This we will call coal No. 11, and take it for our dividing line between the upper barren and upper productive coal measures. From the river to the top of fort Boreman, at the mouth of the Little Kanawha, we have an exposure of about 300 feet of the upper barrens. Examining them in detail, we will find them composed of alternate layers of red shale and compact, fine-grained sand rocks. The sand rock is of considerable value as a building-stone, being the same ledge as that which is extensively quarried between Belpre and Harmar, some parts of it furnishing grindstone grit and others the "Constitution" building-stone.

If, commencing at our coal No. 11 (see Plate V), we should sink a well, we would pass through the following strata: At about 150 feet we would reach the level of coal No. 10, the first vein of the upper productive measures, which has a thickness of from 4 to 6 feet

a Reports, III, p. 156.

on Duck creek, in Washington county, Ohio; at 250 feet we should find coal No. 9, the limestone vein of Duck creek, and the equivalent of the Sewickly vein of Pennsylvania; at 350 feet we should pass the level of coal No. 8, the Federal creek vein of Athens county, Ohio, and the Pittsburgh vein of Pennsylvania, which is the last vein of the upper productive coal measures.

We next pass through the red and variegated shales of the lower barren measures, until at 500 feet we reach the crinoidal limestone. At 600 feet we will pass into a soft, pebbly sand rock, the first oil-rock of Cow run, Ohio; at 700 feet we should strike a hard, black, flinty limestone, several feet of very black shale, with white fossil shells and coal No. 7; at 730 feet, coal No. 6; at 800 feet, coal No. 5; at 850 feet another cherty limestone, probably the "Putnam hill" of the Ohio survey; at 880 feet, coal No. 4; at 900 feet we find another soft pebbly sand rock, the second oil-rock of Cow run, Ohio; at 1,000 feet, coal No. 3; at 1,070 feet, coal No. 2; at 1,200 feet coal No. 1; and at 1,300 feet, the top of the carboniferous conglomerate—the oil-rock of Lick fork and Tate run, in the White Oak district. (*a*)

These are the rocks through which we ought to pass in our Parkersburg wells. This prediction is based upon the fact that the uplift of the "oil break" brings this whole series of rocks above the level of the Ohio river in such a way that any one can examine them at his leisure and verify the intervals for himself.

Going back to our coal No. 11, with its underlying gray limestone, we will cross over into Ohio and trace it up the river on that side. At Marietta we find it coming up from the bed of the Muskingum near the "Children's Home". Keeping back from the Ohio river about two miles we see it in the bed of Duck creek at the old Robinson mill, in the bed of the little Muskingum at the mouth of Long run. We find very little change in the level of the stratum we are tracing till we are opposite the mouth of Cow creek. Here we find it gradually rising higher above the river as we go up the Ohio until, at the mouth of Newell run, on the Ohio side, we find it at the summit of the hill. Since it is evident that a farther rise will take it away from us, we must take our barometer and measure down the hill to coal No. 10; but instead of the 6-foot vein of Duck creek, we have here barely 2 feet; in fact, this vein thins rapidly southward from the maximum thickness at the upper line of Washington county, Ohio.

Having at the mouth of Newell's run substituted coal No. 10 for No. 11, we will go a little farther east until, opposite the mouth of French creek, we find coal No. 10 on the summit of mount Dudley. On mount Dudley we are standing on the axis of the anticlinal called the West Virginia oil break. Measuring down the face of the hill 100 feet from coal No. 10, we find coal No. 9, the limestone vein. Measuring again from coal No. 9 down the hill about 100 feet, we will find the proper horizon of coal No. 8, the Pittsburgh vein of Pennsylvania and the Pomeroy vein of Ohio. It is true that we will not succeed in finding any coal at this point; the overlying sand rock, a little fire-clay, and the underlying gray limestone are all we can find here; but before reaching the end of our journey we will find the coal putting in an appearance. The horizon of this vein is exposed from the Ohio river to the Little Kanawha along the axis of this anticlinal for a distance of about 30 miles, in which distance the coal increases from nothing to 20 inches. Measuring down from No. 8, 150 feet, we will find the crinoidal limestone of the lower barren measures lying about 40 feet above low-water mark. To show that we are upon the axis of the anticlinal, we will trace the limestone eastward along the face of the hill. For about a quarter of a mile we will find it running level, then dipping gradually to the east, until it disappears beneath the river. Returning, we trace it westward, and, after running level for the same distance, it dips to the west and goes under the river. At no other point in Washington county can this limestone be seen. (See Section 1, Plate IV.)

Having thus satisfied ourselves that we have reached the axis of "the break", our purpose is to follow this axis to the point where it crosses the Little Kanawha above Burning Springs, West Virginia.

Starting out from mount Dudley (see Plate III), we bear several degrees west of south, cross the Ohio a little below French creek, in Pleasants county, cross McElroy run at Ned Hammett's, and strike the north hillside of Cow creek near the residence of Hugh McTaggart, esq. In a hollow north of the house, and about on a level with it, we find the crinoidal limestone. Continuing our course, but bearing more nearly south, we cross Cow creek below the old "Willard" mill, the head of Calf creek, near William Nash's, and reach a high point on the north side of Horseneck. On the very summit, by searching carefully, we will find, as though it had been placed there for our especial benefit, the crinoidal limestone about 580 feet above the river. To satisfy ourselves that the anticlinal maintains its form, and that we are still upon its axis, we trace the limestone westward till it dips beneath the bed of Calf creek, near the new school-house, and eastward into the bed of Sled fork of Cow creek; and we notice that the dip is getting steeper on the sides as the axis rises, but no signs of faulting or displacement of the strata are to be found. (See Section 2, Plate IV.) Our crinoidal limestone, which was 500 feet below the river at Parkersburg, is now 580 feet above, having risen 1,080 feet, and, like coal No. 11, having reached the summit of the highest hills, will soon be beyond our reach if the axis continues to rise. We will therefore take the precaution to measure down to some of the lower strata. One hundred feet below the crinoidal lime we find another massive sand rock similar to the one which lies over coal No. 10. Like that, it is a true conglomerate, with layers of quartz pebbles somewhat similar and whiter than those of No. 10. It is the first oil-sand of Cow run and Macksburg, in Washington county, of Buck run, in Morgan county, and of Federal creek, in Athens county, Ohio, easily identified by the interval being about 100 feet in all of the above-named places. At its outcrop at the head of Calf creek it forms a bold ledge, which at one point is broken into huge cubical blocks of about 30 feet in thickness, forming a "rock city" similar to the one near Olean, in New York.

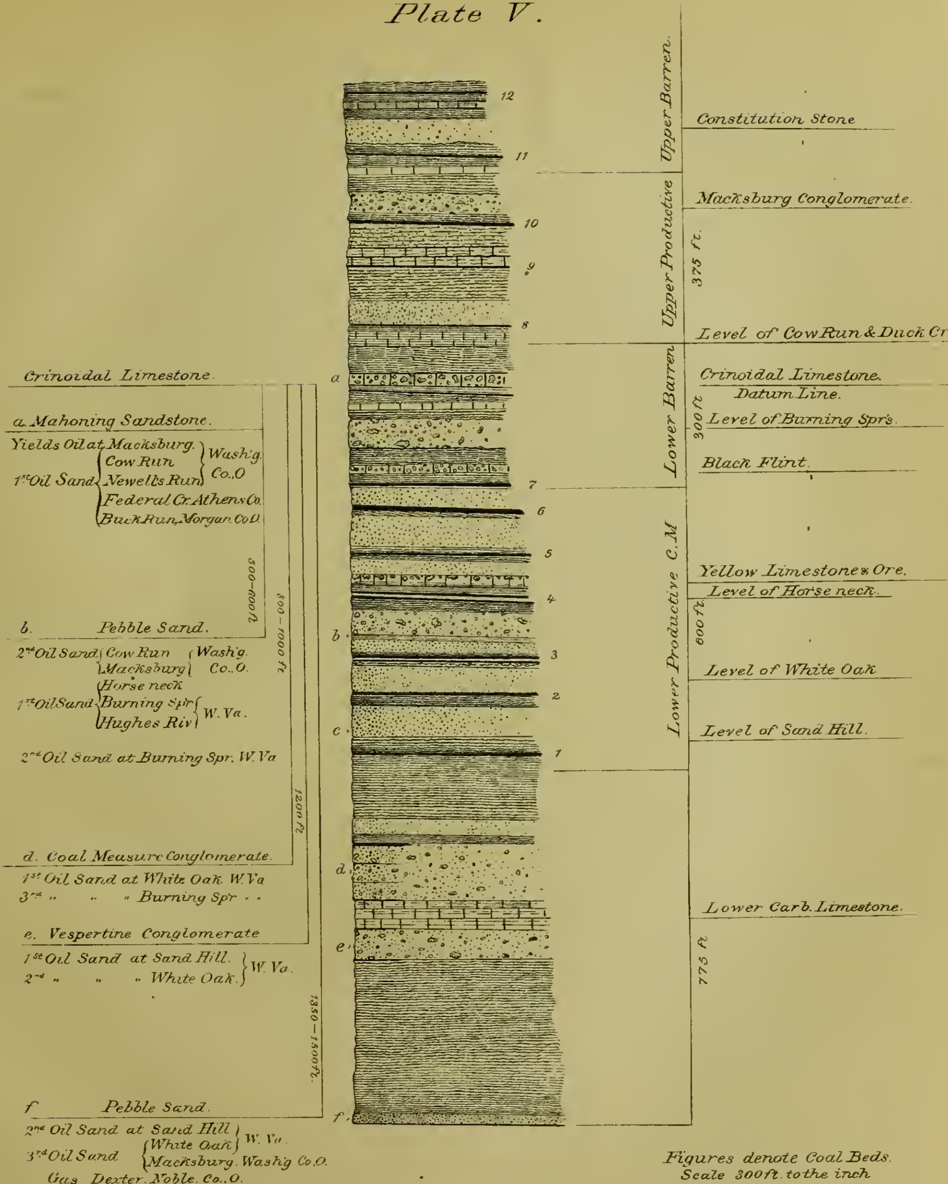
Below this sand rock, and about 200 feet below the crinoidal lime, we find coal No. 7. Although the coal is only 18 inches thick, this vein becomes interesting because of its surroundings. Just over the coal is a stratum of very black shale, about 10 feet thick, filled with fossil shells. Over the shells is a black, flinty limestone, which we will find increasing in thickness southward until it becomes the well-known flint vein of Hughes river and Flint run.

From Horseneck we resume our course, crossing Bull creek near the celebrated mineral well of Judge Borland. In the bed of the run, a short distance above Judge Borland's well, we find the crinoidal limestone. Careful inspection shows us that we are still following the axis of the anticlinal, and that it has come down on the south of Horseneck even more rapidly than it had risen on the north. This will, when examined, prove to be a regular dip along the axial line, without any indications of faulting, and the dip continues until the gray limestone of No. 8 is brought down to the bed of the run; then the dip is suddenly reversed, and the axis rises again to the southward. From this point to Sand hill, on Walker's creek, the rise is very rapid, bringing to the surface in regular succession the rocks above described down to the yellow limestone. This we follow in its upward course till it reaches the top of the high point near the Saint Ronan wells of White Oak district. Looking around us from this vantage-ground we will notice that although the distant hills preserve their graceful outlines the surrounding hills are mostly cone-shaped peaks, bristling with an unnatural kind of timber, the rig timber of the oil-seeker. In prosperous times, when clouds of smoke were pouring forth from hundreds of sooty craters and the clang of tools rivaled the din of old Vulcan and his cyclopic helpers, some genius, in a moment of inspiration, christened the place Volcano.

On the top of the high peak near Saint Ronan's well we will examine the limestone, which lies within 25 feet of the summit. We have assumed this vein to be the equivalent of the "Putnam hill" vein of the Ohio survey; it is also the only vein we will find which might be taken to represent the "Ferriferous limestone" of Pennsylvania; it lies here a few feet above coal No. 4. Examining the

a Also of Johnson county, Kentucky.

Plate V.



VERTICAL SECTION
OF WHITE OAK ANTICLINAL
WEST VIRGINIA.

Compiled by F. W. Minshall, Marietta O.

MAP
OF THE
VOLCANO OIL REGION
OF
WEST VIRGINIA
SHOWING
THE DEVELOPMENTS UP TO THE YEAR
1882

structure of the vein, we find that it is deposited in large, round bowlders, from one to three feet in diameter. The upper layers are heavily charged with iron, showing, when exposed to the weather, a very rusty yellow. A peculiar feature of the ore-bearing bowlders is their formation in regular concentric layers. If one of them be broken through the center you may see, from center to circumference, the rings as regular as the rings of a cross-section of a tree. As the bowlder becomes oxidized these rings peel off successively, leaving its form unchanged. The identification of this vein as the equivalent of the "Ferriferous" would be of great value to us for the purpose of comparing the geological level of our oil-bearing rocks with those of Pennsylvania.

Resuming our measurements from this limestone downward we will find, 30 feet below it, coal No. 4; 160 feet below the lime, coal No. 3; and 230 feet below the lime, coal No. 2. With this vein is a hard, black slate, about a foot thick, which is always piled in masses around the mouth of the mine, and is sometimes called "bone-coal". These measurements can be made to the best advantage by going down the south side of the hill into the hollow on the Saint Ronan lease, in which coal No. 2 is mined, all the points of exposure being on the central axis and as nearly vertical as is possible to find them.

In order to get a good exposure of the limestone for examination, we came beyond the highest point in the axial line. We will therefore retrace our steps for about a mile northward. This will bring us to "Sand hill". Here we find coal No. 2 about 170 feet above Walker's creek, and the horizon of coal No. 1 about 40 feet above the bed of the stream. In lieu of coal we shall have to content ourselves with the thick bed of fire-clay, which is a persistent accompaniment of it in Ohio. Assuming the bed of Walker's creek at this point to be 250 feet above the level of the Ohio river, we have, from the river level up to coal No. 1, 290 feet, plus interval from coal No. 1 to yellow limestone, 360 feet, plus interval from yellow lime to crinoidal lime, 350 feet, plus interval from crinoidal lime to coal No. 11, 350 feet, equal to 1,500 feet, the total amount of uplift to the highest point. Add to this 500 feet of the upper barren measures, which may be seen in the surrounding hills, and deduct the 250 feet which lie below the bed of Walker's creek, and we have 1,750 feet of coal-measure rocks fairly exposed within an area of a few miles, which any student of geology may study at his leisure.

We will now go back to Sand hill and resume our journey southward (see Map IV). Crossing White Oak fork of Walker's creek above Volcano, we keep along the ridge, with Coal Bank run and Rogers gulch on our right and Oil Spring run, with its branches, on our left, till we come to the dividing ridge between Lick fork and Tate run; here we halt and look around us. From Sand hill to this point we have passed through the center of the White Oak producing territory, a strip along the central axis of the break about four miles long and one mile wide, on which there are something like 600 wells now working. The southern end, at which we have stopped, is now the busiest part.

Glancing down at our feet we will see that we are standing upon a soft, yellow sand, filled with pebbles about the size of a pea; some of them have a delicate blue tinge, but most of them are of a very clear white, almost translucent. This is the second oil-sand of Cow run, Ohio, from which a single well has produced $200,000 worth of oil.

* * * * * * * * *

Here there is just as much attention paid to the oil-rock proper as in any other territory. The only peculiar feature about the territory is the fact of its being located on the crest of a well-marked anticlinal, and whether you will find an accumulation of gas, oil, or water in the rock depends upon the comparative level of the point at which you strike a fissure. The statement which Professor Stevenson makes concerning the form of the "break" at Hughes' river along the Staunton pike is accurate and true for the whole length of the line; "there is no evidence of faulting on either side. The succession from the inner portion of the abruptly-tilted strata outward to the horizontal strata is unbroken and perfectly clear. Within the 'break' the rocks are almost horizontal and not much broken. They describe a flattened anticlinal". That this statement is true of the most disturbed portion of the whole line we may see for ourselves. Starting from the point at which we halted, we will go down on to Lick fork. From this point the stream runs nearly west to its junction with Laurel fork. About 40 feet above the bed of the stream we will find coal No. 2 lying horizontal. Following it westward down the run, we find that it soon begins to dip gradually, and in the course of a few rods comes down to the bed of the stream. Just before it disappears we see that it is beginning to dip at a much steeper angle, but shows no displacement. As we continue down the stream we find that we are passing over the upturned edges of the strata, but everything is in its proper place. Coal No. 3, the pebbly sand-rock that lies above it, the yellow limestone, the black flint, the crinoidal limestone, and the gray limestone of the Pittsburgh vein, each is seen in its legitimate position, the intervals being comparatively the same as when we measured them vertically. Laurel fork, from the mouth of the Lick fork to the Baltimore and Ohio railroad, runs very nearly parallel with the axis of the break. Placing the compass upon the upturned edge of the crinoidal limestone, where it is exposed in the bed of the run, we see that it runs straight as a line S. 10° W. Being only 18 inches in thickness, it serves us admirably as an indicator of the course of the break. The black flint and the gray limestone, when tried by the compass, show the same course. From the mouth of Lick fork to the railroad this gray limestone of the upper productive coal group may be traced. Standing almost vertically, it crosses the railroad in the bed of the stream between Laurel junction and the first cut to the west. In this cut the double vein of coal No. 9 of the upper measures shows dipping at a sharp angle to the west. At the west end of this cut the dip becomes more gradual, but continues until the rocks of the upper coal group, including our No. 11, are brought down to the level of the railroad. If we should go eastward from Laurel junction to Petroleum we should find the same state of facts existing that we have just enumerated; in the beds of Oil Spring run and Goose creek all of our well-known rocks, from coal No. 2 to coal No. 11, dipping to the east complete the symmetry of the anticlinal. (See Section 3, Plate IV.)

From the head of Lick fork the axis of the break commences to dip southward. Following the axial line we cross the northwestern branch of the Baltimore and Ohio railroad about midway between Laurel junction and Petroleum, cross the head of Ellis run and along Dry ridge to William Sharpneck's, on the north side of Hughes' river. Near the school-house on Dry ridge may be seen a fine exposure of the crinoidal limestone, here 350 feet above the bed of Hughes' river, showing a southern declination of about 580 feet between this point and the highest point of the axis at Sand Hill. About 200 feet below the crinoidal limestone is the flint vein. The same black shale, filled with white fossil shells, that underlies it at Horseneck is found here, affording a sure means of identification.

Resuming our journey southward, we cross Hughes' river near the old Walton Wait well, climb the steep hill on the south side, and keep along the ridge with the waters of Island run on the west and of Flint run on the east, until we come to the head of Wilson's branch of Parish fork. From Dry ridge to this point we find the crinoidal limestone lying about level; from this point it commences to dip southward. We follow the course of Wilson's branch down to within a few rods of the old Parmenter well, then over the ridge, cross Parish fork above the residence of Mr. Fred. Bailey, cross oil-rock near the old "Orchard" well and the main branch of Standing Stone creek at the Fisher farm. Here we find the crinoidal limestone just 30 feet above the bed of the creek. Total southern dip from Sand hill to Standing Stone, 850 feet. The dip has now been sufficient to bring the soft pebbly sandstone which lies over coal No. 10 into the hills. Going westward down the creek, we may see this ledge of rock, about 40 feet thick, running like a wall from the bed of the stream to the top of the hill.

At Standing Stone the south dip is reversed and the axis rises. Following the line, we cross Dever's fork at David Dever's, where we find the crinoidal limestone 150 feet higher than at the Fisher farm. Continuing our course, we cross the head of Chestnut run, keep along the ridge with the headwaters of Upper Burning Spring run to the east and Nettle run to the west of us, and strike Lower Burning

Spring run near the Newberger and Braidon well. Here we find the crinoidal limestone 125 feet above the Little Kanawha river, making 800 feet in geological level between this point and the head of Walker's creek at Sand hill. The bed of the stream at Walker's creek being 200 feet higher than the bed of the Little Kanawha makes the difference in drilling for any given rock about 600 feet. * * *

At Burning Springs the axis again commences to dip southward, and at the point where it crosses the Little Kanawha, a short distance above the mouth of Spring creek, the crinoidal limestone is 60 feet below the bed of the river.

Our investigation shows that the White Oak anticlinal or "oil break" is a fold or wrinkle in the bottom of the great trough called the "Allegheny coal basin", extending from a point about 4 miles north of the Ohio river to a point about the same distance south of the Little Kanawha at Burning Springs; that there are undulations in the axial line which divide the line into three sections, which, had there been no erosion of the surface, would have presented three peaks of different altitudes; that of Horseneck would have been about 500 feet higher than that of Burning Springs, and that of White Oak about 300 feet higher than that of Horseneck, and the summit of the White Oak peak would have been about 2,000 feet above the level of the Ohio river. Under each of these peaks the rocks lie in the form of a table, say four miles long and from three-fourths to one mile wide. From the ends and sides of these tables the rocks dip at certain angles. Taken as a whole, the rocks form inverted basins, with flat bottoms and sloping sides. In these inverted basins nature for thousands of years had been collecting gases as the chemist collects them in inverted bottles over the pneumatic cistern. At Burning Springs the accumulation of gas became so large that it forced its way through the fissures of the overlying rocks to the surface, forming a natural gas-spring, which often became ignited and burned for days on the surface of the water through which it was escaping.

All of the work done in this region prior to 1864 was done without recognizing the fact that the territory was confined to the crest of an anticlinal, and large sums of money were expended in the purchase of territory and drilling of wells along the margins of other streams in the neighborhood. The operators also remained ignorant of the fact that two of the producing rocks of White Oak lay beneath the conglomerate. The escape of the gas at the summit of the other inverted basins drew the attention of operators to Horseneck and White Oak (from Burning Springs). About the year 1865 General A. J. Warner and Professor E. B. Andrews, of Marietta, became interested in White Oak territory, and these gentlemen soon began to draw geological inferences which led to an abandonment of the old policy of following the beds of the streams and to a recognition of the fact that the oil was confined to the crest of an anticlinal; hence the White Oak section, and that alone, has been thoroughly and systematically worked. After it had been clearly recognized that the oil territory was confined to the crest of the anticlinal, it was somewhat hastily inferred that the crest would be valuable territory for its entire length, and many test wells were drilled on the strength of this inference. These test wells showed such a large percentage of failures that, three years ago, the writer undertook to account for them by making a careful level along the entire length of the axis. The undulations of the rocks shown by the profile (Plate III), taken in connection with the known laws of hydrostatic pressure, satisfactorily account for the failures, and show that part of the crest of the anticlinal is filled with an accumulation of water, and also what part must contain the accumulation of oil and gas.

Taking into consideration our position in the trough of the Allegheny basin, and the fact that on all sides of us the conglomerate is filled with brine, as on the Allegheny river above, at Pomeroy and Charleston below, on the Big Muskingum to the west, and the head of the Little Kanawha to the east, at all of which points it lies at a higher level than it does in the counties through which we have passed, we may safely conclude that the productive oil territory of West Virginia must be confined to the summit of the anticlinals or local rolls similar to the White Oak line.

The question has been raised by some of the Pennsylvania geologists as to whether rocks lying below sea-level can be expected to contain an accumulation of oil. In 1878 the writer drilled a well at Dexter, Noble county, Ohio, in which he struck a sand-rock about 700 feet below sea-level, containing a large accumulation of dry gas, and in the succeeding year George Rice, esq., obtained at Macksburg, Ohio, a flowing well from the same rock at the same level. The writer's well at Dever's fork, in Wirt county, also contains a large accumulation of gas and some oil in the Vespertine sandstone 300 feet below sea-level. This question is mentioned here because all of the Pennsylvania oil-bearing sands, if here at all, would lie several hundred feet below tide-water, even on the crest of our White Oak anticlinal.

CONCLUSIONS.

I have quoted Mr. Minshall's work in great detail, and have introduced all of his sections, for the purpose of showing the facts from which his conclusions have been drawn. His facts were ascertained after many a mile of tramping and careful barometrical measurement; a work far more laborious and valuable than that of collating the records of wells, which, though sometimes correct, are more often defective through ignorance or inattention. Mr. Carll has tramped over the hills and through the forests of northwestern Pennsylvania to gain personal knowledge of the region, and his work has high value in the eyes of the oil producers. Both Mr. Minshall and Mr. Carll have learned the geology of petroleum at the edge of the drill, barometer in hand, both of them seeing and handling what they describe.

Assuming that Messrs. Hunt, Carll, and Minshall have observed correctly and stated their observations correctly, petroleum occurs in crevices only to a limited and unimportant extent. It occurs saturating porous strata and overlying superficial gravels; it occurs beneath the crowns of anticlinals in Canada and West Virginia, and does not occur in Pennsylvania; but in the latter region it occurs saturating the porous portions of formations that lie far beneath the influence of the superficial erosion, like sand-bars in a flowing stream or detritus on a beach. These formations or deposits, taken as whole members of the geological series, lie conformably with the inclosing rocks, and slope gently toward the southwest. The Bradford field in particular resembles a sheet of coarse-grained sandstone, 100 square miles in extent by from 20 to 80 feet deep, lying with its southwestern edge deepest and submerged in salt water and its northeastern edge highest and filled with gas under an extremely high pressure.

It is further to be concluded that, from whatever source the petroleum may have originally issued, it now saturates porous strata, not of any particular geological age, but runs through a vast accumulation of sediments from the oldest to the newest rocks, in Pennsylvania and West Virginia embracing all of the rocks between the Lower Devonian and the Upper Carboniferous.

Chapter IV.—THE CHEMISTRY OF PETROLEUM.

Section 1.—THE CHEMISTRY OF CRUDE PETROLEUM.

The wide distribution of bitumen in nature has already been noticed. As early as 1823 the Hon. George Knox called attention to its prevalence in rocks and minerals, and showed that, along with lithia and fluorine, it had been overlooked in their analyses. (*a*) The following year Vauquelin published a notice, with an analysis of the bitumen contained in the sulphur of Sicily. (*b*) In 1837 Boussingault published the results of an examination of the bitumen of Pechelbronn and other bitumens of southern Europe, which for many years was considered a classic upon the subject. (*c*) In 1853, Dr. C. Völckel examined the asphalt of the Val de Travers. (*d*) These analyses of solid bitumens were mainly attempts to determine the constitution of these materials by ultimate analysis, and were very valuable at the time they were made.

The first research upon fluid bitumen or petroleum was made by Vauquelin in 1817 upon the naphtha of Amiano, which at that time was used in street lamps in the small towns of the duchy of Parma. (*e*) In 1857, Engelbach examined the petroleum sand of the Luneberger heath, in Holstein, which has lately been attracting so much attention; (*f*) and Warren de la Rue and Hugo Miller worked on several tons of Rangoon tar or Burmese petroleum, and distilled the oil with steam at 100° C. and with steam superheated to 200° C., and examined the distillate. (*g*)

American petroleum was examined by Professor Benjamin Silliman, sen., in 1833, (*h*) and by Professor B. Silliman, jr., in 1855, who published his results in his celebrated report on the petroleum of Venango county. (*i*) Since petroleum became an article of commerce innumerable examinations from all parts of the world have been made for technical purposes. These examinations have been chiefly made with reference to determining the amount of distillate available for illuminating purposes. In the earlier period of the commercial production it was assumed that petroleums from different localities were identical, except in specific gravity, and that therefore the distillate of the same specific gravity possessed the same properties. Professor B. Silliman, jr., and myself examined the petroleums of California; (*j*) H. St. Claire Deville and others those of Java, Pennsylvania, and Russia; (*k*) Raveset examined Trinidad pitch, (*l*) Waller the petroleum of Santo Domingo, (*m*) and Silvestri the petroleum-like constituents of the lavas of Etna. (*n*) The distillations essential to these analyses were often conducted in an ordinary glass retort, or with an alembic. Of the two, the alembic is very much to be preferred, as its use prevents the cracking of the oils. In 1868 Dr. H. Letheby contrived an apparatus for this purpose, which is described in the *London Journal of Gas Lighting*, xii, 653. In 1866 Dr. John Attfield published a description of another, (*o*) and the following year I described an apparatus of my own invention for the technical analysis of petroleums or solid bitumens, either with or without pressure. (*p*)

The ultimate analysis of petroleum early showed it to consist of carbon and hydrogen. It was for a long time assumed that crude petroleum contained an equal number of atoms of these elements, but my own examination of Californian and other petroleums in 1867 and 1868 (*q*) showed that the first named variety contained from 0.5645 to 1.1095 per cent. of nitrogen; that Mecca (Ohio) oil contained 0.230 per cent., and oil from the Cumberland well, West Virginia, 0.54 per cent. of the same element. Determinations of the hydrogen and carbon in several samples of petroleum showed that the proportion of carbon increases with the density. The following table shows the percentage of composition of the several different varieties: (*r*)

	Hydrogen.	Carbon.	Nitrogen.
Scioto well, West Virginia	12.929	86.622	....
Cumberland well, West Virginia	13.359	85.200	0.5400
Mecca, Ohio	13.071	86.316	0.2300
Hayward Petroleum Company, California	11.819	86.934	1.1095
Pico spring, California	....	....	1.0165
Cañada Laga, California	....	....	1.0855
Maltba, Ojai ranch, California	....	....	0.5645

a *Phil. Trans.*, 1823; *Phil. Jour.*, ix, 403; A. J. S. (1), xii, 147.
b *Ann. de Chim. et de Phys.* (2), xxv, 50.
c *Ibid.*, lxiv, 41; New Ed. *Phil. Jour.*, 1837.
d *Ann. der Chem. u. Pharm.*, lxxxvii, 139.
e *Ann. de Chim. et de Phys.* (2), iv, 314.
f *Ann. der Chem. u. Pharm.*, ciii, 1.
g *Phil. Mag.* (4), xiii, 512.
h *Am. Jour. Sci.* (1), xxiii, 97.
i *Am. C.*, ii, 18.
j A. J. S. (2), xxxix, 341; (2), II, xliii, 242; C. N., xvii, 257; *Geo. Surv. of Cal.:* Geology, ii, Appendix, p. 49.
k *L'A. S. et Ind.*, 1871, 146.
l *Jour. de l'E. au gas*, 1872; *A. Chem.*, ii, 316.
m *Am. Chem.*, ii, 220.
n *Gaz. Chim. Ital.*, vii, 1.
o *Chem. News*, xiv, 98.
p A. J. S. (2), xliv, 230; C. N., xvi, 199.
q *Rep. Geo. Surv. Cal.:* Geology, II, Appendix, pp. 84, 89.
r *Ibid.*, p. 89; *Am. Chem.*, vii, 327. The methods of analysis used to meet the peculiar difficulties presented by these substances is fully described in both the works referred to.—S. F. P.

Delesse notes 0.154 per cent. of nitrogen in elalerite and 0.256 per cent. in the bitumen from the pitch lake of Trinidad. (*a*)

O. Hesse has shown the presence of sulphur in Syrian and American asphalt to the amount of 8.78 and 10.85 per cent., respectively, and one sample of California petroleum examined by myself contained a sufficient amount of sulphur to form a deposit in the neck of the retort. It is well known that Canada petroleum contains sulphur, but the Pennsylvania and West Virginia oils are remarkably free from it. A qualitative test for sulphur in petroleum is described on page 181. An oil is described from the Kirghish steppe said to contain 1.87 per cent. of sulphur and to be purified with great difficulty. According to Mr. John Tunbridge, gold may be found in the ashes of crude petroleum and in the refuse of petroleum stills, and he is reported to have extracted $34 worth of gold from a ton of residuum, the source of which is not given. (*b*)

In general, it may be stated that the ultimate analysis of petroleum shows it to consist of carbon and hydrogen, with a very small proportion, in some instances, of nitrogen, sulphur, and perhaps oxygen. Metallic arsenic is said to condense in the goose-neck of the retorts in which the bituminous limestones of Lobsan are distilled. (*c*)

Section 2.—THE PROXIMATE ANALYSIS OF PETROLEUM.

In 1824 Reichenbach published his researches upon paraffine and eupion, (*d*) and ten years later published a paper upon petroleum or rock-oil; (*e*) and he appears to have been the first chemist who attempted a separation of the definite chemical compounds that are mixed together in petroleum and similar liquids. Further attempts were made at their separation by Laurent, (*f*) but, as might be expected, they were only partially successful, as the eupion and other liquids obtained by Reichenbach and Laurent were for the most part mixtures still.

In 1863 Schorlemmer, in England, and Pelouze and Cahours, in France, published researches upon American petroleum, which were really the first successful attempts to isolate any number of the constituents of this complex mixture of substances. Schorlemmer showed that American petroleum contained in the portion boiling below 120° C. the same hydrides as are obtained from the distillate from cannel coal, (*g*) but Pelouze and Cahours determined American petroleum to consist of the homologues of marsh-gas. The lowest determined by them was hydride of butyl, C_8H_{10}, which boils a little above 0° C., while the highest had a composition of $C_{30}H_{32}$. They considered paraffine a mixture of still higher terms, and regarded the small quantity of benzole and toluole alleged to have been obtained by Schorlemmer to have been due to destructive distillation of the petroleum. (*h*)

At the same time that the researches just mentioned were being carried on in Europe, C. M. Warren, alone and associated with F. H. Storer, was engaged on a similar research in this country. (*i*) The results obtained by them were published in 1865 and 1866, and while in the main confirmatory of those previously obtained, they were in many respects superior in point of definiteness and accuracy, from the fact that Warren used an apparatus for separating his material greatly superior to any hitherto employed. (*j*) In discussing the identity of the compounds obtained by himself and MM. Pelouze and Cahours, Warren remarks that he considers vapor density and analysis as corroborative evidence with boiling point; but aside from such evidence, he regards the superiority of his process of distillation as a paramount means of securing pure products for analysis, and therefore entitled to great consideration. (*k*)

Warren succeeded in isolating fourteen different liquids in quantities of several hundred cubic centimeters, and so pure that the whole quantity might be distilled from an ordinary tubulated retort within a range of temperature of 1° C. He was consequently enabled to determine their boiling points with great accuracy, and hence the difference in their boiling points, to analyze them and determine their vapor density and establish their formulæ. The composition assigned by him to the fourteen compounds is given in the following table:

FIRST SERIES.		SECOND SERIES.		THIRD SERIES (not completed).	
Formula.	Boiling point.	Formula.	Boiling point.	Formula.	Boiling point.
	Degrees.		*Degrees.*		*Degrees.*
C_4H_{10}	0.0 ?	C_4H_{10}	8—9	$C_{10}H_{20}$	174.9
C_5H_{12}	30.2	C_5H_{12}	37.0	$C_{11}H_{22}$	195.8
C_6H_{14}	61.3	C_6H_{14}	68.5	$C_{12}H_{24}$	216.2
C_7H_{16}	90.4	C_7H_{16}	98.1		
C_8H_{18}	119.5	C_8H_{18}	127.6		
C_9H_{20}	150.8				

a *De l'Azote et des Matières dans l'Ecorce Terrestre.* Paris, 1861, pp. 172, 173.
b J. F. I., cix, 175.
c *Ann. des Mines* (4), xix, 669.
d *P. Mag.* (2), i, 402.
e *Schweig. Seid. Jour.*, ix, 133; *P. Jour.*, xvi, 376.
f *Ann. Chim. et de Phys.* (2), lxiv, 321.
g Proc. Manchester Phil. Soc., March 11, 1863; A. J. S. (2), xxxvi, 115.
h *Ann. C. et P.* (4), i, 5.
i *Mem. Am. Acad.*, N. S., ix; *Am. J. Sci.* (2), xl and xli.
j *Mem. Am. Acad.*, N. S., ix, 121; A. J. S. (2), xxxix, 327.
k A. J. S. (2), xlv, 262.

I have changed the atomic value of 12 given in Warren's memoir to that of carbon = 6, as at present used, in order that these formulæ may be more readily compared with others. Warren does not give the specific gravity of his compounds, nor does he give any hint regarding the relative proportions of these compounds in crude petroleum, and his work was qualitative as regards the crude oil. Messrs. Warren and Storer also examined Rangoon petroleum, with the following result:

	Deg. C.
Rutylene, $C_{10}H_{20}$, boiling at about	175
Margarylene, $C_{11}H_{22}$, boiling at about	195
Laurylene, $C_{12}H_{24}$, boiling at about	215
Cocinylene, $C_{13}H_{26}$, boiling at about	235
Naphthalin, $C_{10}H_8$	—

Also, probably, pelargonene = C_9H_{18}, boiling at about 155°, and members of one or both the series of hydrides (from American petroleum), it being a fair presumption that we have had in our hands hydrides of œnanthyl (C_7H_{16}), of capryl (C_8H_{18}), and of pelargonyl (C_9H_{20}). Our experiments also indicate the probable presence of xylole and isocumole. (*a*)

The latter, with naphthaline, are found in coal-tar.

It will be noted that these researches were had only upon the more volatile portions of the petroleum, without regard to the more dense portions with high boiling points, and that they established the fact that the more volatile portion of American petroleum contained principally the homologues of marsh-gas, with the general formula C_nH_{2n+2}, and also the homologues of olefiant gas, with the general formula C_nH_{2n}, and that the corresponding portion of Rangoon petroleum contained principally the homologues of olefiant gas, the benzole series, and probably some of the higher members of the marsh-gas series.

An examination of paraffine and its chemical relations showed that it was one of the higher homologues of marsh-gas, hence the English chemists have called the whole series paraffines, including the solid, liquid, and gaseous members.

During 1865 E. Ronalds isolated butyl hydride from American petroleum and described it as a liquid with a specific gravity of 0.600 at 32° F.; vapor density, 2.11, colorless, and of a sweet taste and agreeable odor. Alcohol of 98 per cent. dissolves from eleven to twelve times its volume. (*b*) The same year Tuttschew discovered the homologues of olefiant gas (C_nH_{2n}) in illuminating oil from Galician petroleum. (*c*)

Since 1865 up to 1880 the paraffines of American petroleum have been the subject of a vast amount of research, particularly by English chemists. Goldstein, (*d*) Stenhouse, (*e*) Odling, (*f*) Herman, (*g*) Morgan, and Schorlemmer (*h*) have all contributed to the mass of knowledge relating to this subject that is now the possession of chemists. Pre-eminent, however, among these investigators is the name of Schorlemmer; but it would be impossible to give here a *résumé* of his results that would be understood by the general reader; in fact, many of his most elaborate researches are of a purely scientific nature. His numerous papers will be found in the *Philosophic Transactions* and the *Journal of the Chemical Society*.

Very little has been done upon Canadian petroleum. Schorlemmer has shown that the benzole series is present in it. (*i*) Russian petroleum has been examined by Beilstein and Kurbatow (*j*), and they found that the more volatile products of Caucasian petroleum consist of the additive compounds of the benzole series, having a higher specific gravity for the same boiling point than the compounds constituting American petroleum and containing more carbon. Further experiments, undertaken to ascertain if American petroleum contained these bodies in small proportion, yielded negative results, all of the derived compounds showing the presence of the alcohol radicals (C_nH_{2n+2}), and not of benzole or its additive compounds. The relation which these additive compounds sustain to benzole may be inferred from the following formulæ:

Benzole	C_6H_6	Hexahydro benzole	C_6H_{12}
Toluole	C_7H_8	Hexahydro toluole	C_7H_{14}
Isoxylole	C_8H_{10}	Hexahydro isoxylole	C_8H_{18}

Schützenberger and Jonine having also examined Caucasian petroleum, (*k*) found a notable fraction of the light oil to consist of the isomers of ethylene (C_nH_{2n}). Their results confirm in a general way those obtained by MM. Beilstein and Kurbatow.

The liquids which form the heavier portions of petroleum, from which paraffine crystallizes, have not as yet been very fully examined. For some time it was questioned whether paraffine was a constituent of Pennsylvania petroleum, and those who maintained that it was not accounted for the fact that it sometimes crystallized from crude petroleum by assuming that such petroleum had been heated since it escaped from the wells. The phenomena attending the occurrence of petroleum in the Bradford district has, however, removed this question from all future

a *Mem. Am. Acad.*, ix.
b J. C. Soc. (2), iii, 54; *Bul. de la S. Chim.*, 1866, 135.
c *Jour. f. Prak. Chem.*, xciii, 394; *Bul. de la S. Chim.* 1865, ii, 229.
d J. C. S., xxxvi, 765; B. D. C. G. B., xii, 689.
e B. S. C. de P., 1878, 189; *Ann. der Chem.*, clxxxviii, 249.
f *Proc. Roy. Inst.*, viii, 16.
g Rep. B. A. A. S., 1875.
h J. C. Soc., xxviii, 3011.
i C. N., xi, 255; *Trans. Roy. Soc.* (5), xiv, 168.
j B. D. C. G. B., xiii, 1818 and 2028; A. J. S. (3), xxi, 67 and 137.
k B. D. C. G. B., 1880, 2428; Bul. S. C. P., 1880–2, 673.

controversy, as there paraffine is shown to be susceptible of fractional condensation, the extremely low temperature, consequent upon the removal of the enormous pressure, causing the more dense paraffines to condense in the pipes, leaving a large content of those with higher melting points still dissolved in the oil. It now appears to be firmly established that paraffine as at first isolated is not a homogeneous body, but a mixture of several homologous, perhaps isomeric, bodies having similar properties, but different boiling points. For the history of the discovery of paraffine and a description of the principal researches that have been conducted upon it, see the chapter on Paraffine in Part II of this work.

Recently the constituents of residuum have been made the subject of careful study. Professor Henry Morton, of the Stevens Institute of Technology, first called attention to these substances. Speaking of the distillation of "residuum" for the production of paraffine and lubricating oils, he says:

At the end of this operation, when the bottom of the still is already red-hot and some coke has been formed, there runs very slowly from the condenser a thick, yellow-brown tar, which is almost solid in cold weather, and in summer is only semi-fluid. * * * This thick tar, prior to 1873, was only used as a lubricant for the necks of rolls in rolling-mills, its great tenacity securing its adherence under the very unfavorable conditions to which it was there exposed. About March, 1873, however, Mr. John Truax, of Pittsburgh, wrote me as follows, referring to this tar: "Within a few months we have found a new use for it in the manufacture of a lubricating oil." * * * Returning to the production of what may be termed "thallene tar", I cannot do better than quote part of a letter received from Mr. Truax: "This material (referring to the thallene tar) drains or drips from the end of the pipe forming part of the condenser after all the tar has been distilled, and is in reality the product of the distillation of the petroleum pitch remaining in the still. Tar of petroleum (residuum), which we use exclusively, of gravity 20° Baumé (specific gravity 0.936) or thereabouts is distilled in cylindrical stills or retorts set vertically. These are 9 feet in diameter, and from 3 to 4 feet high. The condensation is effected in the usual manner. The stills are inclosed in brick work all around the sides, forming a flue, through which all the products of combustion in the furnace are obliged to pass. After firing the retorts, the first thing to come over is what we call 'light oil', though the man who made your kerosene would not call it so. This is from 35° to 40° Baumé, or 0.850 to 0.830 specific gravity, and we cut this off to return to the kerosene manufacturers. The balance of the charge begins now to fall rapidly in gravity (Baumé), and continues falling or getting heavier till the end of distillation, at which time the 'stuff' begins its exit and drops lazily into the trough. At this time the bottom of the still is red-hot, and has on it as residue from the charge a covering of coke from 8 to 10 inches thick. This coke is very porous and spongy, and very light, but is good for fuel, and makes little or no smoke." Farther on, in reference to the same thing, Mr. Truax says: "After several hours the stream, after having reached its maximum, begins to darken in color, and soon ceases altogether. Then your 'stuff' drags its slow length along. At this time everything is furiously hot; the bottom red-hot; the fire-brick of the furnace glowing like fire itself, and luminous as the fire, and the little oil remaining with the coke has a heat so great as to make its elements interchange in such a way as to make a large quantity of carbon unite with the very small quantity of hydrogen that is left behind the general exit so as to form your stuff. Several times in my experience, owing to some accidents, we have had to draw the fires before your stuff came over, and on opening the still or retort we found regular pitch, resembling in nearly every way pine-pitch or coal-tar (for roofing) pitch, except in absence of odor and taste, and in not being quite so plastic, but nevertheless a true pitch. Now the distillation of this pitch makes your stuff, that is, under favorable conditions."

I agree with Mr. Truax in his theory here expressed, that the thallene does not exist ready formed in the petroleum, or even in the petroleum tar, but is, like anthracine for example, a product of destructive distillation at something like a red heat. (*a*)

In a previous paper Professor Morton thus describes the preparation of thallene:

The crude tarry matter is well washed with benzine (petroleum naphtha), then with alcohol, and is lastly dissolved in benzole (coal-tar naphtha), filtered hot, and crystallized out on cooling. It is then obtained as a mass of very minute, needle-like crystals of a greenish-yellow color and pearly luster in the mass. * * * This I described under the name of Viridin in a paper read before the American Institute in New York, and drew attention to the very remarkable spectrum which its fluorescent light yielded, which resembled in a striking manner that of anthracine, while the crystalline form, solubilities, and fusing points of the two bodies were decidedly unlike. (*b*)

Hemillian also obtained petrocene in 1877 (J. C. S., xxxii, 867).

In 1879 MM. L. Preunier and R. David published a paper "Upon the nature of certain accessory products obtained in the industrial treatment of Pennsylvania petroleum", (*c*) which was followed and continued in another paper by M. Preunier, entitled "Study upon the unsaturated carbides derived from American petroleum". (*d*) In 1876 Dr. H. W. C. Tweddle exhibited at Philadelphia a greenish substance that he called "petrocene", from which he obtained a yellowish-green substance which he called "thallene". This was the raw material of this research, the few kilograms which were exhibited being obtained from 50,000 barrels of petroleum. The density of petrocene, that is to say, the crude material, is about 1.206. It was separated into lighter paraffines having a density of about 0.990, and heavier hydrocarbons of about 1.27, bromine and sulphuric acid separated from 5 to 15 per cent. of paraffine having a very high melting point, 70°, 80°, and 85° C., ordinary paraffine melting at 65° C. The unsaturated hydrocarbons, anthracene, phenanthrene, chrysene, chrysozene, and pyrene were recognized. Organic analysis showed a hydrocarbon containing from 88 to 96 per cent. of carbon, which is a larger percentage than is found in coal, even anthracite rarely attaining 95 per cent.

The following year (1880) MM. Preunier and Eug. Varenne published another paper "Upon the products contained in the cokes of petroleum". (*e*) They obtained a compound giving on analysis a mean of 97.9 per cent. of carbon, which corresponds to the theoretical compound $(C_{16}H_2)_n$, requiring 97.95 per cent. of carbon. These results, say the authors, conform perfectly to the general views of M. Berthelot, and confirm their own previous researches.

In 1873 MM. Le Bel and A. Muntz examined the black coloring matter of the semi-liquid asphalt of Pechelbronn (Bas. Rhin). (*f*) It is obtained in brittle, black scales from solution in carbon disulphide, and its coloring

a *Am. Chem.*, vii, 88.
b *Ibid.*, iii, 162, 106.
c B. S. C. P., xxxi, 158; B. D. C. G. B., 1879, 366.
d *Ibid.*, xxxi, 293; *Ibid.*, 1879, 843.
e *Ibid.*, xxxiii, 545, 567; *Ibid.*, 1880, 1141.
f B. S. C. P., xvii, 156.

power compares with aniline. They gave it the name "asphaltine", first given by Boussingault to a similar substance, and compare the analysis of this compound with that of a China bitumen as follows:

	Pechelbronn.	China.
Carbon	86.2	86.8
Hydrogen	8.8	8.7

As it is not volatile, the authors conclude that the asphalt is not a product of distillation.

In 1874 MM. Hell and Mendinger examined the organic acids of crude petroleum, (*a*) but the examination was not conducted in such a manner as to determine whether the acids obtained were an educt or a product of petroleum. They agitated the second running (specific gravity 0.857) of heavy Wallachian petroleum with caustic soda, and treated the flocculent precipitate with sulphuric acid. The result was a mixture of oily acids very difficult to separate, as they were decomposed by distillation. They finally succeeded in separating a colorless fluid, feebly acid, that produced a flocculent body with sodium or potassium, resembling soft soap, and they believed it belonged to a new series of fatty acids.

While these researches have been undertaken abroad, in this country Professor Samuel P. Sadtler, of the University of Pennsylvania, has been conducting a series of experiments upon petroleum and associated substances, with results that are embraced in the following extract from a letter dated Philadelphia, November 4, 1881, addressed to myself:

Classifying the subject under the three heads of: 1, Gaseous products accompanying crude petroleum; 2, Crude petroleum; and, 3, Solid products accompanying and derived from the petroleum, I started with the first. I made analyses of some ten lots of "natural gas" taken from wells in different parts of the oil-field, and representing different geological horizons as far as possible. As there was some doubt as to whether the results of endiometric analysis could indicate the presence of the higher members of the paraffine series, I supplemented these analyses by a series of absorption tests made on the spot. Thus I passed a current of natural gas for a time through absolute alcohol, which, while it does not dissolve hydrogen, absorbs marsh-gas slightly, ethane, propane, and the higher hydrocarbons in increasing amount. The hermetically-sealed flasks of the alcohol were then examined in my laboratory, and the gases absorbed driven out by heat and collected over mercury and analyzed. They proved to be chiefly ethane and propane. I also passed a current of the gas through bromine, both pure and alcoholic, so as to absorb the olefines. On after examination in my laboratory, by neutralizing the free bromine with soda and diluting, I succeeded in separating out colorless oily drops of ethene dibromide, and presumably, though not certainly, propene dibromide. These results were read in part before the American Philosophical Society, and were reported in its proceedings. (*b*)

In the study of the liquid crude oils, after classifying the oils from the different geological horizons (with information supplied to me by Mr. John F. Carll), and noting gravities, color, and other physical properties, I proceeded to classify them by filtration (as far as possible in the cold) with animal charcoal and with mineral materials, like clay, alumina, etc. I did this with a view of examining chemically and miscroscopically the coloring impurities thus withdrawn. My results with these portions withdrawn by filtration are very incomplete; still I think they are largely made up of the members of the higher and more condensed hydrocarbon series, like anthracene, etc., and not simply amorphous carbon, as supposed by some chemists. In corroboration of this view I may say that in the crude oils picric acid will strike a deep blood-red color, like the color of its compound with anthracene, fluorine, etc., whereas in the yellow oil clarified in the cold by animal charcoal no such result is gotten. I also verified with a number of crude oils Schorlemmer's observation that olefines are present, capable of being withdrawn by bromine, and in small quantities members of the benzole series, capable of yielding nitro-derivatives like nitro-benzole and nitro-toluole. Indeed, taking several distinct fractions, gotten from Bradford oil, I got notable quantities, in the lightest fraction light-yellow nitro-benzole, and in the higher fractions reddish-yellow nitro-toluole and probably higher products. I also extracted paraffine from a number of the crude oils by mixing several volumes of ether with the oil and then chilling, when almost all the dissolved paraffine will separate and can be filtered off.

I commenced a study of the spent acid from a refinery in Titusville that had been running for several weeks exclusively on green oil from Petroleum Centre, hoping to get a class of sulpho-conjugated oils from it for study. I did not get further, however, than to separate them from the free sulphuric and sulphurous acids, and so have them yet.

Lastly, of the solid products which accompany petroleum I examined the paraffine of buttery or firmer consistence which separates out on the tubing or derrick-frames in Bradford oil-wells. This was dark in color, looking like the crude ozokerite of Galicia, but not so firm. It had all the characters of a paraffine mixture. I had also collected a whitish buttery mass from several flowing wells near Warren, Pennsylvania. This, on examination, proved to be a very perfect emulsion of oil and water, one which would stand for months, but separated into distinct layers of oil and water when warmed. I also took up for examination the solids gotten from Pennsylvania petroleum by pyrogenic formation. Of this character were petrocene and allied products first mentioned by Dr. Herbert Tweddle, and from which Professor Henry Morton extracted thallium. I had worked with it some months when Preunier published an account in the *Ann. de Chim. et Phys.* of an examination of the same substance. I then published in Remsen's *American Chemical Journal* an account of my results, showing the presence of several new hydrocarbons. (*c*)

In an article published by Professor Sadtler in 1876, he well shows the unsatisfactory condition in which the chemistry of petroleum stands at present. (*d*) After speaking of the various researches had up to that date, he says:

What was the material used for these investigations? Were the crude petroleums examined by these different authorities exactly the same, or if by chance they might have been, are they to be compared with all other petroleums now known? Those familiar with the crude oils as produced in the different sections of Venango, Clarion, and Butler counties, and very recently in Warren and McKean counties also, will know that these oils vary in color from a light amber to a dark black, and in gravity from 30° to 55° Baumé—from thick lubricating oils to nearly pure benzine. Moreover, they come from very different strata, or "sand rocks", as they are termed. * * *

It will thus be seen that if we wish to study the chemical composition of petroleum thoroughly we have a considerable body of material to choose from. This material must be carefully assorted, too, before any satisfactory study of the petroleum can be made. The great bulk of the crude petroleum that is sent to the refineries or is exported is shipped by the pipe-line companies, who have their network of pipes ramifying through whole districts, collecting the entire yield of a district and storing it in their immense tanks. To study such crude petroleums would be like analyzing the sweepings of a mineral cabinet.

a B. D. C. G. B., vii, 1216. *b* P. Am. P. S., xviii, 44. *c* *Am. Chem. Jour.*, i, 30. *d* *Am. Chem.*, vii, 181.

With perhaps a few exceptions, these remarks apply as forcibly to the work that has been done upon all other petroleums as to those of Pennsylvania.

The various attempts to produce by synthetic processes the oils that constitute petroleum will be noticed in detail when treating the chemical theories regarding its origin. They may be briefly stated as follows: Commencing in 1876 with Berthelot's synthesis of these liquids through the reaction of alkali metals, calcium, carbonate, and steam, we next have, in 1871, Byasson's successful experiments with steam, carbonic acid, and iron at a white heat; then, in 1877, Friedel and Craft's synthesis through the action of chloride of aluminum; then the same and the following year the reaction produced by M. Clœz upon carbides of iron and manganese by diluted sulphuric acid and boiling water; and finally, in 1878, Landolph's complex synthesis through the action of fluoborates. (*a*) M. Adolph Wurtz has shown that hydride of amyl (found in petroleum) and other hydrocarbons can be produced by the action of zinc ethyl on iodide of allyl. (*b*)

These oils have also been produced by the destructive distillation of the animal fats through the use of superheated steam. Warren and Storer fractionated the distillate from a lime soap of menhaden oil and obtained the members of the paraffine series, the homologues of olefiant gas, and the benzole group. (*c*) Cahours and Demarcay fractionated an oil boiling below 100° C., obtained by distilling fats by superheated steam, and found it contained pentane, hexane, and heptane. Another oil having a higher boiling point contained heptane, octane, nonane, decane, undecane, and a small quantity of dodecane, and probably cetane (hexdecane), all members of the paraffine series. (*d*)

SECTION 3.—THE CHEMICAL ACTION OF REAGENTS UPON PETROLEUM AND ITS PRODUCTS.

In attempting to classify the work that properly falls into this section I find it in a very fragmentary condition. The residues from gas works where petroleum is used have been studied by S. Cabot, jr., and he found them to contain the benzole compounds, but neither phenol nor cresol. (*e*) A. Leutz notices that the residues from gas, whether it is made from wood, coal, or petroleum, are identical, viz: aromatic hydrocarbons and phenols, naphthaline, anthracene, and phenanthrene, all of which are likewise obtained by passing petroleum through red-hot tubes filled with charcoal. Leutz experimented with Russian petroleum. (*f*) J. Tuttschew passed the vapor of an American naphtha through a red-hot tube filled with pumice and obtained gas and tar. One gram of the naphtha yielded a liter of gas having the following composition: (*g*)

	Per cent.
Acetylene	1.77
Elayl and homologues	20.51
Marsh-gas and hydrogen	77.72

The effects of oxidation upon petroleum and its compounds have been quite widely studied. I succeeded in converting California petroleums into asphalts, which were lustrous black and brittle, soluble in carbon disulphide and fusible at 212° F.; but I have never examined either the asphalt or the gaseous products of the decomposition. (*h*) Walter P. Jenney has very carefully studied the effects of oxidation upon heavy petroleum distillates. He placed these distillates in a metallic still and aspirated a current of air through the oil continuously for from four to six days, maintaining the oil at the same time at a temperature of from 140° to 155° C, and as a result the volume of oil was greatly reduced, not by oxidation into water, but by cracking into lighter oils and gases and the conversion of a portion of the oil into oxidized residues, soluble in chloroform, but not in petroleum naphtha. He says:

These four substances, formed from one sample of oil, bear a peculiar relation to each other. The resin D, which is in solution in the hot oil, has the composition expressed by the formula $C_{46}H_{46}O_5$. Becoming oxidized, it precipitates as the brown powder $C_{40}H_{40}O_5$, and, settling on the bottom of the still, becomes heated to a higher temperature, changing into the solid asphalt $C_{40}H_{38}O_5$, or by a longer action of air $C_{40}H_{38}O_7$. (*i*)

These interesting and suggestive experiments bear an important relation to the technology of petroleum.

Hell and Mendinger oxidized the acid that they obtained from crude Wallachian petroleum by the action of nitric and chromic acids, and obtained acetic acid and a new acid having the formula $C_9H_{16}O_2$. (*j*) Berthelot has shown that the action of chromic acid on ethylene and its homologues at a temperature of 120° produces aldehyde and its homologues. (*k*) In 1870 E. Willigk treated paraffine at a high temperature with nitric and sulphuric acids, and obtained products that belonged to the series of the fatty acids. (*l*) In 1873, M. Champion subjected paraffine for sixty hours to the action of nitro-sulphuric acid, hyponitric acid vapors were given off, and an oil having been formed with an acid reaction, combining readily with alkalies, of which the formula is $C_{26}H_{26}NO_{10}$, he proposed for it the name paraffinic acid. (*m*) In 1874 M. A. G. Pouchet published a paper in relation to the action of nitric acid upon

a For references see page 60 *et seq.*
b *C. Rendus*, liv, 387.
c *M. Am. Acad.*, N. S., ix, 177; A. J. S. (2), xliii, 250.
d *Jour. Pharm. Chem.* (4), xxii, 241.
e C. N., xxxvi, 140.
f Rus. Chem. Soc., June, 1877.
g J. f. P. C., xciii, 394.
h P. Am. P. S., x, 460; *Geo. Surv. of California:* Geology, Appendix II, 86.
i *Am. Chem.*, v, 359.
j B. S. C. P., 1877–'82, 385; B. D. C. G. B., x, 451.
k J. C. S., xxxvi, 907.
l B. D. C. G. B., 1870, 138.
m *J. de Pharm. et de Chimie*, Aug., 1872.

paraffine and the divers products that result from it. (*a*) He obtained in solution the fatty acids, chiefly caproic, but also butyric, caprylic and capric, and paraffinic acid insoluble. He regards paraffinic acid as having the formula $C_{48}H_{47}O_3$,HO, and paraffine as a definite compound with the formula $C_{48}H_{50}$, and not a mixture of different carbides of hydrogen, a conclusion that does not follow, unless he has shown that paraffines from all sources have the same composition and produce the same paraffinic acid.

In 1868 M. Grotowski, of Halle on the Saale, studying the effects of sunlight on illuminating oil, (*b*) exposed various kinds of oils in glass flasks to the rays of the sun for a period of three months, and found that they invariably absorbed oxygen and converted it into ozone. The air was ozonized even in well-corked vessels, the effect being, however, in some degree dependent upon the color of the glass. The respective results of these experiments were noted after a lapse of three months. American kerosene from petroleum, which had been exposed to the light in white uncovered glass balloons, had become so strongly ozonized that it scarcely burned, and the original bluish-white oil had assumed a vivid yellow color, the specific gravity being found to have increased 0.005; but American kerosene which had been kept in the dark for three months did not show any ozone at all, and burned satisfactorily. The oils were exposed from April to July, 1868. Those oils which had become strongly ozonized had also suffered a distinct change in odor, and the corks were bleached as if attacked by chlorine, while the others had remained unchanged in these particulars. These results are fully confirmed by the experience of the consumers and dealers in these oils, who all avoid obtaining "old oil", as it is called. It appears that redistillation with quicklime and clean iron nails restores the oils to their original state and properties. It is well known that the best illuminating oils, when allowed to stand for a long time in unused glass lamps, become yellow in color, less mobile, and of greatly impaired quality.

Dr. Stevenson Macadam, having investigated the action of petroleum on metals, concludes that it exerts a solvent action upon lead, zinc, tin, copper, magnesium, and sodium. (*c*) Engler refers to these experiments, and maintains that these metals are attacked by petroleum only under the influence of air or oxygen, when acid compounds are formed. Petroleum washed in caustic alkalies and distilled in carbonic acid has no solvent action on metals. (*d*)

Chapter V.—THE ORIGIN OF BITUMENS.

Section 1.—INTRODUCTION.

The origin of bitumens has been a fruitful subject of speculation among scientific men during the last half century. These speculations have been pursued along several quite different lines of investigation, and have been influenced by several different classes of experience. Generally speaking, they fall into three different categories, embracing those who regard bitumen as a distillate produced by natural causes, those who regard bitumen as indigenous to the rocks in which it is found, and those who regard bitumen as a product of chemical action, the latter class being subdivided into those who regard bitumen as a product of chemical change in natural products, of which carbon and hydrogen are constituents, and those who advocate a purely chemical reaction between purely mineral or inorganic materials. I propose to examine these theories in the inverse order in which they have just been stated.

Section 2.—CHEMICAL THEORIES.

The argument for a purely chemical origin of petroleum was first brought to the serious attention of scientific men through the publication of a somewhat noted paper by the distinguished French chemist Berthelot in 1866, whose conclusions are stated as follows:

> If, in accordance with an hypothesis recently announced by M. Daubré, it be admitted that the terrestrial mass contains free alkali metals in its interior, this hypothesis alone, together with experiments that I have lately published, furnishes almost of necessity a method of explaining the formation of carbides of hydrogen. According to my experiments, when carbonic acid, which everywhere infiltrates the terrestrial crust, comes in contact with the alkali metals at a high temperature, acetylides are formed. These same acetylides also result from contact of the earthy carbonates with the alkali metals even below a dull-red heat.
>
> Now the alkaline acetylides thus produced could be subjected to the action of vapor of water; free acetyline would result if the products were removed immediately from the influence of heat and of hydrogen (produced at the same time by the reaction of water upon the free metals) and the other bodies which are found present. But in consequence of the different conditions tho acetylene would not exist, as has been proved by my recent experiments.

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a *C. Rendus*, lxxix, 320; Dingler, ccxiv, 130; C. N., xxx, 154.
b *N. Jahrbuch f. Pharm.*, xxxvii, 187; Chem. C. Bl., 1872, 588.
c T. P. S. E. (3), viii, 463; J. C. S., xxxiv, 355.
d B. D. C. G. B., 1879, 2186; C. N., xli, 284.

In its place we obtain either the products of its condensation, which approach the bitumens and tars, or the products of the reaction of hydrogen upon those bodies already condensed; that is to say, more hydrogenated carbides. For example, hydrogen reacting upon the acetylene, engenders ethylene and hydride of ethylene. A new reaction of the hydrogen either upon the polymeres of acetylene or upon those of ethylene would engender formenic carbides, the same as those which constitute American petroleum. An almost unlimited diversity in the reaction is here possible, according to the temperature and the bodies present.

We can thus imagine the production by a purely mineral method of all the natural carbides. The intervention of heat, of water, and the alkali metals, together with the tendency of the carbides to unite with each other to form matters more condensed, are sufficient to account for the formation of these curious compounds. Their formation could thus be effected in a continuous manner, because the reactions which give birth to them are continually renewed. This hypothesis is susceptible of further development, but I prefer to dwell within the limits authorized by my experiments without wishing to announce other than geological possibilities. (*a*)

Continuing the same line of experimentation and argument, in 1869 M. Berthelot thus concludes another article:

In the preceding experiments wood, charcoal, and coal are changed into petroleum. * * * If one accepts either origin for petroleum that I have just mentioned, he is led to conceive the possibility of an indefinite formation of these carbides, whether they be relegated to an organic origin, and in consequence to the enormous mass of *débris* buried at an inaccessible depth, or whether they be relegated to a purely mineral origin, and in consequence to the incessant removal of the generative reactions. (*b*)

He further applies this hypothesis to the origin of the carbonaceous matter in the meteorite of Orgueil and other meteorites. (*c*)

In 1871 M. H. Byasson read a paper before the French Academy, which he concludes as follows:

The question of the origin of petroleum has already produced four or five different theories. In a research that certain considerations have led us to undertake, we have, by causing carbonic acid and water to react under very simple conditions, obtained a small quantity of an inflammable liquid nearly indifferent to sulphuric acid, and with an odor analogous to that of the carbides of petroleum. * * * The substances that we cause to react upon each other being widely distributed upon the globe, it will perhaps be possible to formulate a new theory of the formation of petroleum, to correllate it with the elevation of mountains and volcanic eruptions, and to group together several important facts prominent in the history of the earth. (*d*)

M. Byasson causes steam, carbonic acid, and iron at a white heat to react upon each other, and provides the requisite conditions in nature by assuming that sea-water penetrates the terrestrial crust and comes in contact with metallic iron at a white heat and at great depths beneath the surface.

In 1877 Messrs. Friedel and Crafts produced the hydrocarbides and acetones by a complex reaction, in which chloride of aluminum performed the essential part. (*e*)

On the 25th of February, 1877, M. Mendeljeff read a paper on the origin of petroleum before the Chemical Society of Saint Petersburg, which has been very widely noticed. I give below a translation of a *résumé* which appeared in the correspondence of the Chemical Society of Paris, and which is printed in its bulletin:

The appearance of springs of petroleum at the surface of the earth shows the tendency of those mineral oils to traverse by infiltration the different strata of the earth in reaching the surface, a natural consequence of their lower density as compared with water. The place where petroleum originates ought then to be situated beneath the strata where the springs themselves are found. The beds furnishing the mineral oil belong in general to several very different formations of the earth's strata. Thus in the Caucasus the petroliferous zone is formed in the Tertiary; in Pennsylvania, in the Devonian, and even Silurian. The place of the formation of the petroleum ought then to be sought in older strata. The sandstones impregnated with petroleum have never exhibited the carbonized remains of organisms. In general, petroleum and carbon are never found simultaneously; but it is difficult to suppose that petroleum resulted from the decomposition of animal and vegetable organisms, because it would be then impossible to represent the origin of petroleum without a corresponding formation of carbon. On the other side, it is impossible to imagine the existence of great quantities of organisms in the epoch preceding the Silurian and Devonian. These reflections have led the author to the supposition that petroleum is in no place of organic origin. In speaking of the hypothesis of La Place upon the origin of the earth, in applying Dalton's law to the gaseous state in which all the elements constituting the terrestrial globe ought to be found, and taking into consideration their relative densities, M. Mendeljeff recognizes the necessity of admitting a condensation of metals at the center of the earth. Among these it is natural to presume iron would predominate, because it is found in great abundance in the sun in meteorites and basalts. Admitting further the existence of metallic carbides, it is easy to find an explanation not only for the origin of petroleum, but also for the manner of its appearance in the places where the terrestrial strata, at the time of their elevation into mountain chains, ought to be filled with crevices to their center. These crevices have admitted water to the metallic carbides. The action of water upon the metallic carbides at an elevated temperature and under a high pressure has generated metallic oxides and saturated hydrocarbons, which, being transported by aqueous vapor, have reached those strata where they would easily condense and impregnate beds of sandstone, which have the property of imbibing great quantities of mineral oil.

This explanation of the origin of petroleum finds support from the following facts: The predominance at the surface of the earth of elements having a small atomic weight; the appearance of petroleum in directions corresponding to great circles; the relation remarked by several naturalists, particularly by M. Abich, between petroleum and volcanic manifestations.

In order to make this question clear, it is indispensable to study the different transformations of petroleum, its decomposition into marsh-gas and non-saturated hydrocarbons; of determining the chemical nature of mineral oils of different origin; also that of the saline water that ordinarily accompanies petroleum. Researches of this kind, in connection with profound geological studies, can alone render justice to the hypothesis stated above. (*f*)

In 1877 Mr. Clœz succeeded in obtaining hydrocarbons resembling certain constituents of petroleum as a result of the action of dilute sulphuric acid on a carbide of iron and manganese (spiegeleisen). The next year, by

a *Ann. de Chim. et de Phys.*, Dec., 1866.
b B. S. C. P., xi, 278.
c C. R., lxvii, 849.
d C. R., lxxiii, 609.
e C. R., lxxxv, 74.
f B. S. C. P., 1877, 501.

using a carbide richer in manganese, he succeeded in producing the reaction with boiling water and obtained the oils as before. In concluding his paper on the subject he regards his results as a sufficient basis for an hypothesis by which to account for the origin of petroleum. (*a*)

In 1878 M. Fr. Landolph succeeded in obtaining these oils by an exceedingly complex process, in which he used fluoborates, affirming that "it is the great energy (affinity) of boron for the elements of water that ought to provoke those classes of reaction and permit us to obtain synthetically a great number of carbides of hydrogen with great facility". (*b*)

These chemical theories are supported by great names, and are based on the most complete and elaborate researches; but they require the assumption of operations nowhere witnessed in nature or known to technology.

I quote here a passage which I wrote in 1867, soon after M. Berthelot's original article, above quoted, first appeared:

The theory of M. Berthelot appears to me to derive less support from observed facts than any which has been proposed. It was doubtless formed with reference to the petroleums of Pennsylvania, which are among the purest mineral hydrocarbons of any found in large quantities. The very small proportion of nitrogen existing in these oils might perhaps be accounted for as an accidental constituent of the limestone, or as being mechanically mingled with the watery vapor. Neither supposition is at all probable, since nitrogen possesses such slight affinities. It adds nothing to its support to admit that the alkali metals do exist in the interior of the earth in the free state. (*c*) The very great difference observed between the varieties of petroleum (*d*) cannot be explained upon any hypothesis that regards them as the results of the same process acting upon like materials; neither should it be expected that a process yielding an almost "unlimited diversity" of products, under slightly varying circumstances, would furnish a uniform result over a very wide area. Samples of Pennsylvania petroleum of the same density, when gathered from widely separated localities, furnish identical (*e*) results upon analysis; so, too, do California petroleums, though gathered from localities 50 miles apart; and yet the two varieties of oil are exceedingly unlike. "It is, moreover, altogether erroneous to attempt to explain the causes of geological facts by the aid of supposed analogies with the complex apparatus of physical cabinets, whose existence in nature could scarcely be conceived by the boldest and most unrestrained imagination." (*f*)

The most conspicuous advocate of the theory that petroleum is a product of chemical reaction, by which marsh-gas is converted into more condensed hydrocarbons, appearing as fluid, viscous, and solid bitumens, is M. Coquand, who has so fully written upon the occurrence of bitumen in Albania and Roumania. He found mud volcanoes associated with the occurrence of petroleum in Sicily, the Apennines, the peninsula of Taman, and the plains of Roumania, and concluded that mud volcanoes produced petroleum and other forms of bitumen by converting marsh-gas into more condensed hydrocarbons. The following passage gives a summary of his opinions:

If the Carpathians have shown me only mineral oils in the state of naphtha more or less charged with tarry matters, and sometimes, but rarely, glutinous bitumen, that is to say, in the first stage of its existence and transformation, Selenitza ought to show me the same phenomena brought to the extreme limit of exhaustion; that is to say, bitumen reduced to a solid substance, incapable of spontaneous decomposition and of engendering new derivative products. It is rational to conclude that the history of that substance consists of two distinct evolutions, of which the first has for the principal theater of its active life North America and the Carpatho-Caucasian region, and the second the coasts of the Black sea and lower Albania, and as occupying an intermediate position between the two extreme states, which represent birth and death, we will mention glutinous bitumen, an intermediate and unstable substance through which petroleum passes, having lost its primitive fluidity and acquired that consistence which ought always to preserve it, which might be called the period of old age and decrepitude. (*g*)

M. Grabowski, in an article on ozokerite, having advanced similar opinions with reference to marsh-gas, says:

Very little is known about its formation. It appears to me to be very probable that it has to be considered as a product of the oxidation and condensation of the petroleum hydrocarbons. * * * By this hypothesis the formation of petroleum may be reduced to an oxidation of marsh-gas, and thus the close connection between ozokerite, petroleum, and coal be explained in the most simple manner. (*h*)

No adequate representation of the reaction is given. C. H. Hitchcock has supported similar views. (*i*)

It may be said, in reference to this theory, that, in so far as it expresses the fact that maltha represents an intermediate stage in the transformation of petroleum into asphaltum and recognizes the chemical relation existing between marsh-gas and the petroleum compounds, it is entitled to consideration; but in the chemical processes of nature complex organic compounds pass to simpler forms, of which operation marsh-gas, like asphaltum, is a resultant, and never the crude material upon which decomposing forces act.

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a C. R., lxxxv, 1003, lxxxvi, 1248; J. C. S., xxxiv, 481, 716.

b C. R., lxxxvi, 1267. Professor A. Wurtz has produced some of the constituent hydrocarbons of petroleum by the action of zinc ethyl on iodide of allyl, but with great forbearance he refrains from assuming that these reagents are found in the interior of the earth. C. R., liv, 387.

c This statement is equally true of spiegeleisen, etc.

d See Chapter IV.

e The word *identical* will not apply to the present condition of the Pennsylvania region as it did in 1867, but should be replaced by *similar*.

f P. A. P. S., x, 445. Quotation from Bischof: *Chemical and Physical Geology*; Cav. Soc. ed., i, 243.

g B. S. G. F., xxv, 35.

h Hübner's *Zeitschrift*, 1877, 83; *Am. Chem.*, vii, 123.

i *The Geo. Mag.*, iv, 34.

SECTION III.—THE THEORY THAT BITUMEN IS INDIGENOUS TO THE ROCKS IN WHICH IT IS FOUND.

The opinion that petroleum is indigenous to the rocks in which it occurs has been maintained with great vigor by Dr. T. S. Hunt and Professor J. P. Lesley, these gentlemen basing their views upon their observations in Canada, West Virginia, and Kentucky. Dr. Hunt, having found the fossiliferous limestones impregnated with petroleum, which is particularly abundant in the fossils themselves, therefore concludes:

The facts observed in this locality appear to show that the petroleum, or the substance which has given rise to it, was deposited in the beds in which it is now found at the formation of the rock. We may suppose in these oil-bearing beds an accumulation of organic matters, whese decomposition in the midst of a marine calcareous deposit has resulted in their complete transformation into petroleum, which has found a lodgment in the cavities of the shells and corals immediately near. Its absence from the unfilled cells of corals in the adjacent and interstratified beds forbids the idea of the introduction of the oil into these strata either by distillation or by infiltration. The same observations apply to the petroleum of the Trenton limestone, and if it shall hereafter be shown that the source of petroleum (as distinguished from asphalt) in other regions is to be found in marine fossiliferous limestones a step will have been made toward a knowledge of the chemical conditions necessary to its formation. (*a*)

In a paper published some years later the same gentleman says:

In opposition to the generally received view, which supposes the oil to originate from a slow destructive distillation of the black pyroschists belonging to the middle and upper divisions of the Devonian, I have maintained that it exists, ready formed, in the limestones below. All the oil-wells of Ontario have been sunk along denuded anticlinals, where, with the exception of the thin black band sometimes met with at the base of the Hamilton formation, these so-called bituminous shales are entirely wanting. The Hamilton formation, moreover, is more oleiferous, except in the case of the rare limestone beds, which are occasionally interstratified. Reservoirs of petroleum are met with both in the overlying quaternary gravels and in the fissures and cavities of the Hamilton shales, but in some cases the borings are carried entirely through these strata into the corniferous limestone before getting oil. A well was sunk at Oil Springs to a depth of 456 feet from the surface and 70 feet into the solid limestone beneath the Hamilton shales before meeting oil. (*b*)

He says further, in support of this opinion:

In this (the Trenton) we meet for the first time with petroleum, though in much less abundance than in the higher rocks. In the township of Packenham, the large orthoceratites of the Trenton limestone sometimes hold several ounces of petroleum in their chambers, and it has been met with under similar conditions in Lancaster. It has also been observed to exude from the fossil corals of the Birdseye limestone at Riviére à la Rose (Montmorency). The limestones of this group, which are generally more or less bituminous to the smell, are peculiarly so in some parts of the county of Montmorency, and not only give off a strong odor when struck, but when burned for lime evolve an abundant bituminous vapor on the first application of heat. The lithològical representative of the Trenton group next appears in the corniferous formation, composed, like the former, of pure limestones, with chert beds, silicified fossils, and petroleum. * * * It is in the Lower Devonian limestone, or corniferous formation, that the greatest amount of petroleum occurs, although Mr. Hall observed that the dolomites of the Niagara formation in Monroe county, New York, frequently contain mineral pitch, which is sometimes so abundant as to flow from the rock when this is heated in a lime-kiln. Concretionary nodules holding petroleum have also been observed in the Marcellus and Genesee slates, while the higher Devonian sandstones in New York and Pennsylvania are often impregnated with petroleum, and from these and from still higher strata issue the oil-springs of those regions. It is probable, however, that the source of the oil in these superior strata is to be found in the corniferous limestone, from which the petroleum of western Canada is undoubtedly derived. * * * In the township of Rainham, on lake Erie, the shells of *Pentamerus aratus* are sometimes found to have an inner cavity, lined with crystals of calcite and filled with petroleum. Coralline beds impregnated with petroleum are found at Wainfleet and in Walpole, in the latter instance immediately beneath a layer of chert; but I have more particularly examined them in the township of Bertie, which is on the Niagara river opposite Buffalo. Here in a quarry are seen massive beds, slightly inclined, composed of a solid, crystalline, encrinal limestone, which appears not only destitute of petroleum, but, from the water by which it is impregnated, to be impermeable to it. In some of the beds are large corals of the genus *Heliophyllum*, the pores of which are open but contain no oil. Two beds, however, one of 3 and one of 8 inches, which are interstratified with these, are in a great part made up of species of *Heliophyllum* and *Favosites*, the cells of which are full of petroleum. This is seen in freshly-broken masses to be absent from the solid limestone, which forms the matrix of the corals, and resembles in texture the associated beds. As the fractured surfaces of the oil-bearing beds become dry, the oil spreads over them, and thus gives rise to the appearance of a continuous band of dark oil-stained rock, limited above and below by the lighter limestone, from which, however, it is separated by no planes of bedding. The layer of 3 inches was seen to be twice interrupted in an exposure of a few feet, thus presenting lenticular beds of the oil-bearing rock. Beside the occasional specimens of *Heliophyllum* without oil disseminated in the massive limestone, a thin and continuous bed of *Favosites* is met with, which is white, porous, and free from oil, although beds above and below are filled with it. It was in the weathered outcrop of one of these that was obtained the specimen in the cells of which was found the infusible and insoluble product of the oxidation of petroleum. When the oil-bearing beds are exposed in working the rock the oil flows out and collects on the water of the quarry. The facts observed in this locality appear to show that the petroleum, or the substance that has given rise to it, was deposited in the bed in which it is now found at the formation of the rock.

In the easternmost part of North America, and at the extremity of the peninsula of Gaspé, petroleum is again met with issuing from sandstones which belong to the base of the Devonian series. Beds of thickened petroleum, like those of Enniskillen, are here met with. Near to cape Gaspé there is a remarkable dike of amygdaloidal trap, 10 or 12 yards in breadth, the cavities of which are often lined with chalcedony or with crystals of calcite and quartz. Many of these cells are filled with petroleum, which in some cases has assumed the hardness of pitch. (*c*)

Petroleum occurs saturating a stratum 35 to 40 feet thick about midway in the Niagara formation at Chicago, Illinois, the rock being so filled with petroleum that blocks of it which have been used in buildings are discolored by the exudations, which, mingled with dust, form a tarry coating upon the exposed surfaces. Though thus discolored, when freed from the bitumen, this rock is a nearly white, crystalline dolomite. An illustration of the effect of this exudation was to be noticed in one of the largest churches in Chicago before the great fire.

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a A. J. S. (2), xxxv, 168. *b* *Ibid.*, (2), xlvi, 361. *c* A. J. S. (2), xxxv, 157.

Dr. Hunt estimated the amount of oil held in the Niagara limestone of Chicago, and found it to be 4.25 per cent., an amount rather beneath the average. He continues:

A layer of this oleiferous dolomite, 1 mile (5,280 feet) square and 1 foot thick, will contain 1,184,832 cubic feet of petroleum, equal to 8,850,069 gallons of 231 cubic inches, and to 221,247 barrels of 40 gallons each. Taking the minimum thickness of 35 feet assigned by Mr. Worthen to the oil-bearing rock at Chicago, we have in each square mile of it 7,743,745 barrels, or, in round numbers, 7,750,000 barrels of petroleum. * * * With such sources existing ready formed in the earth's crust, it seems to me, to say the least, unphilosophical to search elsewhere for the origin of petroleum, and to suppose it to be derived by some unexplained process from rocks which are destitute of the substance. (*a*)

In reply to a letter of inquiry, Professor James M. Safford thus writes regarding the occurrence of petroleum in the neighborhood of Nashville, Tennessee:

In the limestone rocks of Nashville, representing those of the Silurian basin of middle Tennessee, and of course Silurian (lower), geodes or geode cavities in certain horizons are quite common. They are mostly calcite geodes, or cavities lined with crystals of calcite. Sometimes there is nothing but the calcite crystals within; then we have a lining of calcite crystals with dolomite, gypsum, anhydrite, often cleavable, and occasionally fluorite within. I have seen all of these minerals in one. Imperfect quartz geodes lined with quartz crystals occasionally occur. Barite and celestite and baryto-celestite occur together, and sometimes fluorite occurs with these. In a certain horizon there are many geode cavities lined with calcite crystals and containing within beautiful crystals of celestite, white and beautifully blue. Cavities occur containing celestite which are not lined with calcite crystals, and it is not uncommon to meet with geode cavities in our limestones lined with calcite crystals and containing more or less petroleum. I have seen as much as half a pint or even more in them.

There appears to be little room to doubt that the petroleum in these geodes is indigenous to the Nashville limestone.

The Clinton limestones of Ohio, lying immediately above the Cincinnati group and over the whole northern border of the Cincinnati anticlinal, contains petroleum in small quantities, but nowhere sufficient in amount to be of economic value. (*b*)

In the description of the method of "the existence of the petroleum in the eastern coal-field of Kentucky" Professor J. P. Lesley says:

At Old Oil Springs, on the south fork of Paint creek, a black reservoir of tar-like oil here occupies the center of a sloping bog, and is kept always full from a spring at its upper limit, near the top of the slope and foot of the cliffs, about 20 feet above the level of the stream. Fig. 3 shows the conformation of the ground, *a* the spring, *b* the reservoir, *c* the bed of Paint creek, *d* conglomerate No. XII. (*c*)

A mile farther down the stream, but on the opposite or right bank, and apparently 35 or 40 feet above the water, on a steep slope close under the projecting cliffs, is a similar spring, which has not produced any extensive bog for want of a level receptacle, but has yielded "large quantities" of oil in past years, and from which petroleum continues to run slowly all of the time. Fig. 4 shows the contour of the ground and the overhanging cliffs at two places near the spring. Three miles farther down the stream, and within a mile or less of its junction with the north or Open fork at Lyon's well, the oil is to be seen coming from the edge of the coal and ore-shales, just under the cliffs, which here tower to an amazing height. Fig. 5 represents in a formal manner this section and a pile of conglomerate crag called the Crow's Nest, between 100 and 200 feet high. There are here, immediately underneath the lowest plate of conglomerate (20 feet thick), 5 feet of shales, then 2 feet of yellow sandstone, then 1½ to 3 inches of ball ore, then black and blue slates to the creek level. A mile or two up the creek there are in these black slates two distinct beds of coal, 6 feet apart, the upper 10 inches, the lower 24 inches thick; and oil flows from them continually in small quantities. At Davis, where the road crosses Paint creek, just below the mouth of Little Glade run, the conglomerate being here 230 feet thick and the streams flowing from the bottom of it between straight vertical walls, the black petroleum is perpetually welling out, not only from under the conglomerate, but from crevices in the bare faces of the rocks, accompanied, as elsewhere, by yellow peroxide of iron.

It is evident from the description given above—and the same description will answer for a large number of similar springs in the numerous gorges through which the Licking waters find their way westward into the Blue Grass country of middle Kentucky—that the petroleum of the oil-springs of Paint creek (*d*) has had its home in the great conglomerate at the base of the coal measures; still has, we may say, for it is still issuing in apparently undiminished quantities from the same. A conglomerate age or horizon of petroleum exists. This is the main point to be stated, and must be kept in view, apart from all other ages or horizons of oil, whether later or earlier in order of geological time. The rock itself is full of the remains of coal plants, from the decomposition of which the oil seems to have been made. I noticed in the great rock pavement at Lyon's well, over which the creek water flows, many sections of tree branches and stems mashed flat, each section being, say, 6 inches long by one-eighth of an inch wide in the middle, and when a jack-knife was thrust down into the slit, so as to clear it of mud, the black tarry oil would immediately exude and spread itself over the water. A pointed hammer spalling off flakes of the rock on each side showed not only that the slit itself was full of thick oil, but that the whole rock was soaked with it, except along certain belts (an inch or less wide and very irregular), which for some unexplained reason remained free from oil. Some of the great blocks of rock that have fallen from the cliff too recently to be as yet decomposed are literally full of the marks of the broken macerated driftwood of that period. For hundreds of square miles this vast stratum of ancient sea sand is a thick packed herbarium of coal-measure plants. If the loose sands of the bank of Paint creek, derived, as they are, from this sand-rock, can at the present day receive and retain vast quantities of petroleum in spite of the perpetual washings to which they are subjected, we can easily conceive of the wide, flat, sandy shores of the coal islands of the ancient archipelago of the coal era becoming completely charged with the decomposed and decomposable reliquiæ of both the plants of the land and the animals of the sea. (*e*)

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It is as yet beyond our ability to distinguish the several original sources of the petroleum obtained at different depths from any one well. The specific gravities of the oil, decreasing with the increase of depth, is a fact which shows conclusively that a chronic evaporation or distillation of the whole mass of oil in the crust of the earth (within reasonable reach of the surface) has always been, and is still, going on, converting the animal and plant remains into light oils, the light oils into heavy oils, the heavy oils into asphalt or albertite, the process being accompanied at every stage with the liberation of gas. Therefore the quantities of lubricating oil coming out from the

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a A. J. S. (3), i, 420.

b Professor Edward Orton in a communication to S. F. Peckham.

c P. A. P. S., x, 39.

d Professor Lesley appears to regard the name "Paint creek", as suggested by the iridescent film of petroleum floating on the water.

e P. A. P. S., x, 39.

conglomerate along the valleys of Paint creek prove the existence of immense quantities back from the cliff in the rock itself under all the highlands. And for the same reason the heavy oils obtained first from Lyon's and Donnell's and Warner's wells, followed by lighter oils from a greater depth, prove the existence of yet uncalculated quantities of still lighter oils at still greater depths, and of a world of gas-pressure which ought to make its presence known whenever there have been rents in the crusts, down-throws, fallings-in, or serious slopings of the stratification; in a word, any sort of natural vent. (*a*)

The paper from which these extracts are taken was read before the American Philosophical Society, April 7, 1865. It expresses the opinion of which Professor Lesley has been one of the strongest advocates, that the petroleum of the Appalachian system is indigenous to the rocks in which it is found. It is to be inferred, however, that his views as related to the origin of the petroleum found in northwestern Pennsylvania have become somewhat modified, although in precisely what manner is not clear. In the introduction to Report III of the *Second Geological Survey of Pennsylvania*, p. xv, Professor Lesley says:

The origin of petroleum is still an unsolved problem. That it is in some way connected with the vastly abundant accumulations of Paleozoic sea-weeds, the marks of which are so infinitely numerous in the rocks, and with the infinitude of coralloid sea animals, the skeletons of which make up a large part of the limestone formations which lie several thousand feet beneath the Venango oil-sand group scarcely admits of dispute, but the exact process of its manufacture, of its transfer, and of its storage in the gravel beds is utterly unknown. That it ascended rather than descended into them seems indicated by the fact that the lowest sand holds oil, when those above do not, and that upper sands hold oil when they extend beyond or overhang the lower.

If I understand Professor Lesley, these later statements, as well as that quoted regarding the chronic distillation that has always been, and still is, going on, express his opinion respecting the changes that convert the original petroleum content of the rocks into the different varieties of petroleum now met with, rather than the origin of the petroleum itself.

Professor T. Rupert Jones examined the asphaltic sand or rock of Trinidad, and found that when it is boiled several times in spirits of turpentine "it loses its bitumen and resolves itself into loose orbitoides and nummulinæ, with a few other foraminifera, and (when cleaned by acid) a small proportion of green-black sand and a very few rounded grains of quartz". (*b*)

In a paper on the "Geology of a part of Venezuela and Trinidad" Mr. G. P. Wall describes the occurrence of bitumen as follows:

The asphalt of Trinidad is almost invariably disseminated in the upper group of the "Newer Parian".(c) When *in situ* it is confined to particular strata, which were originally shales containing a certain proportion of vegetable *débris*. The organic matter has undergone a special mineralization, producing bituminous in place of ordinary anthraciferous substances. This operation is not attributable to heat, nor to the nature of distillation, but is due to chemical reaction at the ordinary temperature and under the normal conditions of the climate. The proofs that this is the true mode of generation of the asphalt repose not only on the partial manner in which it is distributed in the strata, but also on numerous specimens of the vegetable matter in process of transformation and with the organic structure more or less obliterated. After the removal by solution of the bituminous material, under the microscope a remarkable alteration and corrosion of the vegetable cells becomes apparent, which is not presented in any other form of the mineralization of wood. A peculiarity attending the formation of the asphalt results from the assumption of a plastic condition, to which property its frequent delivery at the surface is partly referable; where the latter is hollow or basin-shaped, the bitumen accumulates, forming deposits such as the well known Pitch lake. Sometimes the emission is in the form of a dense oily liquid, from which the volatile elements gradually evaporate, leaving a solid residue. Mineral pitch is also extensively diffused in the province of Maturin, on the main (the other districts of the llanos were not sufficiently examined to determine its existence, which, however, is generally affirmed), and in still larger quantities near the gulf of Maracaibo, on the northern shores of New Granada and in the valley of the Magdalena, where it probably is a product of the same Tertiary formation. (*d*)

In England petroleum has been observed in a peat bog, and the lower layers of the peat were compacted into a sort of bituminized mass, which has been described by E. W. Binney as follows:

The only remarkable feature connected with the upper bed of peat at Down Holland Moss is the western portion of it being covered up with a bed of sand, and being probably sometimes subject to an infiltration of sea-water. * * * These circumstances, added to the fact of petroleum being found most plentifully at the edge of the sand, lead to the conclusion that it is produced by the decomposition of the upper bed of peat under the sand.

The chemical process by which such singular effects have been produced is a subject more fitted for the consideration of the chemist than the geologist, but the author supposes that petroleum is the result of slow combustien in the peat, and has been produced by a process partly analogous to that which takes place in the distillation of wood in closed vessels, when, owing to a total absence of oxygen, the combiuation of hydrogen and carbon in the form of hydrocarbons is effected. (*e*)

Petroleum has also been observed dripping from shales overlying a highly bituminous coal; (*f*) also in limestone containing remains of crustacea. (*g*)

Concerning the origin of the petroleum of Shropshire, Arthur Aiken says:

The thirty-first and thirty-second strata are coarse-grained sandstone entirely penetrated by petroleum; are, both together, 15½ feet thick, and have a bed of sandy slate-clay about 4 feet thick interposed between them. These strata are interesting as furnishing the supply of petroleum that issues from the tar-spring at Coalport. By certain geologists this reservoir of petroleum has been supposed to be sublimed from beds of coal that lie below, an hypothesis not easily reconciled to present appearances, especially as it omits to explain how the

a P. A. P. S., x, 53.
b Q. J. G. S., xxii, 592.
c A South American Tertiary group.
d Q. J. G. S., xvi, 467.
e *Proc. Manchester Lit. and Phil. Soc.*, iii, 136.
f T. G. S. L. (2), v, 438.
g *Ibid.* (1), ii, 199.

petroleum in the upper of these beds could have passed through the interposed bed of clay so entirely as to leave no trace behind. It is also worthy of remark that the nearest coal is only 6 inches thick, and is separated from the above beds by a mass 96 feet in thickness, consisting of sandstone and clay strata, without any mixture of petroleum. (*a*)

The observations of Wall in Trinidad appear to establish beyond a doubt that the bitumen of that locality has been and is being produced from a peculiar decomposition of woody fiber. Bright and Priestwich both regard the petroleum of England as indigenous in the limestones and shales, and the testimony of Binney is conclusive as to its production from the decomposition of peat on Down Holland Moss.

Professor A. Winchell says:

It seems to have become established from recent (1866) researches that the petroleum of the Northwest not only accumulates in several different formations, but also originates from materials stored up in rocks of different geological ages from the Utica slate to the coal conglomerate, and perhaps the coal measures. (*b*)

Professor J. D. Whitney has suggested that the infusoria, the remains of which are so abundant in certain sedimentary rocks, are the original source of the petroleum occurring in them, and says:

In conclusion, it may be remarked that the marine infusorial rocks of the Pacific coast, and especially of California, are of great extent and importance. They occur in the coast ranges from Clear lake to Los Angeles. They are of no little economical as well as scientific interest, since, as I conceive, the existence of bituminous materials in this state, in all their forms, from the most liquid to the most dense, is due to the presence of infusoria. (*c*)

SECTION 4.—THE THEORY THAT BITUMEN IS A DISTILLATE.

Humboldt, in 1804, observed a petroleum spring issuing from metamorphic rocks in the bay of Cumana, and remarked:

When it is recollected that farther eastward, near Cariaco, the hot and submarine waters are sufficiently abundant to change the temperature of the gulf at its surface, we cannot doubt that the petroleum is the effect of distillation at an immense depth, issuing from those primitive rocks beneath which lie the forces of all volcanic commotion. (*d*)

The researches of Reichenbach led him to suggest, in 1834, that "when we remember that coal is so filled with the remains of plants that its origin has been attributed entirely to the destroyed vegetables of an early period, it must appear probable that petroleum was formed from such plants as afford these oils, and, in one word, that our mineral oil is nothing but turpentine oil of the pines of former ages; not only the wood, but also the needle-like leaves, may have contributed to this process, which is not a combustion, but is, I believe, simply the result of the action of subterranean heat." (*e*)

French writers generally have expressed their conviction that bitumens have resulted from the action of heat on strata containing organic matter.

In 1835 M. Rozet read a paper before the Société Géologique de France, in which he discussed the occurrence of asphaltic limestone at Pyrmont. He represents it as a mass of limestone not stratified, but crossed with fissures in all directions, and contains 9 to 10 per cent. of bitumen and pure carbonate of lime. The limestone is accompanied by a molass or a sort of breccia, consisting of gravel of quartz and schistose rocks cemented with asphalt. The molass contains from 15 to 18 per cent. of asphalt, but the bitumen extracted from the limestone and molass is identical. He continues:

The bituminous matter is found equally in the calcareous rock and the molass that covers it. It is evident that the action that introduced it into the two rocks is posterior to the deposition of the latter. The manner in which it disistributed in great masses, which throw their ramifications in all directions, joined in such a manner that the superior portions contain generally less bitumen than the remainder of the mass, indicate that the bitumen has been sublimed from the depths of the globe. * * * The nature of the bituminous rocks (molass, cretaceous limestone, and calcareous schist) admit perfectly of this sort of action. The molass and the limestone are so porous that they easily absorb water and the calcareous schist sticks to the tongue. Thus these rocks could have been easily penetrated by the bituminous vapors, which probably penetrated all three of them at the same time.

The epoch of the introduction of the bitumen into the preceding rocks being necessarily posterior to the deposition of the molass, it may be presumed that it corresponds to that of the basaltic eruptions which many facts prove to have been often accompanied with bituminous material. * * *

It may be objected that such basaltic rock does not appear in all the extent of the Jura. To that I reply that they are found in the neighborhood, in Burgundy and in the Vosges; and further, that in the changes in the surface of the soil, whether occasioned by fractures or by the disengagement of vapors, the plutonic rocks do not necessarily appear at the surface. Perhaps in the deep valleys of the Jura the basalts are at a very slight depth. * * * In the Val de Travers, near Neufchatel, similar phenomena are observed. (*f*)

In 1846 Mr. S. W. Pratt described the occurrence of bitumen at Bastenee, a small village in the south of France, 15 miles north of Orthez. The surrounding country is formed of small conical hills 200 or 300 feet high, separated by a coarse sandy limestone belonging to the cretaceous system. The upper part consists of variously colored sands and clays from 50 to 60 feet thick, the whole covered by gravel and sand, which in all directions

a T. G. S. L. (1), i, 195.

b A. J. S. (2), xli, 176.

c *Bul. Acad. Sci. San Francisco*, iii, 324. Dr. J. S. Newberry has lately erroneously attributed this theory to S. F. Peckham, *Ann. N. Y. Acad. Sci.*, ii, No. 9.

d *Humboldt's Travels*, III, 114, Bohn's ed.

e *Schweigger Seidel's Jahrbuch*, ix, 133; *Ph. Jour.*, xvi, 376.

f B. S. G. F. (1), vii, 138.

extends for many miles. These sands and clays are usually horizontal, but are occasionally disturbed and highly inclined. This is occasioned by the protrusion of igneous matter, which is there found in connection with them. The bitumen is worked in three localities near each other, and occurs in beds from 5 to 15 feet thick, which vary much in character, the upper part consisting of looser and coarser sand, with a less proportion of the bitumen, while the lower part is more compact, containing finer sand, and being chiefly composed of bitumen. The sands and clays contain no fossils except occasional pieces of lignite and bitumen, and are generally free from extraneous matters, except in two localities, where numerous shells are found which may be referred to the Miocene period. In one of these localities, where the bitumen bed is from 10 to 12 feet thick, the shells are disposed in numerous layers a few inches apart, those of the same kind generally forming distinct layers, though sometimes, where the layer is thicker, many species are found together; and where the mass has been cut through vertically the appearance is very striking, bright, white lines appearing on a black bed of bitumen. The shells are neither broken nor disturbed, but are perfectly preserved, nor are the valves separated; but, owing to the loss of animal matter, on being exposed to the air they fall into powder. Perfect casts may be readily procured, as they easily separate from the sandy mass. The bitumen has evidently been forced into them when in a soft or liquid state, as the smallest cavities are filled, and this must have taken place after their deposition in the sands in which the animals lived. The date of this formation, as indicated by numerous species, may be referred to the Miocene era; and as the eruption of bitumen is evidently connected with the appearance of the ophite, an igneous rock which has produced such great changes in the Pyrenees, a limit may thus be obtained for these changes. (*a*)

In a notice upon the occurrence of asphalt in the environs of Alais, published in 1854, M. Parran makes the following statements:

Whatever be the origin of these substances, whether they be due to interior emanations from fissures of dislocation or to circumstances exterior and atmospheric, it is evident that there was during the Tertiary period an asphaltic epoch (*époque asphaltique*) in relation to which it is convenient to recall the numerous eruptions of trachytes and basalts which characterize that period and have probably acted by distillation upon the masses of combustibles hidden in the bosom of the earth.

He further remarks that asphalt occurs between Mons and Auzon, and continues:

The lacustrine formation, of which we have studied the bituminiferous part, is deposited in a vast depression of the secondary formation (*terrains*), represented here by the lower cretaceous and chloritic formations (*néocomienne et chloriteés*).

M. Parran concludes as follows:

Emanating by distillation from beds of combustible material inclosed in the inferior Cretaceous (*néocomienne*) formation or perhaps in the Carboniferous, if, as is probable, they extend to that place, the bitumen is raised in the midst of the fresh-water limestones (*calcaires d'eau douce*); there it is fixed by imbibition. Hot springs and sulphur springs abound in the vicinity. (*b*)

In 1868 M. Ch. Knar published an article on "The theory of the formation of asphalt in the Val de Travers, Switzerland". His conclusions are:

1. Asphalt (limestone impregnated with bitumen) is due to the decomposition in a deep sea of beds of mollusks, the decomposition taking place under a strong pressure and at a high temperature.

2. The free bitumen is formed also by the decomposition of certain mollusks or crustaceans in a sea of little depth, at a high temperature, but under an insufficient pressure to make this bitumen impregnate the oyster shells (*pour former ce bitume à imprégner les coquilles d'huitre*).

3. Petroleum is due to the decomposition under water of mollusks, a decomposition which has taken place at a temperature too low to transform it into bitumen (asphalt), but under a pressure more or less considerable.

4. The beds of white limestone formed also by the accumulation of fossil oysters, and which contain neither asphalt nor petroleum, have been formed under such conditions that the products of the decomposition of animal organic matter have been evaporated.

5. Finally, combustibles only, or pyroschists (*bitumés fixes*), have been formed by the decomposition of plants, while all the preceding are of animal origin. (c)

In 1872 M. Thoré published a paper on the "Presence of petroleum in the water of Saint Boés (Basses-Pyrénées)", in which he says "petroleum floats on the water of the springs, and the rocks are saturated with it", and continues:

The comparison of observations seems to indicate in the department of the Basses-Pyrénées between the lower and middle Cretaceous formations a considerable impregnation of petroleum, due probably to igneous action or an eruption of ophite. The more this origin is examined the more one is convinced, because the greater part of the deposits of petroleum which prove valuable to the countries in which they are found are evidently related to the rocks of igneous origin, which may be considered as being the principal cause of its formation, or, at least, of the appearance of mineral oil. (*d*)

In 1837 M. Dufrenoy showed that the change from colored to white marble in the Pyrenees was due to the expulsion of bitumen by heat. (*e*) It is also maintained that jet is a distillate. (*f*)

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a Q. J. G. S., ii, 80.

b *Ann. des Mines* (5), iv, 334. $(C_aSO_4)_2 + C_3 = (C_aCO_3)_2 + CO_2 + S_2$. The hydrogen of the bitumen also becomes oxidized and H_2S is formed.

c *Mon. Sci.*, 1868, 381.

d *L'Année Sci. et Ind.*, 1872, 251.

e B. S. G. F. (1), ix, 238.

f Simpson. San Franciso Min. and Sci. Press, 1874, 246.

One of the most noted papers on petroleum that has appeared in the United States was published by Dr. J S. Newberry in 1859. In this paper he says:

The precise process by which petroleum is evolved from the carbonaceous matter contained in the rocks which furnish it is not yet fully known, because we cannot in ordinary circumstances inspect it. We may fairly infer, however, that it is a distillation, though generally performed at a low temperature.

We know that vegetable matter—and the same may be said of much animal tissue when the conservative influence of life has ceased to act—if exposed to the action of moist air, is completely disorganized by a process which we call decay, which is in fact combustion or oxidation. This change takes place slowly, and without evolution of light and heat, the usual accompaniments of combustion, in a degree appreciable by our senses.

When, however, carbonaceous organic tissue is buried in moist earth or submerged in water oxidation does not at once ensue, or at least takes place to a limited extent, measured by the amount of oxygen present. In these circumstances bituminization takes place. This process consists mainly in the union of hydrogen, from the tissue itself or its surroundings, with a portion of the carbon, to form carbureted hydrogen, which perhaps escapes, and the hydrocarbons constituting the bitumen, which usually remains as a black, pitch-like mass, investing the fixed carbon. By this process peat, lignite, and coal are formed, which are solids, and doubtless some liquid and gaseous hydrocarbons which escape. Now, when we heat these solid bitumens artificially at a sufficiently high temperature, if in contact with oxygen, combustion ensues, and water and carbonic acid are formed from them. At a lower temperature they are converted into gaseous hydrocarbons; still lower to oils. (*a*)

In an article published by Professor E. B. Andrews in 1861 he calls attention to the fact that the town of Newark, Ohio, has been for several years lighted by the uncondensed gas from the coal-oil manufactories, and infers that in the spontaneous distillation of bituminous substances a large amount of gas must be generated along with the oil. He refers to the theory which had been recently brought forward by Dr. Newberry, and says:

The chief objection to it is the fact that the coal, cannel and bituminous, in our oil regions gives no evidence of having lost any of its full and normal quantity of bitumen or hydrocarbons. For example, at Petroleum, Ritchie county, Virginia, where strata have been brought up by an uplift from several hundred feet below, seams of cannel and bituminous coal appear, which, if judged by the standard of Nova Scotia or English coals, have lost none of their bituminous properties. * * *

The other theory, that the oil was produced at the time of the original bituminization of the vegetable or animal matter, has many difficulties in its way. If the oil were formed with the bitumen of the coal, we should expect that wherever there is bituminous coal there would be corresponding quantities of oil. This is not so, in fact; for there is no oil, except in fissures in the rocks overlying the bituminous strata. * * * Again, upon this theory, it will be difficult to explain the large quantities of inflammable gas always accompanying the oil. If it is generated exclusively from the oil, then we should expect to find the quantity of the oil least where the gas-springs have for ages been most active, but at such places the oil, instead of being wasted, is most abundant. (*b*)

The distinguished French geologist, Daubrée, had published the previous year his *Studies upon Metamorphism*, in which he had discussed the relation of bituminous substances to metamorphism as follows:

Bitumens and other carbides of hydrogen, according as their state is solid, liquid, or gaseous, whether impregnating beds, flowing as petroleum, escaping from the soil, as in salses, mud volcanoes, burning springs, etc., are in general only the vent-holes (èvents) of deposits of bitumens. The different deposits of bitumen present as general or at least remarkably frequent characteristics:

1. Association with saline formations.
2. Being situated in the neighborhood of deposits of combustible minerals, or strata charged with vegetable *débris*.
3. Being associated with igneous accidents, ancient or modern; that is to say, with volcanoes or irruptive rocks, or with dislocated strata.
4. Frequently accompanying thermal springs, often sulphurous, and deposits of sulphur. (*c*)

Several of my experiments account for these relations. In submitting fragments of wood to the action of superheated steam I have changed it into lignite, coal, or anthracite, according to the temperature, and I have also obtained liquid and volatile products resembling natural bitumens and possessing the characteristic odor of the petroleum of Pechelbronn. It is thus that the presence of bitumen in certain concretionary metalliferous veins is accounted for; as, *e. g.*, Derbyshire, Camsdorf, and Raibl, in Carinthia.

Finally, bitumens are probably derived from vegetable substances; as it appears not to be a simple product of dry distillation, but to have been formed with the concurrent action of water, and perhaps under pressure, graphite being only the most exhausted (*épuisé*) product of these substances. These divers compounds of carbon are incident, then, to certain transformations which take place in the interior of the rocks, apparently under the influence of an elevated temperature. The activity and even the violence, at times capable of producing slight earthquakes, with which carbureted hydrogen has sometimes been associated in the Tauride, on the borders of the Caspian sea, and in the environs of Carthagena, in South America, prove that the action that has sometimes disengaged bitumen continues to the present time. (*d*)

SECTION 5.—AN ATTEMPT TO INCLUDE OBSERVED FACTS IN A PROVISIONAL HYPOTHESIS.

The studies which I have made upon petroleum, extending now over a period of more than twenty years, and especially those which I have made in preparing this report, lead me to the conclusion that as yet very little is known regarding its chemical geology. As no one has studied the chemical properties of different varieties of petroleum in relation to their geological occurrence in any effective manner, it would be extremely rash for any one to dogmatize with reference to the origin of bitumens. I am, however, led to state the conclusions that a careful survey of our available knowledge of the subject has enabled me to reach. I am convinced that all bitumens have, in their present condition, originally been derived from animal or vegetable remains, but that the manner of their derivation has not been uniform. I should therefore exclude both classes of chemical theories; the first as

a Rock Oils of Ohio; *Ohio Ag. Rep.*, 1859.

b A. J. S. (2), xxxii, 85.

c I have omitted the numerous illustrations.

d *Études sur le Métamorphisme*, p. 73. M. Daubrée adds in a note: "Graphite and bitumen are associated in Java in proximity to volcanic formations and a Tertiary lignite, from which jets of carbureted hydrogen escape."

impossible, the second as unnecessary. There remains the hypothesis that bitumen is indigenous in the rocks in which it is found and that which regards all bitumens as distillates, but whichever of these hypotheses be accepted, the modifying fact remains that there are four kinds of bitumen:

1. Those bitumens that form asphaltum and do not contain paraffine.
2. Those bitumens that do not form asphaltum and contain paraffine.
3. Those bitumens that form asphaltum and contain paraffine.
4. Solid bitumens that were originally solid when cold or at ordinary temperatures.

The first class includes the bitumens of California and Texas, doubtless indigenous in the shales from which they issue. It is also probable that some of the bitumens of Asia belong to this class.

I have described the conditions under which bitumens occur on the Pacific coast of southern California in great detail in the reports that I have made to the geological survey of that state, (*a*) the forms found there being almost infinite in gradation, from fluid petroleum to solid asphaltum; but I have been unable to obtain any information from the parties who are operating in Santa Clara county other than that contained in newspaper reports, which are too unreliable to be used in this connection. In Ventura county the petroleum is primarily held in strata of shale, from which it issues as petroleum or maltha, according as the shales have been brought into contact with the atmosphere. The asphaltum is produced by further exposure after the bitumen has reached the surface. These shales are interstratified with sandstones of enormous thickness, but I nowhere observed the petroleum saturating them, although it sometimes escaped from crevices in the sandstone; nor was the bitumen held in crevices of large size nor under a high pressure of gas, as the disturbed and broken condition of the strata, folded at very high angles, precluded such a possibility.

The relation of the asphaltum to the more fluid materials became a question of great importance to those engaged in prospecting for petroleum in that region in 1865 and later, and having made the solution of this problem a constant study for months, I finally came to the conclusion expressed above. My opinions were based on the following facts: a quantity of petroleum from the Cañada Laga spring remained in an open tank for fifteen months fully exposed to the elements, and increased 0.035 in specific gravity. Maltha has been obtained in wells so dense as to lead to their abandonment. Three attempts were made by the Philadelphia and California Petroleum Company to drill a well on the San Francisco ranch, and the greatest depth reached was 117 feet; but at that depth the maltha was so dense that it could not be pumped out, nor could it be drawn out with grappling-hooks, and was so tenacious as to clasp the tools so firmly as to prevent further operations. These wells were located near an asphalt bed on a gently sloping hillside, where the strata were very much broken and easily penetrated by rain-water. The Pico spring, yielding petroleum issuing from shales, overlaid with unbroken bands of thick sandstone, was only a short distance beyond in the same range of hills, and still further were several other localities, all yielding more or less fluid maltha from natural springs, wells, and tunnels. The density of the bitumen, however, was in every case in direct proportion to the ease with which rain-water could percolate the strata from which it issued. On the plains northwest of Los Angeles an artesian boring that penetrated sandstones interstratified with shale yielded maltha at a depth of 460 feet.

Perhaps that portion of the sulphur mountain lying between the Hayward Petroleum Company's tunnels in Wheeler's cañon and the Big Spring plateau on the Ojai ranch furnishes the most striking illustration of the occurrence of bitumens in this region. A section of the strata at this point is given in Fig. 6. From this section it will be perceived that there is a synclinal fold in the shale forming the mountain, and that the strata dip into the mountain on both sides. The belt of rock yielding petroleum on the south side, in which the tunnels are driven, is fully protected by from 700 to 800 feet of shale, while the mountain side is nearly perpendicular. On the opposite side, however, the belt comes to the surface, presenting the upturned edges over a nearly horizontal area. These tunnels yielded the lightest petroleum at that time obtained in southern California, while the maltha in the Big Spring that issued from the detritus covering the shale was so dense in December, 1865, that it was gathered and rolled into balls, like dough, and removed in that condition. (*b*)

The topography and stratigraphy of the coast ranges of Santa Barbara, Ventura, and Los Angeles counties are very complex. The Santa Barbara islands are volcanic, and lava-flows are described as having formed cascades over cliffs of sedimentary rocks as they descended into the sea. On the mainland no lava appears to have reached the surface, although between Las Posas and Simi, along the stage-road leading from San Buenaventura to Los Angeles, on an eroded plateau surrounded by low mountains, fragments of scoriæ are scattered over the ground. The coast ranges here appear to have been produced by parallel folds, each successively higher, by which enormously thick beds of sandstone, interstratified with shale, were thrust up at an angle of about 70°, producing parallel anticlinals. These anticlinals were subsequently eroded in such a manner as in many instances to produce valleys and plateaus, where the sandstones are broken through to the softer shales beneath. This is the case with the western extremity of the fold which, commencing at point Concepcion, extends eastward to Mount San Bernardino. West of the Sespé the sandstone crest has been completely removed and the shales cut away, until, at the Rincon, east of Santa Barbara, the erosion reaches the sea-level, and beyond, to the westward, the upturned edges of the shale form the bed of the ocean. The narrow plain on which Santa Barbara stands, lying between the

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a *Report Geological Survey of California:* Geology, II. Appendix, pp. 48–90.

b S. F. Peckham, Am. C., iv, 6.

Santa Iñez mountains and the sea, consists of Pliocene and Quaternary sands and gravels resting upon the eroded shales. East of the Rincon and mount Hoar the table-lands lying in the trough of the anticlinal gradually ascend until at the Sespé the sandstone caps the high mountain to the eastward, said to be the highest in that region. This range extends eastward, occasionally broken by transverse cañons, until, near the headwaters of the Santa Clara river, at the Soledad pass, it becomes merged in the San Rafael range, beyond the San Fernando pass.

Between point Concepcion and point Rincon, where the stratum of sand occurs saturated with maltha, (*a*) the latter has risen and floated on the sea and attracted the notice of travelers ever since that coast was known to Europeans. At point Rincon, where the anticlinal recedes from the coast, maltha rises and saturates the Quaternary sands. As the ascending plateau passes farther inland, we find in the line of hills east of mount Hoar and in the Santa Iñez mountains a line of outcrop of the bituminous strata on the east and west sides of the basin. East of the San Buenaventura river the local synclinal fold in the shale forming the sulphur mountain gives four lines of bituminous outcrop, shown on the section, Fig. 6*b*. In the cañons east of the Sespé, wherever the bituminous strata have been reached by erosion, tar-springs and asphalt beds are the result. The deeply eroded narrow valleys which cover the country east of Santa Barbara and south of the coast range present in a distance of a few miles the greatest lithological variations, and expose the bituminous strata under the greatest possible diversity of conditions. For this reason we meet here every possible form of bitumen in every possible degree of admixture, with pure sand, soil, detritus, and animal and vegetable remains.

The exceedingly unstable character of these petroleums, considered in connection with the amount of nitrogen that they contain and the vast accumulation of animal remains in the strata from which they issue, together with the fact that the fresh oils soon become filled with the larvæ of insects to such an extent that pools of petroleum become pools of maggots, all lend support to the theory that the oils are of animal origin. (*b*)

The second class of petroleums includes those of New York, Pennsylvania, Ohio, and West Virginia. These oils are undoubtedly distillates, and of vegetable origin. The proof of this statement seems overwhelming. Pennsylvania petroleum was examined in 1865 by Warren and Storer (*c*) in this country, and in 1863 by Pelouze and Cahours in France, (*d*) who found the lighter portion to consist of a certain series of hydrocarbons, identical with those obtained in the destructive distillation of coal, bituminous shales, and wood when the operation was conducted at low temperatures. Messrs. Warren and Storer also discovered that the same series of hydrocarbons could be obtained by distilling a lime soap prepared from fish-oil. (*e*) The experience of technology has shown that if coals or pyroschists are distilled at the lowest possible temperature, particularly in the presence of steam, a black tarry distillate is obtained, along with a considerable quantity of marsh-gas and very volatile liquids, that cannot be condensed except at low temperatures. If these distillates are redistilled, the second distillate may be divided into several different materials, beginning with marsh-gas and ending with very dense oils, heavily charged with paraffine. It is impossible to conduct this primary or secondary distillation without producing marsh-gas, but the amount and the density of the fluid produced will depend on the temperature at which the distillation is carried on and the rapidity of the process. The use of superheated steam is found to increase the quantity of the distillate, and to prevent overheating and the formation of other hydrocarbons than those belonging to the paraffine series.

The section compiled by Mr. Carll shows the Devonian shales above the corniferous limestone and below the Bradford third oil-sand to be 1,600 feet in thickness. This shale outcrops along lake Erie, between Buffalo, New York, and Cleveland, Ohio. It is for the most part the surface rock in the neighborhood of Erie, Pennsylvania, and southward to Union City, and no one can examine it without noticing the immense quantity of fucoidal remains that it contains. Professor N. S. Shaler discusses in much detail the extent and character of the Devonian black shale of Kentucky, and estimates it to cover 18,000 square miles at an average depth of 100 feet, and to yield on distillation 15 per cent. of fluid distillate. It is not necessary to follow him in his calculations of the enormous bulk of this distillate as represented in barrels; the important point in this connection is that it is a very persistent formation, being revealed by borings over a very wide area, and doubtless extends beyond the boundaries of Kentucky, eastward beneath the coal measures which contain the petroleum. (*f*)

If, however, the Devonian black shales are inadequate, both on account of extent and position, as a source of supply, we may descend still lower in the geological series to the Nashville limestone and other Silurian rocks that underlie that region. Professor Safford, in a recent letter, writes:

The Lower Silurian limestone in the basin of middle Tennessee is about 1,000 feet thick. I have divided it in my *Geological Report* into the Lebanon limestone (or division) and the Nashville, each about 500 feet, the Nashville being the upper division. Including the Upper Silurian limestones, the whole thickness of the limestones, in which are found occasionally little pockets or geodes and cavities of petroleum, is not far from 1,200 feet.

	Feet.
Upper Silurian	200
Lower Silurian (Trenton):	
Nashville limestones	500
Lebanon limestones	500

The most of the petroleum has been found in the upper part (the Nashville) of the Lower Silurian, as, for example, the larger cavities near or on the upper Cumberland river, in the neighborhood of the Kentucky line, both within Kentucky and Tennessee.

a See page 21.
b S. F. Peckham, P. A. P. S., x, 452.
c *Mem. Am. Acad.* N. Si., ix, 176; A. J. S., (2), xli, 139.
d *Ann. C. et P.* (4), 1, 5.
e *Mem. A. A. N. S.*, ix, 177.
f *Rep. Geo. Survey, Kentucky*, N. S., iii, 109.

These limestones underlie the whole petroleum region of southeastern Kentucky and middle Tennessee.

The objection urged by Professor Andrews, that the coals in the measures of West Virginia and Ohio among which these oils occur have lost nothing of their volatile content, is without force here. Professor Shaler (*Report of the Geological Survey of Kentucky*, new series, iii, 171) says:

The condition of the beds that lie below the black shale in the Cincinnati group or in the Niagara section show that there has been no great invasion of heat since the beds were deposited. Clays, which change greatly under a heat of 1,000° F., are apparently exactly as they were left by the sea, and beds retain their marine salts just as when they were deposited. Any great access of temperature in this deposit of the Ohio shale would have been attended by an almost equal rise of temperature in the coal-beds which lie within a few hundred feet above; but these coal-beds are free from any evidences of distillation or other consequences of heat. We have already seen reasons for supposing an erosion of some 3,000 or 4,000 feet of strata from this section; if we could reimpose this section we should probably bring up the temperature of these rocks by the rise in the isogeothermals, or lines of equal internal heat, about 60°. * * * We are not able to suppose that the accumulation of strata would have elevated the temperature above the boiling point of water.

The hypothesis which may be found to account for the formation of this coal-oil must take into consideration the impossibility of its generation at another point and its removal to this set of beds and the impossibility of supposing that it has been in any way the result of high temperatures.

The range of temperature between "the boiling point of water" and "1,000° F.", which is here allowed, is ample for all purposes of explanation.

Mendeljeff objects that "the sandstones impregnated with petroleum have never exhibited the carbonized remains of organisms. In general, petroleum and carbon are never found simultaneously". These three objections—first, that the supply of organic matter is inadequate; second, that there are no evidences of the action of heat upon the rocks holding the oil; third, that there are no residues of fixed carbon observed in the rocks holding the oil—are those which have appeared to satisfy those who do not accept the hypothesis that regards petroleum as a distillate. I think the first has been already answered. The second and third I shall now examine.

It is not the effects of heat, as represented by volcanic action, that have produced petroleum, although in one notable instance paraffine and other constituents of petroleum have been found in the lava of Etna. (*a*) A comparison of the analyses of the gaseous emanations of volcanoes with those of gas and petroleum springs shows that the former consist mainly of carbonic acid and nitrogen, while the latter consist mainly of marsh-gas. Bitumens are not the product of the high temperatures and violent action of volcanoes, but of the slow and gentle changes at low temperature due to metamorphic action upon strata buried at immense depths.

The extent of the Paleozoic formations of the Mississippi valley and the general conformation of the bottom of the ancient seas has been fully described by Professor James Hall, who says: (*b*)

In all the Lower Silurian limestones we trace the outcrop to the west and northwest from the base of the Appalachians, in New York or in Canada, to the Mississippi river, and thence still in the same northwesterly direction. * * * Instead of finding the lower Helderberg (Upper Silurian) strata in lines parallel with those of the preceding rocks, the relative direction of the main accumulation and the principal line of exposures is diagonally across the others. * * * The line of outcrop and of accumulation has been from northeast to southwest, and they occur in great force far to the northeast in Gaspé, on the gulf of Saint Lawrence. * * * The greatest accumulation of material in the period of the Hamilton, Portage, and Chemung groups (Lower and Middle Devonian) lies in the direction of the Appalachian chain. * * * In Gaspé there are 7,000 feet of strata, * * * while in western New York the whole together would scarce exceed 3,000 feet. We have therefore the clearest evidence that the strata thin out in a westerly direction. * * * In considering the distribution of the masses of the formations which we have here described we find that the greatest accumulations have been along the direction of the Appalachian chain. The material thus transported would be distributed precisely as in an ocean traversed by a current like our present Gulf Stream, and in the gradual motion of the waters during that period to the west and southwest the finer material would be spread out in gradually diminished quantities, till finally the deposit from that source must cease altogether. * * * I have long since shown that * * * the portion of the Appalachians known as the Green Mountain range is composed of altered sediments of Silurian age. * * * The evidences in regard to the White mountains, to a great extent, are of newer age than those of the Green mountains, or Devonian and Carboniferous. * * * The statements of Sir William Logan in regard to the great accumulation of strata in the peninsula of Gaspé, together with the observations of Professor Rogers in the Appalachians of Pennsylvania, lead to the inevitable conclusion that the sediments of this age must everywhere contribute largely to the matter forming the metamorphic portion of the Appalachian chain, as well as to the non-metamorphic zone immediately on the west of it.

Reference to Map III shows the manner in which the outlined areas that have yielded petroleum correspond to the trend of these deposits of sediment as described by Professor Hall.

It is not necessary here to discuss the nature or origin of metamorphic action. It is sufficient for our purpose to know that from the Upper Silurian to the close of the Carboniferous periods the currents of the primeval ocean were transporting sediments from northeast to southwest, sorting them into gravel, sand, and clay, forming gravel bars and great sand-beds beneath the riffles and clay banks in still water, burying vast accumulations of sea weeds and sea animals far beneath the surface. The alteration, due to the combined action of heat, steam, and pressure, that involved the formations of the Appalachian system from point Gaspé, in Canada, to Lookout mountain, in Tennessee, involving the carboniferous and earlier strata, distorting and folding them, and converting the coal into anthracite and the clays into crystalline schists along their eastern border, could not have ceased to act westward along an arbitrary line, but must have gradually died out farther and farther from the surface.

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a Silvestri, *Gaz. Chim. Ital.*, vii, 1; *Chem. News*, xxxv, 156; B. D., C. G., 1877, 293.
b *Nat. Hist. N. Y.*, Paleontology, iii, 45–60.

The great beds of shale and limestone containing fucoids, animal remains, and even indigenous petroleum, must have been invaded by this heat action to a greater or a less degree, and that "chronic evaporation" of Professor Lesley must have been the inevitable consequence.

Too little is known about petroleum at this time to enable any one to explain all the phenomena attending the occurrence of petroleum on any hypothesis; but it seems to me that the different varieties of petroleum, from Franklin dark oil, near the surface, to Bradford and Clarendon amber oil, far beneath the surface, are the products of fractional distillation, and one of the strongest proofs of this hypothesis is found in the large content of paraffine in the Bradford oil under the enormous pressure to which it is subjected. So, too, the great pools of oil in southern Kentucky are without doubt distilled from the geode cavities beneath and concentrated in superficial fissures of the rocks near the surface. The oil of the American well is very different in many respects from Pennsylvania oil; and that from the Phelps well, on Bear creek, Wayne county, Kentucky, has an odor identical with that of the petroleum of southern California, in that respect totally unlike the petroleum of West Virginia, and evidently an oil of animal origin that has not been subjected to destructive distillation.

If this hypothesis, which embraces all the facts that have thus far come within my knowledge, really represents the operations of nature, then we must seek the evidences of heat action at a depth far below the unaltered rocks in which the petroleum is now stored. We ought to expect to find the coal in its normal condition. We should not expect to find the carbonized remains of organisms in the rocks containing petroleum. As the metamorphic action took place subsequent to the carboniferous era, we should expect to find the porous sandstones of that formation in certain localities saturated with petroleum. We should expect a careful observer like General A. J. Warner to write concerning them:

Now, while these several sand rocks when they come to the surface contain calamites, stigmaria, and other fossil plants of the lower coal measures, they contain nothing from which petroleum could possibly have been derived. (*a*)

Moreover, we should expect to find these coal-measure sandstones and conglomerates on the western border of the heated area, where the thinning out of the deposits brought down the coal measures nearer the Devonian shales and Silurian limestones, first saturated with petroleum, and then, through ages of repose, gradually cut down by erosion into the cañons of Johnson county, Kentucky, and exhibiting all of the phenomena described by Professor Lesley.

The inadequacy of the scattered remains of plants in the coal-measure sandstones as a source of the petroleum that saturates them is shown by the following calculation:

Should the Mississippi send down one tree a minute for a century, with an average length of 40 feet and a foot in diameter, and these be laid together side by side at the bottom of the sea in a single stratum, they would only cover a space of 200 acres. Were it possible, which it is not, to compress and crystallize these lignites into one stratum 6 feet thick, they might then constitute a coal-bed covering 20 acres. All the forests of the Mississippi valley could not furnish to the sea from their river spoils during a hundred thousand years one of the anthracite coal-beds of Schuylkill county. (*b*)

M. Coquand gives the following *résumé* of the geological formations represented in Roumania:

The Tertiary formation in connection with the clays of the steppes constitutes a continuous and concordant system, in which may be distinguished at the base the nummulite beds representing the great Paris limestone.

1. The Superior Eocene, composed at its base of rock-salt, gypsum, saliferous slates, bituminous schists, and marls with menilites; and above of the "Flysch formation" properly speaking, consisting of alternations of micaiferous sandstones (*macigno*), of limestones (*albérèse*), and of argillaceous schists (*galestri*), this superior part being characterized by *Chondrites Targioni, intricatus, furcatus*, and by *alveolinus*, the ensemble corresponding to the fucoidal Flysch of Switzerland, the Apennines, Algeria, Sicily, the gypsums of Montmartre, and the saline and sulphurous gypsum of Sicily; also the rock-salt of the high plateau of Algeria.

2. The Miocene stage, which is the first level of petroleum in the Carpathians. The inferior part comprises at its base sandstones and saline slates, with *Cyrena convexa* and sandstones corresponding to those of Fontainebleau, the superior part of sandstones, slates, and limestones corresponding to the molass of Carry and Syracuse; also to the gypsum and rock-salt of Volterra, in Tuscany, and the province of Saragossa, to *Marinen Tegel und Sand* (*néogoène* of M. Haidinger); to the *terrain tertiaire miocène marin* of M. Abich; to the *terrain tertiaire inférieur* of M. de Verneuil. The superior part comprises slates and the *grés à congéries* with lignites, amber, and asphalt, and is characterized by *Paludina, Achatiformis, Congeria subcarinata*, Cardium, Souriéffé, etc., corresponding to the *Congerientschisten* of MM. Haidinger and Hauer (*partie supérieure de leur terrain tertiaire néogène*), to the *terrain tertiaire supérieur* of M. de Verneuil, and to the Pliocene of M. Abich.

3. Pliocene stage, which is the second level of petroleum in the Carpathians. It comprises conglomerates and pudding-stones at its base, and above black slates, producing the steppe formation of Moldavia and Wallachia. It corresponds to the superior marine sub-Apennine formation, to the steppes of the Crimea and the Caucasus, to the desert of Sahara, and the marine deposits of Kertsch with *Ostrea lamellosa, Brocchi; Chama gryphina, Lani; Colyptrea sinensis*, and *Linni*.

4. The recent formations comprising the earthy deposits in the environs of Buséo and the recent alluvium of the Danube.

It is noted further, according to M. Coquand, "that the petroleum of Wallachia is in the inferior Tertiary, with mud volcanoes and rock-salt; that the "*Flysch à Fucoids*" is the horizon in Moldavia corresponding to the formation in which it occurs in the Crimea, Transylvania, Galicia, Volterra of Tuscany, the Apennines, Sicily, and Algeria, being everywhere rich in fucoids", who further remarks "that it is only in the slates that it preserves its liquid state, and when it had been brought in contact with permeable rocks, such as sandstones, those rocks imbibed the mineral oil and were changed into asphalt. He accounts for this by assuming that in the porous strata the oil loses by evaporation its volatile principles. He further remarks that the petroleum is not in the rock-salt, but in the slates contiguous to it, rich in fucoids and the remains of marine animals. (*c*)

a A. J. S. (3), ii, 215. *b* J. P. Lesley: *A Manual of Coal and its Topography*, page 49. *c* B. S. G. F. (2), xxiv, 505.

In Galicia the petroleum is found saturating coarse and fine sandstones in zones or horizons, the lighter oils being found deepest.

This sandstone is abundantly permeated with limestone; yet in all fissures and on almost all surfaces the products of dry distillation are plainly recognizable, as also earth-wax and tough black maltha, and particularly asphalt. These products of distillation in many places extend even up to the surface, particularly in the northwestern part of the oil-bearing formations. The cavities of asphaltum were known in ancient times, and the thick fluid earth-oil which oozed out upon the surface was sometimes used as a lubricant for the axles of wheels. (*a*)

The largest yield of petroleum has not been found in the neighborhood of asphalt beds, but farther east, where gas-springs called attention to the probability of reaching petroleum below the surface. It was remarked that the harder the sandstone the greater the pressure of gas and the deeper the source of the oil.

Fig. 7 gives a section from Boryslaw, in east Galicia, to Schodinca. It exhibits a synclinal of schists, standing, where exposed, nearly perpendicular and flanked with sandstones. The wells are sunk in the schists. It resembles a section of the sulphur mountain in California. (See Fig. 6, page 68.)

The conclusions reached by geologists regarding the occurrence of petroleum in Galicia show that the central core of the Carpathians consists of metamorphic rocks, on the flanks of which lie the members of the cretaceous and tertiary formations, consisting of limestones, sandstones, and shales, the latter being, for the most part, rich in organic matter, both vegetable and animal, such as fossil fucoids and fish. In east Galicia and Bukowina heavy beds of black bituminous shales are particularly noticeable. (*b*) These formations lie in folds, the petroleum occurring under the arches of anticlinals rather than in the troughs of the synclinals.

The facts to be obtained regarding the occurrence of the petroleum of Asia are very few. It appears to be generally conceded that the formation from which the petroleum in the neighborhood of the Caucasus arises is Tertiary, but so far as I can ascertain it issues rather from erratic beds of sand in superficial clays than from any well-defined formation. Lartet appears to regard the bitumen of the Dead sea as of volcanic origin. (*c*) The petroleum of Java lies in the Tertiary beneath alluvium, which flanks the volcanic core of the island. (*d*)

Granting that the petroleum of the Niagara limestone at Chicago is indigenous, the invasion of that limestone by steam under high pressure would cause the petroleum to accumulate in any rock lying above sufficiently porous or fissured to receive it. The mingling of oils that contain paraffine and oils that produce asphaltum, and the occurrence of paraffine in large masses in porous strata filled with the remains of fucoids and marine animals that flank the core of crystalline metamorphic schists in Roumania and Galicia, offers the strongest support to this hypothesis. The fact that the eruptive rocks of lake Superior and the metamorphic rocks farther east prevail to such an extent that that vast inland sea has been supposed to be the crater of an extinct volcanic lake lends the strongest support to an hypothesis that regards the vast accumulations of petroleum in western Canada as due to the invasion of strata on the borders of this heat-center, in which the petroleum is indigenous, by a sufficiently elevated temperature to cause its distillation.

It appears to me that mud volcanoes and hot springs are properly regarded as the phenomena attending the gradual subsidence of metamorphic action in the crust of a cooling earth, and that petroleum or maltha is but the accident of such phenomena, when strata containing organic matter are still invaded at a great depth by a temperature sufficient to effect the distillation of their organic content. Gas-springs may also own the same origin, or the gas may escape from deep-seated reservoirs, the product of a distillation long since completed.

The fourth class of solid bitumens occur in great variety. The universal distribution of bituminous material in rocks was noticed in 1823 by the Hon. Geo. Knox, in a paper read before the Royal Society of Great Britain. (*e*) The occurrence of disseminated bitumen in metamorphic rocks at Nullaberg, in west Sweden, supposed to be Laurentian, has been described; (*f*) also in the Lower Silurian of south Scotland, (*g*) in Trap, near New Haven, Connecticut, (*h*) and in northern New Jersey, (*i*) all of which are manifestly the result of the action of heat upon the organic matter in stratified rocks. The occurrence of bituminous limestones in France and the valley of the Rhone, and the almost unanimous opinion of the French geologists that they are the result of igneous or metamorphic action, has already been mentioned.

There remain the phenomena attending the occurrence of large veins of solid bitumen in Cuba, West Virginia, and New Brunswick, for which no adequate explanation has been proposed that does not regard them as a product of distillation from deep-seated strata, which has been projected into a fissure formed by the sudden rupture of the earth's crust. Dr. R. C. Taylor examined the vein which occurs in metamorphic rocks near Havana, and gives a section (Fig. 8) of the vein as it is exposed in the working of the mine. He says:

It was evidently originally an irregular open fissure, terminating upwards in a wedge-like form, having various branches, all of which have been subsequently filled with carbonaceous matter, as if injected from below, and that not by slow degrees, but suddenly and at once. (*j*)

a J. K. K. G. R., xviii, 311.
b Bruno Walter, J. K. K. G. R., xxx, 115.
c B. S. G. F., xxiv, 12.
d Bleekrode, C. N., v, 188.
e *Phil. Trans.*, 1823.
f L. J. Inglestrom: *The Geo. Mag.*, iv, 160.
g *Quar. Jour. Geo. Soc.*, xi, 468.
h A. J. S. (1), xxxvi, 114; (3), xvi, 112.
i A. J. S. (3), xvi, 130.
j *Phil. Mag.*, x, 161.

Pl. I.

DRAWING OF A PIECE OF THE HURONIAN SHALE ENCLOSING THE ALBERTITE VEIN IN NEW BRUNSWICK, SHOWING THE MANNER IN WHICH THE ALBERTITE CLEAVES FROM THE ENCLOSING ROCK.

In 1869 I made the origin of albertite and allied substances the subject of a paper, (*a*) in which I discussed the views held by others regarding it and compared them with the observations made in New Brunswick and West Virginia by Jackson, Wetherell, Lesley, Wurtz, and others, with my own observation of a vein on the coast of California. This latter vein is exposed on the coast west of Santa Barbara, and stands vertical, cutting the Pliocene and recent sands. With this vein are associated lenticular masses, extending horizontally, from which a sort of talus projects vertically into the sands beneath. The eruptive origin of these deposits is beyond question.

Similar deposits are described by M. Coquand as occurring in Albania, as follows:

The bitumen at Sélenitza does not lie in regular beds, but in masses, in the midst of the sandstones and conglomerates that preserve a sort of parallelism, each mass consisting essentially of a central portion of considerable thickness, which gradually thins out in all directions to zero. In no case does the bitumen penetrate the roof above the mass, but was evidently injected from below. Fig. 2 (*b*) shows a deposit that has furnished an enormous quantity of bitumen. These deposits occur as if during the sedimentation of the rocks at the bottom of the tertiary area the bitumen in a viscous state had filled the depressions in which it has accumulated, remaining pure or being incorporated with the slaty materials with which it is contaminated. A section of the mass corresponds in many cases to a flask filled with solidified water. The aligned basins appear to have been filled successively from the overflow of one into the other. It is evident that the masses, in spite of their irregularity, are parallel with the stratification. Generally the bitumen consists of compact, very homogeneous matters, and next to this variety the bituminous breccia should be mentioned. This consists of beds of gray slate of varying thickness, inclosing angular fragments of bitumen, separated from each other, but which are easily obtained by soaking in water the slate which serves to cement them. This breccia is represented by Fig. 9, often overlying a bed of asphalt, into which it passes by insensible gradations, and seems to form the upper portion of a liquid bath, into which the slate plunged and afterward regained the surface before its entire solidification. Exactly as in a blast-furnace, the slag becomes mingled with the metal in the last products of the tapping, producing a species of magma. More rarely the bitumen rolls itself upon itself (Fig. 10), thus producing spheres analogous to those which invest viscous matters when rolled in water or dust. The structure of them is concentric, resembling pea-stone, but is destitute of any nucleus so far as observed. These envelopes might result from progressive desiccation, the result of which leaves the bitumen divided into thin pellicles, like certain basalts, in which, on cooling, spheres of variable volume are produced composed of concentric coats. The globules are for the most part isolated in the midst of the slate, and are about one-third of an inch in diameter. Another curious form is shown in Fig. 11. It consists of an infinite number of threads crossing each other in all directions, producing a sort of stockwork. Fig. 12 shows a form which differs from the preceding in that the threads instead of being scattered in a capricious plexus are vertical and parallel. The contraction of the sandstone having opened these vertical and parallel vents, the bitumen following filled them, but from above downward. Sometimes the bitumen, as indicated by Fig. 13, is molded in cup-like depressions, which are terminated by a capillary tube. At other times ellipsoidal masses are introduced, some of which are as large as a cannon-ball. They are aligned in positions parallel to the plane of the beds in which they repose. Masses of sandstone are sometimes met inclosed within the bitumen. Such are sometimes observed in beds of coal.

It is to be observed that the threads that sometimes connect the masses of bitumen spring from the side and not from the top of them—a fact that is explained if we assume the ascending mass overflowed horizontally in this particular locality.

A great many bivalves, especially *Cardium*, were observed filled with bitumen. He also discovered a very large Planorbis and other species with the interior filled with bitumen. After showing that the material could not have entered the rocks in a fluid state, he says: "It is then in the condition of glutinous bitumen that the maltha primarily entered the formation at Sélenitza. There is no evidence of the phenomena of salses, nor solfataras, nor volcanoes, which distinctively characterize the occurrence of petroleum properly so called."

M. Coquand states that there exists at present at one point in the ancient excavations a sort of crater that emits smoke and a great heat, but he assumes that the fire was lighted by the hand of man, which, as in burning collieries, slowly pursue their work of destruction. The clays from which the volatile products are expelled become a sort of brick, sonorous and red, and the sandstones are converted into porcelainites and quartzite, and break at the least shock into a thousand fragments. Fig. 14 represents a section of the rocks in which the bituminous strata occur.

M. Coquand mentions in connection with the bituminous strata solfataras and mud volcanoes, both active and extinct, with which was associated more or less fluid maltha, which is at first very liquid, but soon becomes sirupy, and is finally added to the accumulations of the bituminous cone. The volcanic phenomena assume three forms: First, when inflammable gas escapes through the soil; second, when they escape with water and petroleum, forming craters of bitumen; third, volcanoes emitting hot water (*volcan ardent*). (*c*)

From the foregoing it will appear that solid bitumen occurs in great abundance, filling variously-formed cavities in the Pliocene strata of Albania, and that maltha accompanies the water of springs from deep-seated strata, often in close proximity to active or extinct volcanic action of the mild forms observed as solfataras, mud volcanoes, or salses.

The great similarity in the occurrence of intruded tertiary bitumens in Albania and California is very remarkable.

No hint is given by Dr. Taylor respecting the age of the rocks inclosing the bitumen vein in Cuba, as at the time he wrote (1837) all metamorphic rocks were called primary. There is little doubt, however, that the vein in

a A. J. S. (2), xlviii, 362.

b See page 32.

c B. S. Q. F., (1), xxv, 35. The precise volcanic phenomenon designated by M. Coquand as *volcan ardent* is not clear. In one case it appears to be an ordinary volcano emitting lava, and in the present case a hot-water volcano; but he afterward remarks that the Tertiary formations in the valley of the Vojutza do not contain the least trace of volcanic action, nor is there a volcanic or thermal spring in the whole country. I presume he refers in this latter sentence to outflows of scoriæ and lava, and does not include in the phrase *volcanic action* the mud volcanoes and solfataras, which he describes at some length.

New Brunswick and in West Virginia originated at nearly the same time and subsequent to the Carboniferous era, and it is certain that subsequent to that era a great convulsion caused an upheaval that in collapse produced the White Oak anticlinal. Very near the southern end of this anticlinal the vein of grahamite occurs, cutting the horizontal sandstones of the coal measures vertically, but those who mined the vein declare that the material must have welled up from beneath into the fissure the instant it was formed, numerous fragments of the wall-rock being found imbedded in the asphaltum only 12 or 15 feet below the cavities from which they fell, with all their edges and angles sharp and exactly fitting each other. Curious curved lines, resembling those produced when a stone is dropped into mortar, are formed on these horses, suggesting the probability that they fell into a plastic mass that rolled upon them, producing lines of unequal pressure and adhesion that remain after the asphaltum has cleaved from them or the inclosing walls. Moreover, these walls of porous sandstone have not absorbed the bitumen to the thickness of a piece of paper. The significance of these facts was more forcibly impressed upon my mind when I found among a set of specimens from the albertite vein of New Brunswick a piece of the inclosing shale, marked with the mineral in forms almost identical with those observed on the sandstone in West Virginia. Plates I and II are very carefully drawn from specimens from the two localities.

It should be borne in mind that while this subject is one of speculation, pure and simple, it is one that has its valuable consideration outside the domain of scientific inquiry or curiosity, as affecting the sources and duration of supplies of petroleum, its profitable development, and commercial permanence.

If petroleum is the product of a purely chemical process, we should not expect to find Paleozoic petroleums of a character corresponding with the simple animal and vegetable organisms that flourished at that period, and tertiary petroleums containing nitrogen, unstable and corresponding with the decomposition products of more highly organized beings, but we should expect to find a general uniformity in the character of the substance, wherever found, all over the earth.

A mass of polypi undergoing decomposition upon a beach would doubtless saturate the sand with about the same kind of decomposition products as an equal bulk of algæ; but when a mass of animal matter, consisting not only of the muscular tissue, but of all the non-nitrogenous substances entering into animal organisms, was thus subjected to decomposition, submerged in water, the product could not fail to be a nitro-hydrocarbon, which upon exposure to atmospheric oxygen would undergo a second decomposition into a greater or less number of the following-named products: carbon, hydrocarbons, ammonia or free nitrogen, carbonic acid, and water. The petroleums of southern California, issuing primarily from Miocene shales, are of precisely this unstable character. (*a*)

The advocates of the chemical theory affirm that they provide for a process the conditions of which are perpetually renewed. It is thus continuous and at present active. On the contrary, if petroleum is the product of metamorphism, its generation is coexistent only with that of metamorphic action; an action which we have no reason to believe has been prevalent on a large scale during the recent period. If we accept this hypothesis, the generation of petroleum is then practically ended.

M. A. Rivière has published a paper on the origin of combustible minerals. (*b*) His opinions are based on his observations of the effect on soil and organic matter in the soil of the leakage of illuminating gas from the pipes in which it is conducted. The effects which he attributes to marsh-gas are, however, due to the condensation of the tarry matter that is dissolved in the escaping gas, the coal-tar products produced at a high temperature not being constituents of petroleum to any great extent. The experiments of Professor Sadtler indicate the presence of minute quantities of benzole in the Bradford oil of Pennsylvania, (*c*) but it was not found by Warren and Storer in the Oil creek oils, its presence in the Bradford oil furnishing an additional reason for supposing it to be a fractional distillate produced under great pressure, and consequently at a comparatively high temperature.

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a S. F. Peckham, P. A. P. S., x, 453. *b* C. R., xlvii, 646. *c* Communication to S. F. Peckham.

Pl. II.

DRAWING OF A PORTION OF THE SURFACE OF A HORSE OF SANDSTONE FOUND ENCLOSED IN THE GRAHAMITE VEIN RITCHIE CO. W.V^A SHOWING THE MANNER IN WHICH THE GRAHAMITE CLEAVES FROM THE ENCLOSING ROCK.

Chapter VI.—THE DEVELOPMENT OF OIL TERRITORY.

In 1858 and 1859, just before Drake obtained oil in his well, the region now known as the "oil region" was an almost unbroken forest. Here and there along the valleys of the Allegheny and its tributaries the bottom-lands had been broken into farms, but on the hills, excepting in the neighborhood of the larger towns, there were but few cultivated tracts. The landscape along these winding streams was very beautiful. The towns were but little more than lumbering camps and trading stations, with few churches or school-houses, and the stores were for the most part kept by those engaged in the lumbering business, who employed nearly the entire population. This population traded a large proportion of the value of their earnings at the stores, and when the yearly settlements came they found a small balance due them. Those who were not engaged in rafting the lumber to Pittsburgh worked their small farms in summer and raised the small amount of produce required in the country, but in the winter lumbering was the engrossing occupation. Off the valleys of the main streams the roads were few and wretchedly poor. A few farms on the bluff southwest of Titusville had been occupied since 1798, and yet no public road had been built until some time after 1860.

After Drake's well was drilled, a demand arose for barrels and teams to haul the oil to points of shipment. This quiet and secluded region was invaded by adventurers from every direction, and the production of oil increased in volume so much more rapidly than the means of gathering and transportation that, although the production for the whole year of 1861 was only 1,035,668 barrels, less than the production of two weeks in 1880, the price fell in the fall of that year to 10 cents per barrel, and sales were reported as low as 6 cents per barrel. The influx of such an immense population into the villages and hamlets of this region taxed its agricultural resources to the utmost, and the construction of countless derricks, and the towns that were springing up like mushrooms along Oil creek and the Allegheny river, the making of tanks and thousands of barrels for storing and transporting the oil, gave a home market for the lumber of the country and stimulated an activity in business before unknown. Land along the creek supposed to be favorable for drilling purposes commanded fabulous prices; everybody had an interest in an oil-well; fortunes were suddenly made in one day and recklessly lost in another; and although railroads were pushed toward Titusville as rapidly as possible, the oil reached the surface faster than it could be disposed of, and was floated down the Allegheny river to Pittsburgh in bulk barges, many of which were broken up in the accidents of such navigation and the contents poured upon the stream. The valley of Oil creek became filled with derricks, and by 1863 the oil territory was supposed to be defined, when a daring prospector, having drilled a "wild-cat" well on the hills that border the valley, got oil, and wells were then spread over the hill country between Titusville and Tidioute. Meantime trunk lines had reached the valleys of the Allegheny and Oil creek, and the oil was moved out of the country.

The development of oil territory had mean time acquired a habit which has become well defined, and has been repeatedly exemplified during the last fifteen years. Commencing with the sinking of test or "wild-cat" wells outside the limits of any proved productive territory, the progress of such wells is eagerly watched, not only by those who pay for them, but also by many others who hope to profit by the experiment. While the experiment is in progress frequently all sorts of devices are resorted to to deceive others, not only to enable those engaged in the experiment to secure all the adjacent territory at favorable prices or leases, but also to prevent others from doing the same thing.

The striking of oil in a new well is the signal for a grand rush, as those who have territory to dispose of express extravagant opinions regarding the yield of the wells and the extent of the territory. A quiet country village at once becomes the center of a large business. Teams come pouring in with oil-well supplies, lumber, and provisions; a narrow-gauge railroad is projected and built with astonishing rapidity; corner lots are sold at fabulous prices; a speculative population floats into the place, the individuals of which come and go; and a common laborer to-day becomes a month hence a foreman, and in six months the owner of a well, and after a year is a gentleman of fortune. The quiet country town, too, with its modest school-houses and churches, takes on metropolitan airs and vices, and farmers become money-changers, the lucky ones who "strike ile" and do not lose their heads usually gathering together their thousands and leaving the overgrown village for New York or some other city. Some few remain and help to permanently improve the home of their childhood. Titusville, Oil City, Tidioute, Franklin, and Bradford are all examples of such towns. After a time the speculative phase is succeeded by that of settled and steady development, and the oil territory becomes outlined, the sagacious having secured control of the profitable tracts, and the floating population having by this time passed on to a new field, while their places have been filled by a more solid element, largely the moderately successful, because less reckless, who have come to stay. The influence of the floating and unsettled class is seldom salutary. In one instance that has been brought to my notice the most reckless system of public improvements was undertaken. School-houses greatly larger and more expensive than were necessary were built, and instead of being paid for by taxes levied on the oil that was then being taken from the ground, bonds were issued, payable at some future day, and left as a burden upon a community the extraordinary resources of which have long since been removed.

The development of the oil territory proceeds, after its existence has been demonstrated, without regard to any other interest. The derrick comes like an army of occupation. In the towns a door-yard or a garden alike surrender its claims. The farms, fields, orchards, or gardens alike are lost to agriculture and given to oil, and on the forest-covered hills the most beautiful and valuable timber is ruthlessly cut and left to rot in huge heaps wherever a road or a derrick demands room. Pipe-lines are run over the hills and through the valleys, through door-yards, along streets, across streets and railroads, and here and there the vast storage-tanks stand, a perpetual menace to everything near them that will burn. Nothing that I ever beheld reminded me so forcibly of the dire destruction of war as the scenes I beheld in and around Bradford at the close of the census year; and nothing else but the necessities of an army commands such a complete sacrifice of every other interest or leaves such a scene of ruin and desolation.

But the wave of desolation passes over, and nature changes the scene in the same manner as she gathers and restores the ruins of battle-fields. Along Oil creek, for the most part, the derricks have disappeared, and the brambles and the young forest are fast removing even a trace of their former presence. A visit to the famous Pithole City, which in 1865 was, next to Philadelphia, the largest post-office in Pennsylvania, showed a farmer plowing out corn where the famous Shearman well had been, a waving field of timothy where the Homestead well had been, the site of the famous United States well hardly to be found by one who had known it all through its career, and of the city there remained but fifteen or twenty houses, rapidly tumbling to decay, but not an inhabitant. The country around this scene of so much activity fifteen years ago is growing up to forest, and is not now valued at an amount equal to a year's interest on the valuation of that time.

Between the period of active development and absolute exhaustion comes the period of decay, when the derricks are rotting and falling to wreck, when property that has ceased to be productive has been sold at an extravagant price, and after accumulating debts has been abandoned. No one dares to claim the engine, boiler, and other tools, for fear he may become liable for the debts. Fine-engines go to ruin, and boilers are eaten with rust; small boys and idle men throw tools and pebbles in the well, and finally the vender of old iron comes along and carries off the junk to the foundery. At other times the owners of the well have made strikes somewhere else; and the well is then "pulled out" and all the machinery is carried to another field. Enormous quantities of material were carried from Oil creek to Clarion and Butler counties, and from there to the Bradford district.

The Oil creek region has now returned to the condition of an agricultural and manufacturing community, in which the production of oil is no longer the absorbing topic of conversation and the paramount interest. On the lower Allegheny, in Clarion and Butler counties, the production of oil has become much lessened in importance, and the wreck of abandoned derricks in many localities presents a dismal picture. The Bradford field is now in fully developed activity, and the destructive subordination of every other interest, and of all other considerations of ordinary value, is everywhere painfully apparent. With all this there is an evidence that so-called public improvements are only of a temporary character. The towns that are the result of the production of oil are scarcely more substantial than a military camp, and from lack of orderly arrangement, neatness, and sanitary regulations are far less inviting in their appearance. The railroads remind one forcibly of those built around Petersburg during the war, although they possess the elements of permanency to a greater degree, and the destruction of so much valuable timber produces a melancholy aspect.

The Allegheny district in New York is just opening up around Richburg, and all the phenomena peculiar to the first stages of an oil excitement are to be observed there.

It is not to be inferred, however, that any of the sections into which the oil regions have been divided have ceased to produce oil. There are wells now producing in sight of the spot where Drake drilled the first well; but large tracts of country cease to be the centers of speculative investment, and old wells to be remunerative, and the new wells no longer hold the possibilities of a grand lottery prize. It is the opinion that large areas in the Oil creek district will be redrilled and will produce in the aggregate large quantities of oil if the price ever reaches $2 a barrel. At present prices, the pumping wells of that district cannot successfully compete with the flowing wells of McKean county.

Chapter VII.—THE PRODUCTION OF OIL.

Section 1.—PRIMITIVE METHODS.

Oils and malthas appear to have been obtained in Persia from a very early period, but the methods employed were extremely simple. Most frequently the basin of the spring appears to have been surrounded by a stone coping, and sometimes it was covered with some sort of a niche or building, but often the oil was simply skimmed from the surface of the water which it accompanied. Herodotus describes the manner in which, by means of myrtle branches, the bitumen was obtained from the springs in Zacynthus, now Zante. It is, however, by means of dug wells or shafts that petroleum has been usually obtained in regions where the art of drilling artesian wells was unknown.

In Japan from a very remote period wells have been dug and tunnels have been run into hillsides for oil. Some of these abandoned drifts have caved in and large trees are growing upon them.

In relation to the manner of working these wells, B. S. Lyman, in his *Reports on the Geology of Japan*, 1877, says:

The present mode of working is very simple, a method that has probably grown into its present form in the course of centuries of experience, and is now apparently practiced in all the oil regions with little or no variation. The digging is all done by two men, one of whom digs in the morning from nine o'clock until noon, and the other from noon until three. The one who is not digging works the large blowing machine or bellows that continually sends fresh air to the bottom of the well. The blowing apparatus is nothing but a wooden box about 6 feet long by 3 wide and 2 deep, with a board of the same length and width turning in it upon a horizontal axis at the middle of each long side of the box, and with a vertical division below the board between the two ends of the box. The workman stands upon the board and walks from one end of it to the other, alternately pressing down first one end and then the other. At his first step on each end he gives a smart blow with his foot, so as to close with the jerk a small valve (0.3 foot square) beneath each end of the board, a valve that opens by its own weight when the end of the board rises. The air is therefore driven first from one end of the box, then from the other into an air pipe about 0.8 foot square, provided at top, of course, with a small valve for each end of the blowing-box, made of boards in lengths of about 6 feet, and placed in one corner of the well. The well is, besides, timbered with larger pieces at the corners and light cross-pieces, which serve also as a ladder for going up and down, though at such a time, in addition, a rope is tied around the body under the arms and held by several men above the mouth of the well. The earth or rock dug up is brought out of the well in rope nets by means of a rope that passes over a wheel 1 foot in diameter, hung just under the roof of the hut, about 10 feet above the mouth of the well, and is pulled up by three men, one at each corner of one side of the well, and the third in a hole two or three feet deep and a foot and a half wide dug along side of the well. * * * Wells are dug in this manner to a depth of from 600 to 900 feet, a depth at which great difficulty is experienced in securing sufficient light to carry on the work, which is often prosecuted only from nine a. m. to three p. m. These wells are dug about 3½ feet square. One well 900 feet deep is reported to have cost only about $1,000. The oil is skimmed from the surface of the water and drawn up in buckets.

In a letter dated Toungoo, British Burmah, September 14, 1881, Rev. J. N. Cushing, D. D., says:

At Yenangyoung the construction of the wells is after the most primitive method. The wells are dug about 5 feet square. A native spade for loosening the soil and a basket for conveying it from the well are the implements used. As fast as the well is sunk it is planked up with split, not sawed, planks. There are generally three or four men engaged in the work of digging, each one taking his turn. A man remains below with a large rope fastened about him. A small rope attached to a basket is used to draw up the earth, which is saturated with oil, and is often quite warm to the touch. Sometimes the gas is so strong as to prevent a person from remaining below more than a couple of minutes, and occasionally a man is drawn up quite insensible The usual time of remaining down is about twenty minutes, when the man gives the signal that he wishes to be drawn up by jerking the rope. The yield is seldom very rapid, as I have never heard of any petroleum rising to the surface. Still some of the wells yield a large amount and then dry up. A windlass is built upon a frame over the well at a height of about 5 feet from the mouth. Over this windlass a rope is placed having a bucket at one end. The rope is not much longer than the depth of the well. The other end is fastened around the waist of a man or a woman, who generally has two or more half-grown boys or girls to help pull. As soon as the bucket fills, these persons start on a run down a well-beaten path until the bucket has come up so that the person standing by the well can empty it. The work is done by a class of people whose families have been allotted this work from time immemorial by the royal law. They are not slaves, but do not have permission to remove, and are considered as bound to work for the production of the royal monopoly.

In Galicia wells were dug as for water, and in some instances congeries of wells were united at the bottom by galleries, into which the petroleum filtered from the rock. The digging of these wells and shafts was frequently attended with considerable danger of suffocation with gas. M. Coquand mentions that at Damanostotin, in Moldavia, the pits or wells were dug 40 meters (131.2 feet) deep, and lined with sticks, woven in a manner resembling a military gabion. The petroleum is obtained in a bucket, to which a stone is attached for a sinker. This bucket is drawn up by a rope. (*a*) Petroleum was also obtained for many years in the valley of the Po from wells that were dug.

In the United States several different methods for obtaining oil were employed before wells were drilled. It is reported that shafts were found in the Mecca (Ohio) oil district, of the sinking of which all record or tradition has been lost. Since the curbed pits on Oil creek, Pithole creek, and other tributaries of the Allegheny have been proved to be of French origin, it is not unlikely that the old shaft at Mecca was also made by the French. An unsuccessful attempt to obtain oil in this way was made at Mecca about 1864, and another attempt to sink a shaft to the Venango oil-sand was made in 1865 in the bend of the Allegheny river, on the east side, below Tidioute.

It was about 16 feet square and a little over 100 feet in depth. It was a failure in respect to obtaining oil, for just before it was deep enough to reach the third sand, or oil-producing rock, an accident occurred which resulted in its abandonment. The foreman, who was an experienced miner, was seated over the mouth of the shaft, which was covered, in company with one or two of his laboring men,

a B. S. G. F., xxiv, 518.

eating their dinner. As they lighted their pipes it was suggested that a lighted paper be dropped into the shaft to see if any gas was there. It was done, and an explosion followed which killed the foreman and some of his men. It [the well] was immediately closed, and work was never resumed. (*a*)

Other shafts were sunk on Oil creek, but as none of them were successful in reaching the Venango third sand, they were abandoned.

Professor Silliman, sr., in 1833, thus described the method employed for obtaining Seneca oil at the famous spring at Cuba:

A broad, flat board, made thin at one edge, like a knife; it is moved flat upon and just under the surface of the water, and is soon covered by a coating of petroleum, which is so thick and adhesive that it does not fall off, but is removed by scraping on the edge of a cup. (*b*)

Near Burning Springs, West Virginia, the oil was collected early in this century "by digging trenches along the margin of the creek down to a bed of gravel a few feet below the surface. By opening and loosening with a spade or sharpened stick the gravel and sand, which is only about a foot thick, the oil rises to the surface of the water, with which the trench is partially filled. It is then skimmed off with a tin cup and put up in barrels for sale. In this way from 50 to 100 barrels are collected in a season". (*c*)

Professor J. P. Lesley thus describes the method employed for collecting oil on Paint creek, Johnson county, Kentucky:

Here are to be seen the old "stirring places", where, before the rebellion broke out and put an end to all manner of trade in Kentucky, Mr. George and others collected oil from the sands by making shallow canals one or two hundred feet long, with an upright board and a reservoir at the lower end, from which they obtained as much as 200 barrels per year by stirring the sands with a pole. (*d*)

J. D. Angier, of Titusville, worked the springs on Oil creek for some years prior to 1859. He found the springs logged up 6 to 8 feet square and as many feet deep. He arranged a sort of sluice-box, with bars, that held the oil while the water flowed on beneath. In this way he obtained from 8 to 10 gallons a day of 36° specific gravity, which he sold at Titusville for medicine and for lighting saw-mills and the derricks of salt-wells.

Seneca oil was obtained for many years and in many localities by saturating blankets with oil and wringing it from them.

SECTION 2.—ARTESIAN WELLS—THE DERRICK.

ARTESIAN WELLS.

The Jesuit missionaries to China found there artesian wells in full operation. These wells were drilled for brine and natural gas, the latter being frequently accompanied by petroleum. The following extract from L'Abbé Huc's celebrated travels in China describes their method of drilling very deep wells:

They [the wells] are usually from 1,500 to 1,800 (French) feet deep, and only 5 or 6 inches in diameter. The mode of proceeding is this: If there be a depth of 3 or 4 feet of soil on the surface, they plant in this a tube of hollow wood, surmounted by a stone, in which an orifice of the desired size of 4 or 5 inches has been cut. Upon this they bring to work in the tube a rammer of 300 or 400 pounds weight, which is notched and made a little concave above and convex below. A strong man, very lightly dressed, then mounts on a scaffolding, and dances all the morning on a kind of lever that raises this rammer about 2 feet and then lets it fall by its own weight. From time to time a few pails of water are thrown into the hole to soften the material of the rock and reduce it to pulp. The rammer is suspended to a rattan cord not thicker than your finger, but as strong as our ropes of catgut. This cord is fixed to the lever, and a triangular piece of wood is attached to it, by which another man, sitting near, gives it a half-turn, so as to make the rammer fall in another direction. At noon this man mounts on the scaffold and relieves his comrade till the evening, and at night these two are replaced by another pair of workmen. When they have bored 3 inches they draw up the tube, with all the matter it is loaded with, by means of a great cylinder, which serves to roll the cord on. In this manner these little wells or tubes are made quite perpendicular and as polished as glass. * * * When the rock is good the work advances at the rate of 2 feet in twenty-four hours, so that about three years are required to dig a well. (*e*)

The first artesian well drilled in the United States, in 1809, has already been described, as also the gradual improvements in tubing wells and in stopping off the surface water with a seed-bag (page 6). Prior to 1858 a great many wells had been drilled for brine in the valley of the Ohio and its tributaries, with such additional improvements as rendered them very effective for this purpose. Steam-, horse-, and hand-power had been employed in drilling with equal success, the tools and general manipulation of the well being essentially the same. The drilling of wells with hand-power was accomplished by means of a spring-pole. For this purpose a straight tree, forty or fifty feet in length, was selected. After the branches were removed, the butt was secured in the ground in such a position that the pole extended at an angle of about 30° over the spot at which the well was to be bored. To the smaller end the tools were attached, and by the elasticity of the pole, as it was alternately pulled down and allowed to spring back, they were lifted and made to strike at the bottom of the well.

The drilling of wells for oil has long since outgrown the spring-pole age, the figures on Plate VI showing the successive steps by which this has been accomplished.

THE DERRICK.

When the location of a well has been decided upon a derrick or "rig" is built. This consists of the derrick itself and a small house for an engine, with the necessary foundation for both. For this purpose masonry is not used, but instead a very heavy foundation of timber. The owner of the well owns the rig, boiler, and engine. The contractor who drills the well owns the cable, bit, blacksmith's and other tools, and supplies fuel for the engine and the blacksmith.

a Letter of W. W. Hague, of Tidioute, to S. F. Peckham.
b A. J. S. (1), xxiii, 99.
c S. P. Hildreth, A. J. S. (1), xxix, 86.
d P. A. P. S., x, 40.
e *Travels in the Chinese Empire*, 1,300, Harper's ed., 1855.

The following list of rig-timbers embraces, first, the foundation timbers, which are frequently hewn, and, second, sawed timber. The plan of foundation timbers (Fig. 15) is drawn for square timber, but in a region like the northern field, where the wells are chiefly located in forests, these timbers are often hewn from the trees around the well:

HEWED RIG-TIMBERS.

	Inches.	Feet long.
2 derrick-sills, spotted	12	21
2 derrick-sills, spotted	10	21
2 derrick-sills, flatted	12	21
2 derrick-sills, flatted	10	21
3 mud-sills, faced	16	20
5 mud-sills, faced	16	12
1 main-sill, squared	18 by 18	30
1 sub-sill, squared	18 by 18	14
1 cross-sill, squared	12 by 12	12
1 samson-post, squared	18 by 18	14
1 jack-post, squared	16 by 18	14
2 bull-wheel posts, squared	10 by 10	10
1 engine-block, squared	20 by 20	8
1 walking-beam, squared	12 by 26	26
1 bull-wheel shaft, squared	14 by 14	14
2 pulley-blocks, squared	12 by 12	6
4 braces, squared	6 by 8	14
1 lever, squared	7 by 9	7

Equal to 7,800 feet board measure.

SAWED RIG-TIMBER.

	Inches. Feet.	Feet.
8 pieces	2 by 10 by 20 =	267
5 pieces	2 by 8 by 20 =	133
6 pieces	2 by 12 by 18 =	216
4 pieces	2 by 10 by 18 =	120
7 pieces	2 by 8 by 18 =	168
8 pieces	1½ by 8 by 18 =	144
4 pieces	1½ by 12 by 16 =	96
18 pieces	2 by 10 by 16 =	480
18 pieces	2 by 8 by 16 =	384
6 pieces	2 by 6 by 16 =	96
25 pieces	2 by 4 by 16 =	267
4 pieces	2 by 6 by 14 =	56
20 pieces	1 by 12 by 16 =	320
20 pieces	1 by 8 by 16 =	213
20 pieces	1 by 7 by 14 =	245
2-inch plank, 20 feet long		800
1-inch boards, 14 feet long		500
1-inch boards, 16 feet long		4,500
		9,005

The foregoing dimension timbers may be either pine or hemlock, the latter being used almost exclusively at the present time:

HARD-WOOD LUMBER (OAK OR MAPLE).

	Inches. Feet.	Feet.
7 pieces	2 by 8 by 16 =	149
1 piece	2 by 12 by 12 =	24
		173

Hewed timber	7,800
Sawed lumber	9,005
Hard lumber	173
	16,978

Total, 17,000 feet of lumber for a rig.

To put the rig together requires—

	Pounds.
10-penny nails	150
20-penny nails	25
30-penny nails	125
40-penny nails	10
	310
Bolts	13
Strap-hinges ... pair..	1

If the wheels for reeling the cable and sand-pump rope are not purchased separately, but are made with the derrick, there will be required:

32 arms for 2 bull-wheels.
104 cants of 3 feet 9 inches radius for 2 bull-wheels.
32 cants of 4 feet 6 inches radius for band-wheel.
8 cants of 3 feet 3 inches radius for tug-pulley.

HARDWARE (RIG-IRONS).

1 walking-beam stirrup, 2¾ inches by ¾ inch.
4 bolts for securing the same by a wooden cap to the walking-beam.
2 boxes for band-wheel shaft, babbitted, and each with 4 bolts.
1 band-wheel shaft 4 feet 6 inches long, 3½ inches diameter, with 1 crank, 14 to 46 inches stroke, 6 holes; 1 wrist-pin, 2⅝ inches diameter; 2 flanges, 24 inches diameter; 2 flanges, 20 inches diameter; 12 flange-bolts, 7 inches long, ¾ inch diameter; 5 steel keys for flanges and crank; 1 collar and set screw (not always used).
1 saddle for walking-beam.
4 bolts for same.
2 side irons, boxes and bolts for samson-post.
1 derrick-pulley, 20 inches in diameter.
1 walking-beam hook, to hold temper-screw.
1 sand-pump pulley.
2 gudgeons, with bands, for bull-wheel.

The derricks require each about thirty days of skilled and ten days of ordinary labor. During the census year they cost from $325 to $400, according to the cost of getting the materials to the place where the rig was to be built. At the same time a set of "rig-irons" cost from $75 to $100. A rig for winter use must be closed in, and therefore requires a larger outlay for 1-inch lumber. The increased expense, however, amounts to only a small sum.

Figs. 16, 17, and 18 represent plans and elevations of a fall oil-well rig. As originally drawn, they were prepared by H. Martyn Chance from working plans furnished by J. F. Carll. They exhibit in great detail the construction of a "rig" suitable for drilling a well from 2,500 to 3,000 feet in depth. The following description is abridged from the report of the *Second Geological Survey of Pennsylvania*, Report III:

The mud-sills *a* (Fig. 15) are generally sunk in trenches where the nature of the ground admits of its being done. They have gains cut into them to receive the main sill *d* and sub-sills *e* and *e′*. After all have been put in place and leveled up, the keys or wedges *h* are driven, and the whole foundation is thus firmly locked together. The samson-post *k* and jack-posts *l*, *s*, and *r* are dovetailed into the sills and held by properly fitted keys, *h*, as seen in the side elevation (Fig. 16). The braces are all set in gains and keyed up, *no mortises and tenons being used in the structure*, the advantages of which are (1) greater strength; (2) the keys can be driven to compensate shrinkage; (3) the posts and braces are easily put in line and kept there; (4) the whole is easily taken apart for removal.

Referring to the horizontal projection (Fig. 17), it will be observed that the samson-post is placed flush with one side of the main sill, and the band-wheel jack-post is put flush with the other side. In this way the walking-beam will run parallel with the main sill. If the main sill is less than 24 inches wide, these posts must, in order to get a bearing upon it, be set toward the center of the sill, the effect of which will be to throw the derrick end of the walking-beam to one side of the center of the derrick, and thus throw the engine and running-gear out of line with it.

If, therefore, the main sill be less than 24 inches wide, it should be placed in position and the point marked on it where the center of the samson-post is to come; then mark also the point on which a perpendicular will fall from the center of the wrist-pin. The dimensions of samson-post and band-wheel irons, with the length of the walking-beam, easily furnish these points, through which a chalk-line should be snapped, and all the work squared to this line. This throws only the main sill out of square with the other work. On this account a slightly crooked stick is found serviceable for a main sill.

A great variety of boilers are used, but the one in general use is a tubular boiler constructed very nearly on the plan of a locomotive boiler. Formerly the boiler was set up in the engine-house, frequently with the engine bolted on the top or side of it, or the whole thing was mounted on wheels; but the heavy drilling tools employed in the deep wells now drilled render a stationary engine necessary. The plan of drilling dry wells, now so universal, has been accompanied with so many fires and explosions by the ignition of gas at the boiler that prudence has caused the boiler to be removed to some distance from the engine and well. When near the oil-rock, it is now customary to remove both boiler and forge from near the derrick until the gas and oil are under control. A large boiler, centrally located, is sometimes used to supply steam to the engines of several wells that are being drilled simultaneously.

A 12 or 15 horse-power engine, *b′*, with a reversible movement, is bolted to the engine-block *b* (Fig. 16), and by means of its driving-pulley carrying-belt, *o o*, communicates motion to the band-wheel *m*, and through it to all parts of the machinery. The throttle-valve *l l* is operated by a groove vertical pulley. From this pulley an endless cord, called "the telegraph", extends to the derrick and passes around a similar pulley, *n n*, fixed upon the headache-post *z*, within easy reach of the driller. The driller has thus an easy control over the throttle-valve, and can stop and start the engine or increase or decrease its speed without leaving his position (Fig. 16). The reverse link *pp* is also operated from the derrick by the cord *q q*, which passes over two pulleys, one of which is fixed in the engine-house and the other on the derrick. A slight pull raises the link and reverses the motion, which is restored as soon as the cord is released and the link drops back.

The band-wheel *m* receives its motion direct from the driving-pulley of the engine, to which it is connected by the belt *o o*. On or near the end of its shaft *o* is the bull-rope pulley *n*, and upon its other end is the crank *o′*. This crank has six holes to receive an adjustable wrist-pin *p*, which is easily moved from one hole to the other to regulate the length of stroke required in drilling or pumping. As the band-wheel communicates motion through the pitman *q* to the walking-beam while drilling; to the bull-wheels, by the bull-rope *r r*, while running up the tools; and to the sand-pump reel, by the friction pulley *w*, while sand-pumping, all of which movements are used separately, the machinery is so constructed that the connections may be rapidly made and broken. The sand-pump reel *w* is put in motion by pressing on the lever *v*, which is joined by the connecting-bar *u* to the upright lever *t*. This brings the face of the beveled pulley *w* into contact with the face of the band-wheel. The sand-pump descends by gravity and is checked in its motion by pressing the lever *v* back in such a manner as to throw the friction-pulley *w* against a post, which acts as a brake. The sand-pump line is a cable-laid rope, seven-eighths of an inch in diameter, and is coiled upon the shaft *x*, from which it passes over the pulley *i i*, and thence to the well mouth. The most common sand-pump is a plain cylinder of light galvanized iron, with a bail at the top and a stem-valve at the bottom. It is usually 6 feet long, but is sometimes 15 or 20 feet in length. As the valve-stem projects downward a few inches beyond the bottom, it is only necessary to let it rest on the bottom of the waste-trough in order to empty it. Other forms of sand-pumps are more complicated in construction.

The walking-beam connections cannot be interrupted without stopping the engine. When disconnected, it is tipped at an angle of about 25°, which throws the derrick end back about a foot from its perpendicular over the well, and thus removes it from interference with cables, tools, sand-pumps, etc., as they are run up and down. The headache-post receives the walking-beam in case the wrist-pin should break or the pitman fly off. It is about 8 inches in section, and is placed on the main sill, directly under the walking-beam, in such a manner that in case of accident the walking-beam can fall only a few inches. (*a*) Fig. 19 shows the interior of a closed derrick at night, with the use of the temper-screw and derrick light.

SECTION 3.—THE DRILLING-TOOLS.

The illustrations given in this report are only those of the ordinary drilling-tools. The tools used for "fishing" other tools, broken or lost anywhere from 100 to 2,000 feet from the surface, are too numerous even for mention. These tools are of all kinds, from the delicate grab, designed to pick up a small piece of valve-leather or a broken sucker-rod rivet from the pump-chamber, to the ponderous string of "pole-tools" containing tons of iron, which, at a depth of 1,500 feet or more, can unscrew a set of "stuck tools" and bring them up piece by piece, or cut a thread on the broken end of a sinker-bar or an auger-stem, to which tools can be screwed fast, so that it may be loosened by the use of "whisky jacks" at the surface. (*b*)

A string of drilling-tools is represented together in Fig. 5, Plate VI, and separately in Figs. 20 to 30. The string weighs about 2,100 pounds, and consists of two parts, separated by the jars. The lower portion, or drill, that delivers its blow downward and cuts the rock, consists of the bit (Figs. 20 and 21), the auger-stem (Fig. 22), and the lower half of the jars (Fig. 23). The upper portion that delivers its blow upward consists of the upper portion of the jars (Fig. 23), the sinker-bar (Fig. 24), and the rope-socket (Fig. 25). The upper link of the jars, by delivering an upward blow upon the auger-stem and bit, prevents the bit from sticking and remaining fast, while the elasticity of the cable permits the motion of the walking-beam. The "jars" therefore become the center of importance as well as of action. They were invented in 1831 by Billy Morris, but were never patented. Fig. 23 shows a pair of jars closed and another opened, with cross-sections. They are made like two flat links of a chain, with a male screw attached to one link and a female screw attached to the other. The slots in the links are each 21 inches long, and the cross-heads 8 inches deep; there is, therefore, 13 inches of "play" to the jars.

J. F. Carll, in Report III, *Second Geological Survey of Pennsylvania*, page 299 *et seq.*, says:

The manner in which the jars perform their work may be best explained, perhaps, in this way: Suppose the tools to have been just run to the bottom of the well—the jars closed as in *a*, Fig. 23—the cable is slack. The men now take hold of the bull-wheels and draw up the slack until the sinker-bar rises, the "play" of the jars allowing it to come up 13 inches without disturbing the auger-stem. When the jars come together they slack about 4 inches, and the cable is in position to be clamped in the temper-screw. If, now, the vertical movement of the walking-beam be 24 inches when it starts on the up-stroke, the sinker-bar rises 4 inches and the cross-heads come together with a smart blow, then the auger-stem is picked up and lifted 20 inches. On the down-stroke the auger-stem falls 20 inches, while the sinker-bar goes down 24 inches to telescope the jars for the next blow coming up. A skillful driller never allows his jars to strike on the down-stroke. They are only used to "jar down" when the tools stick on some obstruction in the well before reaching the bottom and in fishing operations. An unskillful workman sometimes "looses the jar" and works for hours without accomplishing anything. The tools may be standing on the bottom while he is playing with the slack of the cable, or they may be swinging all the time several feet from the bottom. If he cannot recognize the jar, he is working entirely in the dark; but an expert will tell you the

a J. F. Carll, Rep. III, *Sec. Geo. Surv. Penna.*, chap. xvii.

b *Ibid.*, p. 298.

moment he puts his hand upon the cable whether the drill is working properly or not. As the "jar works off", or grows more feeble, by reason of the downward advance of the drill, it is "tempered" to the proper strength by letting down the temper-screw to give the jars more play.

The temper-screw, Fig. 26, forms the connecting link between the walking-beam and cable, and it is "let out" gradually to regulate the play of the jars as fast as the drill penetrates the rock. When its whole length is run down, the rope clamps play very near the well mouth. The tools are then withdrawn, the well sand-pumped, and preparations made for the next "run". With the old-fashioned temper-screw a great deal of time was spent in readjustment, for it had to be screwed up by tedious revolutions of the clamps. But this delay is now obviated. The nut through which the screw passes is cut in halves, one half being attached to the left wing of the screw-frame, the other half to the right wing. An elliptical band holding the set-screw *a* passes around the nut. It is riveted securely to one of the halves, and the set-screw presses against the other half to keep the nut closed. The wings *b b* are so adjusted that they spring outward and open the nut whenever the set-screw is loosened. To "run up" the screw the driller clasps the wings in his left hand and loosens the set-screw; he then seizes the head of the temper-screw in his right hand, and, relaxing his grip upon the wings, the nut opens, when he quickly shoves the screw up to its place, again grips the wings and tightens the set-screw.

The dimensions of the different tools required to make up a set are given in the figures that represent them. The lengths of the different parts are given below:

	Feet.	Inches.
Rope-socket	3	6
Sinker-bar	18	0
Jars	7	4
Auger-stem	30	[illegible]
Center-bit	3	3
	62	1

The wings of the temper-screw are 1½ inches by ⅝ inch, and 4 feet 6 inches long. The screw is 1⅝ inches in diameter and 4 feet long, with two square threads to the inch. The weight of the string of tools is as follows:

	Pounds.
Fig. 25.—Rope-socket	80
Fig. 24.—Sinker-bar, 3½-inch	540
Fig. 23.—Jars, 5½-inch	320
Fig. 22.—Auger-stem	1,020
Fig. 21.—Bit	140
	2,100

The other tools weigh as follows:

	Pounds.	
Fig. 26.—Temper-screw	145	
Fig. 23.—Jars, 8-inch	565	
Fig. 20.—Two bits, 8-inch	320	
Fig. 30.—Reamer	180	
Fig. 21.—Two bits, 5½-inch	280	
Fig. 29.—Reamer, 5½-inch	140	
Fig. 27.—Ring-socket	50	
Fig. 28.—Two wrenches	210	
		1,890
Total weight of set		3,990
Total cost of set		$700
Driller's complete outfit, including cable, costs about		900

These tools are made of the best of steel and Norway iron.

Section 4.—DRILLING WELLS.

By reference to Chapter I, page 6, it will be observed that the Ruffner Brothers "provided a straight, well-formed, hollow sycamore tree, with 4 feet internal diameter, sawed off square at each end". This was placed on end, and by digging out beneath it was gradually sunk to the bed-rock. This device was in time replaced by a smaller conductor, that was placed in the center of a sort of shaft or well that was dug (when practicable) to the bed-rock. This conductor was made of two-inch plank spiked together, 6 or 8 inches square on the inside, and placed in position vertically beneath the center of the derrick floor, as shown in Fig. 1, Plate VI, and Fig. 31. When the bed-rock is below a depth to which it is practicable to dig, an iron pipe is driven to the rock (shown in Fig. 3, Plate VI, and Fig. 33). When the "drive pipe" is to be inserted a "mall" and "guides" must be provided. This mall is made of any tough, hard log that will dress 15 to 18 inches square and 10 or 12 feet long. Two sides only are dressed, one end being encircled by a heavy iron band, to prevent its splitting, the other having a strong staple driven into it, in which to tie the cable. Two pairs of wooden pins are put into each of the dressed sides, one pair near the top, and the other near the bottom. They are two inches apart and two inches long, the guides fitting between them. The guides consist of two 2-inch planks, placed perpendicularly upon a line drawn through the center of the well at right angles to the walking-beam, and 15 or 18 inches apart. They are securely stayed and strengthened by having narrower plank nailed on both sides of them, leaving their edges projecting 2 inches toward each other, to enter between the pins on the m

PUMPING WELL. 1861.

PUMPING WELL. 1868.

PUMPING WELL. 1878.

FLOWING WELL. 1880.

DRILLING WELL AND FULL STRING OF TOOLS.

The well is started by spudding. To do this a short cable is run up over the crown pulley in the top of the derrick. One end is attached to the ring-socket (Fig. 27) and screwed to the auger-stem; the other is passed around the bull-wheel shaft two or three times and the end left free. The bull-rope is now put on and the engine started. A man in front of the bull-wheels seizes the free end of the rope coiled around the shaft, a slight pull causes the coils to tighten and adhere to the revolving shaft, and the auger-stem rises in consequence, until it hangs suspended on the derrick, when it is swung over the spot where the well is to be started. The engine is kept running and the bull-wheels continue to revolve, but the man holding the shaft-rope has full control of the tools. When he pulls on the rope the coils at once "bite" the revolving shaft and the tools rise; but when he gives his rope slack they fall, and so long as the coils remain loose upon the shaft it revolves smoothly within them and communicates no motion. Thus, by alternately pulling and slacking the rope, this animated substitute for a walking-beam raises and drops the tools as much or as little as may be required, while the driller turns the drill to insure a round hole.

After spudding awhile to prepare the way for the drive-pipe, the drill is set aside, and the pipe to be driven, armed at the bottom with a steel shoe, as shown in Fig. 3, Plate VI, is put in place.

The following graphic description of the drilling of a well is given by J. F. Carll, in Report III, *Second Geological Survey of Pennsylvania*, page 306:

The mall is attached to the spudding cable and let down between the guides, where it is alternately raised and dropped upon the casing or drive-pipe by the man at the bull-wheels, precisely the same as in spudding. The casing used is of wrought-iron, screwed together in thimbles the same as tubing. A heavy cap of iron is screwed in the top when driving, to prevent its being injured by the blows of the mall.

When two or three hundred feet of pipe are to be driven, as is frequently the case in some of our northern valleys, it requires a great deal of skill and judgment to put it in successfully. In these deep drivings, after a sufficient depth has been reached to admit of the introduction of a string of tools, they are put in and operated by the walking-beam in the usual way; the cable (a short one, furnished for the purpose) being coiled upon one end of the bull-wheel shaft, while the other end is left free to work the mall-rope on.

To facilitate the necessary changes, which must be made every time the drill is stopped and pipe driven, the lower part of the guides are cut and hung on hinges some 10 or 12 feet above the derrick floor, and when not in use may be swung up overhead out of the way of the workmen.

When a sufficient depth has been reached by spudding to admit of the introduction of a full "string of tools", the spudding machinery is abandoned.

Now the coil of drilling cable is rolled into the derrick and set upon end. The free end in the center of the coil is tied by a connecting cord to the rope just detached from the ring-socket, and by it drawn up over the crown-pulley and down to the bull-wheel shaft, where it is fastened; the bull-rope is put in place, the engine started, and the men carefully watch and guide the cable as it is wound, coil after coil, smoothly and solidly upon the shaft. When this is done the end of the cable depending from the crown-pulley is secured to the rope-socket, and the full set of tools is attached and swung up in the derrick. After carefully screwing up all the joints (the bull-rope having been unshipped), the tools (Fig. 5, Plate VI) are lowered into the hole by means of the bull-wheel brake c c, shown in Fig. 16. The band-wheel crank is then turned to the upper center; the pitman is raised and slipped upon the wrist-pin, where it is secured by the key and wedges; the temper-screw is hung upon the walking-beam hook; the slack in the cable is taken up by the bull-wheels until the jars are known to be in proper position; the clamps are brought around the cable (after a wrapper has been put on it at the point of contact) and securely fastened by the set-screw; the cable is slacked off from the bull-wheels, and the tools are now held suspended in the well from the walking-beam instead of from the top of the derrick, as before. Some fifteen or twenty feet of slack cable should be pulled down and thrown upon the floor to give free movement to the drill. When the drill is rotated in one direction for some time the slack coils around the cable at the well mouth; if it becomes troublesome, the motion is reversed and it uncoils. Only by this constant rotation of the drill can a round hole be insured.

Having now made all the necessary connections, it only remains to give the engine steam, and the drill will rise and fall with each revolution of the band-wheel and commence its aggressive work upon the rock below. From this point downward the daily routine of the work is very monotonous unless some accident occurs to diversify it. Day and night the machinery is kept in motion. One driller and one engineer and tool-dresser work from noon until midnight (the "afternoon tour"), and another pair from midnight until noon (the "morning tour"). Up and down goes the walking-beam, while the driller, with a short lever inserted in the rings of the temper-screw, walks round and round, first this way, then that, to rotate the drill. He watches the jar, and at proper intervals lets down the temper-screw as the drill penetrates the rock. When the whole length of the screw has been "run out", or the slow progress of the drill gives warning that it is working in hard rock and needs sharpening, he arranges the slack cable upon the floor so that it will go up freely without kinks, and informs the engineer that he is ready to "draw out".

After attending to the needful preliminaries, the driller throws the bull-rope upon its pulley, and quickly steps to the bull-wheel brake, while the engineer commands the throttle of the engine. The walking-beam and the bull-wheel are now both in motion, but at the proper moment one man stops the engine and the other holds the bull-wheels with the brake just when all the slack cable has been taken up, and the weight of the tools is thus transferred from the temper-screw to the crown-pulley.

This is a performance requiring experience and good judgment, for should any blunder be made a break-down must certainly result. To loosen the clamps on the cable and unlock the pitman from the wrist-pin and lower it to the main sill is but the work of a moment. Dropping the pitman raises the end of the walking-beam with the temper-screw attached to it and throws them back from their former perpendicular over the hole, so as to allow the cable and tools to run up freely without interference with them. Steam is now turned on again, and the tools come up. When the box of the auger-stem emerges from the hole the engine is stopped. A wrench is slipped on the square shoulder of the bit, and the handle dropped behind a strong pin fixed for that purpose in the floor; another wrench is put on the shoulder of the auger-stem; a stout lever is inserted in one of the series of holes bored in the derrick floor in a circle having a radius a little less than the length of the wrench-handle, and it is brought up firmly against the upper wrench-handle, thus making a compound lever of the wrench and greatly increasing its power. Both men give a hearty pull on the lever, which "breaks the joint", or, in other words, loosens the screw-joint connecting the bit with the auger-stem, so that the bit can be unscrewed and taken off by hand after it has been brought up above the derrick floor. The wrenches are then thrown off, steam is let on again, and the bit rises from the hole. Now the driller throws off the bull-rope by operating a lever with one hand, while with the other he catches the bull-wheel with the brake, holding the tools suspended a few inches above the derrick floor. At the same instant the engineer shuts off the steam, or else, suddenly relieved of its heavy work by unshipping the bull-rope, the engine would "run away" with lightning speed. It only remains now to hook the suspended tools over to one side of the derrick, and the hole is free for the sand-pump.

While the driller is sand-pumping the engineer unscrews the worn bit and replaces it by one newly dressed, so that there may be no delay in running the tools into the well again when sand-pumping is ended.

The "line" to which the sand-pump is attached (as before described) passes up over a pulley near the top of the derrick, and thence down to the sand-pump reel, which is operated from the derrick by means of hand-lever *v* and connecting levers *u* and *t*. While sand-pumping the pitman remains disconnected, the bull-rope lies slack on its pulleys, and the band-wheel is kept constantly in motion. A slight pressure on lever *v* brings the friction-pulley *w* in contact with the band-wheel, and the pulley immediately revolves, the slack sand-pump line is quickly wound up, and the sand-pump, which is usually left standing at one side of the derrick, swings out to the center and commences to ascend. Just now the lever is thrown back, and the connection between the friction-pulley and the band-wheel being thus broken, the sand-pump commences to descend into the well by its own gravity. If it be likely to attain too great speed in its descent, a movement of the lever to bring the pulley either forward against the band-wheel or backward against the brake-post will quickly check it, and thus the speed may be regulated at will.

As soon as the pump strikes bottom additional steam is given to the engine, and the lever is brought forward and held firmly, while the sand-pump rises rapidly from the well. The sand-pump is usually run down several times after each removal of the tools, to keep the bottom of the hole free from sediment, so that the bit may have a direct action upon the rock.

After the hole has been sufficiently cleansed, the sand-pump is set to one side, the drilling tools are unhooked, and, swinging to their place over the well mouth, are let down a short distance by the brake, the wrenches are put on, and the lever is applied to "set up" the joint connecting the replaced bit to the auger-stem. Then removing the wrenches, the tools are allowed to run down to the bottom under control of the bull-wheel brake. Connections are now made as before, the driller commences his circular march, the engineer examines the steam- and the water-gauges and the fire, and then proceeds to sharpen the tool required for the next "run", and thus the work goes on from day to day, until the well is completed.

The derrick and other apparatus here described is that employed in the oil regions of Pennsylvania, where the wells are deep and the tools required for drilling them are heavy. In the Franklin, Mecca, and Belden districts the shallow wells require a comparatively simple and inexpensive apparatus, the derricks being often not more than 30 feet in height, and the entire cost of a well only about $300. In West Virginia and southern Ohio the "light rigs" of the early time are still largely used, but are gradually being replaced by the higher derricks, in which heavier tools and long lengths of pipe can be conveniently handled.

Section 5.—THE TORPEDO.

In 1862 Colonel E. A. L. Roberts, then an officer in the volunteer service, conceived the idea of exploding torpedoes in oil-wells, for the purpose of increasing the production. Having applied for a patent, in the fall of 1864 he constructed six torpedoes, and early in 1865 he visited Titusville to try his first experiment. The risk of damaging the wells prevented their owners from allowing the tests to be made; but Colonel Roberts finally persuaded Captain Mills to allow him to operate on the Ladies' well, on the Watson flats, near Titusville. The explosion of two torpedoes caused this well to flow oil and paraffine. This result produced great excitement, and led to the filing of several applications for patents and as many lawsuits for infringement, which were all finally decided in favor of Roberts. The complete success of the torpedo was not established, however, until December, 1866, when Colonel Roberts exploded one in the Woodin well, on the Blood farm. This well was a "dry hole", and had never produced any oil. The first torpedo caused a production of 20 barrels a day, and the second raised it to 80 barrels. This established the reputation of the torpedo on a firm basis. (*a*)

The following notice of the decision of Judge Strong, sustaining the patent of Colonel Roberts, explains the method of using torpedoes and the opinion of the inventor regarding their action:

The patent consists in sinking to the bottom of the well, or to that portion of it which passes through the oil-bearing rocks, a water-tight flask, containing gunpowder or other powerful explosive material, the flask being a little less in diameter than the diameter of the bore to enable it to slide down easily. This torpedo or flask is so constructed that its contents may be ignited either by caps with a weight falling on them or by fulminating powder placed so that it can be exploded by a movable wire or by electricity, or by any of the known means used for exploding shells, torpedoes, or cartridges under water. When the flask has been sunk to the desired position, the well is filled with water, if not already filled, thus making a water tamping and confining the effects of the explosion to the rock in the immediate vicinity of the flask and leaving other parts of the rock surrounding the well not materially affected. The contents of the flask are then exploded by the means above mentioned, and, as the evidence showed, with the result in most cases of increasing the flow of oil very largely. The theory of the inventor is that petroleum or oil taken from wells is, before it is removed, contained in seams or crevices, usually in the second or third stratum of sandstone or other rock abounding in the oil regions. These seams or crevices being of different dimensions and irregularly located, a well sunk through the oil-bearing rock may not touch any of them, and thus may obtain no oil, though it may pass very near the crevices; or it may in its passage downward touch only small seams or make small apertures into the neighboring crevices containing oil, in either of which cases the seams or apertures are liable to become clogged by substances in the well or oil. The torpedo breaks through these obstructions and permits the oil to reach the well.

Judge Strong, in delivering the opinion of the court, said:

While the general idea of using torpedoes for the purpose specified is not patentable, the particular method of employing them invented by Mr. Roberts is patentable; therefore he is entitled to protection.

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a Abridged from Henry's *Early and Later History of Petroleum*, p. 257.

The material used now in the Pennsylvania oil regions is nitro-glycerine, which is manufactured for the purpose by the ton. This was first used in quantities of from 4 to 6 quarts ($13\frac{1}{2}$ to $20\frac{1}{4}$ pounds, equal to from 108 to 162 pounds of gunpowder). This amount was gradually increased to 20, 40, 60, 80, and even 100 quarts. When the well is ready to be "shot", word is sent to the torpedo company, and the canisters are prepared in sections of about 10 feet in length and 5 inches in diameter. These sections are made conical at the bottom, so that they will rest securely on top of each other. The nitro-glycerine is carried in cans that are placed in padded compartments in a light spring wagon, which is often driven over the roughest mountain roads with great recklessness. Arrived at the well, one of the sections of the canister is suspended by a cord that passes over a pulley and is wound upon a reel. The nitro-glycerine is poured into the canister until it is filled, and then it is lowered by the cord to the bottom of the well. Another section is filled and lowered in like manner until the proper amount is put in place. Then the cord is drawn up and a piece of cast-iron weighing about 20 pounds, and made of such a form that it will easily slide down the bore, is allowed to drop down upon the cap, which is adjusted to the last section that was lowered. At a depth of 2,000 feet no sound reaches the surface, although 80 quarts of nitro-glycerine, equal to 2,160 pounds of gunpowder, may have been exploded by the hammer. After from three to ten minutes has elapsed a gurgling sound gradually approaches the surface, and the oil, welling up in a solid column, filling the bore-hole and mounting higher and higher, falls first like a fountain, and then like a geyser, and forms a torrent of yellow fluid, accompanied by the rattle of small pieces of stone and fragments of the canister, in a shower of oil-spray 100 feet in height. In five or ten minutes it is all over; 25 or 30 barrels of oil have been thrown to the winds, and the derrick has been saturated with it, so that in a short time it becomes as black as ink and as combustible as tinder. In some instances but little oil escapes from the well, and sometimes none at all. The position of a torpedo just before explosion is shown in Fig. 31.

While not disputing that in some instances the theory of the action of torpedoes formulated by Colonel Roberts may explain such action, I am forced to the conclusion that when a torpedo is exploded in such rock as the Bradford oil-sand the crushing effect of the explosion is comparatively limited. The generation of such an enormous volume of gas in a limited area, the walls of which are already under a very high gas pressure, and which is held down by a motionless column of air of 2,000 feet (the use of water tamping has been abandoned), must be followed by an expansion into the porous rock that drives both oil and gas before it until a point of maximum tension is reached. The resistance then becomes greatest within the rock, and, reaction taking place, oil and gas are driven out of the rock and out of the well, until the expansive forces originally generated by the explosion are expended. By this reaction the pores of the rock are completely cleared of obstructions, and the pressure of the gas within the oil-rock continues to force the oil to the surface until it is no longer sufficient for that purpose.

It is found that in shallow wells of only a few hundred feet in depth, like those of West Virginia, nitro-glycerine is not as efficient as gunpowder, the violent action of the nitro-glycerine throwing the column of air or water out of a well of that depth, while gunpowder is held down.

The expense incurred by using torpedoes in wells under the Roberts patent has led to many attempts to escape it, and many parties manufacture nitro-glycerine in the oil regions and explode it in wells by stealth. Such torpedoes are called "moonlighters". Another and more safe method is to purchase two-thirds or three-fourths the amount of nitro-glycerine required of outside parties, say 40 quarts for a 60-quart charge, and then engage the torpedo company to put in the other 20 quarts and fire it off, thus avoiding the payment of the royalty on the 40 quarts. These are called "setters".

The value of torpedoes in individual cases is unquestioned; but, as a whole, their value to the oil interest is doubtful. Some very remarkable instances are on record where the yield of a well has been greatly increased by their use. The Mathew Brown well No. 6, in Fairview township, Butler county, Pennsylvania, is said to have yielded an increased production of 300 barrels the first twenty-four hours, and this from a charge of only 4 quarts. Another instance is on record where a torpedo in one well increased the flow in a second well 80 rods distant so that the yield did not run down to its former amount for six months. It is, however, the opinion of those whose long experience well qualifies them to judge that, especially in close sand, torpedoes are of very little use. By some they are no longer employed. It is manifestly a destructive method of operation that yields quick results, attended with great waste.

Section 6.—LOCATION OF WELLS.

The production of petroleum is in a general sense a speculative business. It may, however, be conducted as a regular business, involving the sagacious use of capital in such a manner as experience and judgment would dictate, with due account as to its elements of uncertainty. Conducting their affairs on such a basis, there are large corporations and individuals who command large capital and who control large tracts of proved productive territory either in fee or under leases. There are also many adventurers, who, either alone or in company with others, drill wells as they might purchase lottery tickets, losing little if they prove dry and reaping a rich reward if they prove valuable. This latter class operate almost exclusively under leases. It would be impossible to give details of the varied conditions incorporated in leases, as they are cunningly drawn in favor of the lessee or lessor. The lease generally provides that the lessee shall drill a certain number of wells within a certain time and pay to the lessor, as a royalty, a certain proportion of the oil obtained, varying, according to circumstances, from one-tenth to one-fourth. As the reputation of territory improves, the undeveloped portion of a tract held under lease is subleased for a larger royalty or on a bonus, sometimes both. A tract originally leased on a royalty of one-eighth is subleased on a royalty of one-fourth, with perhaps a bonus of $300 an acre in addition.

The location of wells upon a given piece of land will depend upon circumstances; but I think it may be safely stated that, as a general rule, wells will be drilled along the border of a tract, rather than toward the middle. This is often to be regarded as a measure of protection, because if A does not draw as much as possible from B's territory, B is quite sure to drill a line of wells and draw from A. Wells have in many cases been located with a total disregard of all prudential considerations. In the valley of Oil creek, just above Oil City, leases of only a quarter of an acre were taken and wells drilled on them, thus insuring about twenty times as many wells as there ought to be, and reducing at the same time in a corresponding ratio the possibility of both continued yield and profit. On the Clapp farm, at the northeast end of this tract, good wells were struck, one of which, drilled in 1863, was pumping one barrel per day in 1881. Here the wells were not drilled close, but nearer the city six and even eight wells were drilled on an acre, and as a result nearly one-half of them were soon abandoned. Experience has proved that one well to five acres is as close as they should be drilled. The man who owns a lot has no safety but in getting his oil to the surface; for as long as his land remains undeveloped he is constantly exposed to the risk of having it sucked dry by the wells of his more energetic neighbor, and that is equivalent to disaster and financial ruin. If all the operators in a given district could be persuaded to enter a movement for suspending drilling, it would in the end be mutually beneficial; but in many instances lease-holders are compelled, either by the terms of their leases or by their own pecuniary embarrassments, to go ahead with development and realize as promptly as possible upon their investments.

Section 7.—THE OIL-SAND.

The character of the oil-sand has been easily studied from specimens thrown out by torpedoes. The Venango sand, extending from Tidioute to Herman station, in Butler county, is a conglomerate of small pebbles with large interstitial spaces. The depth or thickness of this sand varies from 10 or 12 to 125 feet at Triumph. When this great thickness was observed, the wells were drilled into the sand from 15 to 20 feet and pumped for a while, when it was discovered that they had not passed through the sand. On drilling through to the bottom the wells continued to produce for a long period. The Warren sand is fine-grained, bluish in color, and is inclined to be muddy, while the Bradford sand is a friable sandstone, somewhat coarse-grained, and is of a brown color.

The opinion formerly held respecting the occurrence of oil in fissures has been noted elsewhere (see page 18). It was not only held as a scientific hypothesis, but it exerted a very important practical influence on the methods employed for obtaining oil. At one time an instrument was very widely used for indicating the point at which a crevice occurred in a well, and torpedoes were introduced at such points. It cannot be denied that near the surface oil-bearing rocks do contain fissures. The Berea sandstone, where it comes to the surface at Berea, and the different members of the Venango oil-sand when they reach the surface, are fissured. The experience gained in drilling wells also shows the presence of fissures below the surface. Wells are sometimes started, and after passing through several strata reach one where, in spite of all attempts to remedy the evil, the hole will go crooked, the drill glancing from the rock on one side of the fissure, and the well, in consequence, has to be abandoned. At the same time the extent to which fissures exist in the deep beds of oil-sands is now believed to have been very much overrated. The experience gained in sinking deep wells leads rather to the conclusion that in them the drill penetrates a homogeneous solid sandstone, in the pores of which the oil is held under great pressure. Although oil is sometimes found in the joints of fractured slate or shale, the solid shale is nearly impervious, often to both oil and water, and is separated from the sandstone by a hard and wholly impervious shell or crust, which prevents the escape of the oil and gas. Sometimes, however, this crust is absent or is thin and soft, in which case oil is found in the sand-rock above; in other words, where oil is found in the second sand the crust of the third sand is not impervious.

The motion of oil laterally through the oil-sands is illustrated by numerous phenomena attending the drilling and operation of contiguous wells. It is observed that the wells and springs of water in the superficial strata fail when these strata are penetrated by deep wells. Even artesian wells sunk for water to the second sand are often drained by contiguous oil-wells sunk to the third sand in consequence of the lateral movement of the water through the second sand to the oil-well. It is asserted that the swampy section around Power's Corners, in the Mecca district, has been greatly improved by surface drainage through the numerous oil-wells that have been sunk in that neighborhood.

The capacity of a porous sandstone, or even of the coarse pebble conglomerate constituting the Venango third sand, to hold the vast quantity of oil that has poured forth from some wells has been questioned; but when we consider (1) the strong attraction existing between oils and dry surfaces, (2) the powerful capillary attraction exerted in consequence, and (3) the enormous pressure under which the oil is held in the rock and forced out when the reservoir is perforated, there seems to be no reasonable ground for doubting the sufficiency of such a source of supply. This opinion receives further confirmation from the large content of oil proved by Dr. Hunt to exist in the Chicago limestone (see page 63).

J. F. Carll has shown by experiment that the pebble sand will absorb from one-fifteenth to one-tenth of its bulk of oil, and, further, that "the aggregate sum of the pores or interspaces of a sand-rock of this kind, as exposed in the walls of a well of 5½ inches diameter, is equivalent to the area of an open crevice one inch wide, extending from top to bottom of the gravel bed, whatever its thickness may be". He further shows that "on Oil creek there is generally from 30 to 50 feet of third sand, and also from 15 to 30 feet of stray sand, both locally producing oil. Of this total, suppose only 15 feet is good oil-bearing pebble, we shall then have a producing capacity of 15,000 barrels per acre, or 9,600,000 barrels per square mile, which is adequate to the requirements of the most exceptional cases known". (*a*)

While the Warren and Bradford sands are quite dissimilar from the Venango sand, their porosity is sufficient to hold their content of oil.

The occurrence of so-called slush oil at North Warren and at Limestone, in the Tuna valley, has been attributed to fissuring of the sandstones and shales in such a manner as to allow the oil to rise into the fissures in the shales. These cases are local and exceptional, and are therefore not to be regarded as typical of the manner in which oil occurs generally.

SECTION 8.—THE MANAGEMENT OF WELLS.

Having shown how the oil-well is carried down upon a reservoir of sufficient capacity to contain a remunerative quantity of oil, it will next be shown how the well is managed after it is drilled and torpedoed. The present methods of management are the result of an historical progressive development, which will be best understood if discussed chronologically and in connection with the figures in Plate VI and the sections, Figs. 32, 33, 34, and 35. Figs. 1, 2, and 3, Plate VI, and Figs. 32, 33, and 34 were originally drawn by H. Martyn Chance, to accompany Mr. Carll's report, and were afterward redrawn by Miss Laura Linton, with some changes, to bring them into conformity with Fig. 4, drawn by Mr. Opperman. An examination of these figures shows the well divided into four sections, viz: the surface section, the bottom of the drive-pipe section, the bottom of the casing section, and the bottom section. These different sections show the arrangements at the derrick floor, at the bottom of the drive-pipe, at the bottom of the casing or seed-bag section, and at the bottom of the well. Fig. 1, Plate VI, and Fig. 32 show a well as arranged in 1861. It is the direct descendant of the well of the Ruffner Brothers, and was then in use around Tarentum and elsewhere for salt-wells. From the well-head at the derrick floor to the bed-rock was a plank conductor or drive-pipe, which held the loose sand or gravel of the drift. From the bottom of this conductor to the bottom of the well the rocks through which the drill had cut formed the walls of the bore, which was 4 inches in diameter. Within this 4-inch hole a 2-inch pipe was inserted, with the pump-barrel screwed to its lower end. At a point estimated to be below that at which the water infiltrating the surface rocks entered the well the "seed-bag" was fastened in such a manner as to stop off this water from entering the bore of the well below. The pump-barrel being securely screwed to a length of pipe, it was lowered into the well, and piece after piece connected, until the point at which the seed-bag was to be introduced was reached; then a bag of calfskin or buckskin was securely tied to the pipe immediately below a thimble to prevent it from sliding. This bag was filled with flaxseed, and the upper end was so insecurely tied that if the tube was raised the bag would turn and empty itself. It was then lowered and the pipe added joint by joint until the required amount was put in. Beneath the thimble, at the end of the last joint, clamps were placed and securely fastened above the head-block, which rests upon the derrick floor. As the seed-bag absorbs moisture it expands and fills the 4-inch hole so completely that all of the water above the bag is held and prevented from passing below. Of course this well is drilled wet, that is, full of water, no attempt being made to stop off this water until the oil is reached and the well is prepared for pumping. If for any reason it became necessary to withdraw this tubing, the seed-bag came with it, and the water flowed into the bottom of the well.

Fig. 2, Plate VI, and Fig. 33 show the well of 1868. At this time it had become customary, after sinking the conductor or cast-iron drive-pipe to the bed-rock, to commence a 5½-inch hole, which was continued to the bottom. The position of the seed-bag was then determined, and it was securely fastened to the lower end of a section of casing-pipe 3¼ inches inside diameter. This was lowered to the proper depth. The 2-inch tubing, with the pump attached, was then lowered to the proper depth and secured at the top with the proper clamp. This well was of course drilled full of water, as the water was not stopped off until the tools were drawn out and the casing inserted. Instead of the ordinary seed-bag, a patent packer was sometimes attached to the casing in place of it. This packer was formed by pressing a sort of leather cup over an iron ring that was a little smaller than the drill-hole and was fastened to the outside of the casing. The pressure of the column of water above held the leather firmly to the drill-hole when the oil was pumped from below. Sometimes, as is represented in the figure, both the cup-packer and seed-bag were used at the same time. A casing-head was screwed on, usually with one or two outlets for gas,

a Rep. Sec. Geo. Surv. Penna., III, p. 252.

and the gas that escaped inside the casing and outside the tubing could thus be utilized as fuel; at the same time the casing-head took the place of the head-block and formed a support for the tubing. In this way the casing was made a permanent fixture, effectually stopping off the water and permitting the tubing to be introduced or taken out at pleasure.

Although this methed of drilling and casing wells was a great improvement over those previously employed, it still presented two very grave defects: First, the well must be drilled full of water, and, second, the hole was larger than the casing, and accidents sometimes occurred, which made it necessary to draw the casing and let the water into the well. To remedy these defects the plan was adopted that is shown in Fig. 3, Plate VI, and Fig. 34. According to this plan an 8-inch iron pipe is driven to the bed-rock. An 8-inch hole is then carried down below the surface water. The drilling-bits are then made smaller, and the hole is contracted to $5\frac{5}{8}$ inches. A second tube, armed with a steel shoe, is then carried down inside the drive-pipe, and ground in the tapering drill-hole to a water-tight joint. This casing thus effectually cuts off the water. The 8-inch jars and drills are exchanged for $5\frac{1}{2}$-inch tools, and the hole is carried down from that point of the same diameter as the interior of the casing to the bottom of the well, with only water enough introduced to sand-pump properly. The buoyancy imparted to the tools and cable by 1,000 to 1,500 feet of water is thus avoided, and the presence of oil in any of the strata penetrated is immediately manifested by escaping gas and soiled tools, and sometimes by a gush of oil that fills and overflows the well before the tools can be withdrawn.

Mr. Carll (Report III, *Second Geological Survey of Pennsylvania*, page 320) estimates that "the average cost of drilling cased wells (especially if we take into account the reduced liability to accidents from tool-sticking, etc.) is probably little, if any, greater than it would be if they were drilled wet. Quite an item in the cost of fuel is sometimes realized, for a vein of gas may be struck several hundred feet from the bottom of the well, which will fire the boiler until the work is finished".

The advantage of having a hole of the same diameter all the way down is very great when fishing operations are necessary, and also when the packers which are now used are to be inserted. These are used in preparing the well for flowing, and their use is represented in Fig. 4, Plate VI, and Fig. 35, where a cased well, with tube and packer, are indicated in full operation. These packers are of rubber, and are so constructed that the tube within them moves in a sliding joint. The lower piece of pipe enters the bottom of the mass of rubber, and the upper section, being securely fastened to the upper portion of the mass, slides in the lower section in such a manner as to press with its whole weight against the rubber and force it against the sides of the drill-hole. A well prepared for flowing as represented in Fig. 4, Plate VI, and Fig. 35, and properly connected with a tank, will operate with very little attention for months. The flow will finally run down either from the exhaustion of the supply or the clogging of the pipes with paraffine.

The clogging of pipes with paraffine occasions a great deal of trouble in the Bradford district. This is occasioned, first, by the much larger percentage of paraffine in the Bradford oil, and, second, from the condensation of the less volatile and soluble paraffines, due to the very intense cold produced by releasing the oil from the high pressure under which it exists in the rock, and consequently rapid evaporation of the more volatile portions. No attempt has been made to ascertain accurately this temperature, but many incidental facts indicate that it is very low.

After a well has ceased to flow, and in those localities where the gas pressure is not sufficient to cause the oil to flow, the well is pumped. In the method of pumping represented in Fig. 1, Plate VI, and Fig. 32 the sucker-rods were introduced immediately after the pipe and seed-bag, and, after the seed-bag had had time to swell, connection was made with the walking-beam, and the water pumped out below the seed-bag. After this water was removed and its pressure taken from the rock the gas and oil entering the well were brought to the surface. With the adoption of the first method of casing wells (Fig. 2, Plate VI, and Fig. 33), the water was removed from the space between the casing and tubing, and the oil-rock being quickly relieved of its pressure, the oil and gas rushed in to supply its place, and after the removal of the water was brought to the surface. With the drilling of dry holes the method of pumping represented in Fig. 3, Plate VI, and Fig. 34 has been adopted. In this well there is no water to pump, and the oil is brought to the surface as long as any will enter the well. Sometimes so-called gas-pumps are applied to wells that have ceased to yield oil and a partial vacuum has been created, with the result of causing the oil to flow laterally into the well through the rock.

In some localities, where the oil is valuable and the yield of the wells small, as among the heavy-oil wells of the Franklin district or in the older portions of the Oil Creek district, a method of pumping wells by sucker-rod connections has been adopted. The use of sucker-rods was no doubt adopted on account of the fact that old rods were suitable, numerous, and cheap. An engine is attached to a circular horizontal table by an elbow-joint in such a manner that it is made to perform a quarter revolution and return to its former position. To the circumference of this table from two to a dozen or fifteen connections are made, in such a manner that each connection is given an equal stroke sufficient to move a pump connection, such as is represented in Fig. 36. The pull of the engine comes on the down-stroke of the pump, and the up-stroke of the pump is balanced by the stones or other heavy material placed in a box on the arm, *a*. The rods by which these connections are made for long distances are supported by light frames, which have a swinging motion as the rods move slowly to and fro. In the Franklin district, where the wells are shallow, the rods are made of strips of ash 2½ inches square, nailed together by wooden straps. From thirty to forty wells are thus sometimes attached to one engine. In the White Oak district of West Virginia, where the ground is too uneven to admit of wooden connections, motion is communicated to a dozen or more wells by an endless rope, usually of wire, that is supported on wheels and runs up one hill and down another and along the valleys to a convenient site for the engine. By this method wells can be profitably pumped that would otherwise have to be abandoned.

At the Katie Hough well, on Mud run, in the White Oak district, West Virginia, in the summer of 1881, the curious phenomenon was exhibited of pumping two kinds of oil from the same well. In this region there are several oil horizons, and at the point penetrated by this well the first White Oak sand produces oil of 27° specific gravity, and third White Oak sand beneath it yields oil of 45° specific gravity. The well was in 1865 put down 255 feet to the first White Oak sand, and was pumped at intervals for 15 years; it was then reamed to an 8-inch hole, and a 4½-inch hole sunk to the third sand. A tube, with a seed bag at the bottom of the 8-inch hole, was inserted, and the heavy oil stopped off. From this tube amber oil of 45° specific gravity is pumped from the third sand. A second pump and tube was then inserted in the 8-inch hole beside the other tube and proper connections made with the walking-beam, every stroke of which pumped dark, heavy oil of 27° specific gravity from the first sand, worth $7 per barrel, and amber oil of 45° specific gravity from the third sand, worth $1 per barrel. The Shaw well, on Gales' Fork, also in the White Oak district, said to have produced $80,000 worth of oil, pumps oil of 25° specific gravity from a depth of 160 feet and an oil of the specific gravity of 40° at a point between 600 and 700 feet.

It has been the custom around Titusville and Pleasantville, when the production of a well ran very low, to introduce into it five to ten barrels of crude naphtha (benzine), and after allowing it to remain for a few days to resume pumping, an increased production being the result.

The large amount of oil that has at different times and in certain localities run to waste upon the streams has been due to unavoidable waste, to the bursting of pipes and tanks, the sinking of barges, and to oil which has escaped destruction during extensive fires. On the Allegheny river at Oil City may always be seen a thin film of oil often sufficient to produce iridescence. The quantity of oil required to produce this effect, although apparently very small, is in the aggregate quite large. Where booms are stretched across such streams the floating oil is arrested and may be pumped from the surface with water into settling tanks and collected. In this way the collection of oil has been made a profitable business, as occasion might warrant, thousands of dollars' worth having been gathered in a single season that would otherwise have gone to waste. In 1862, 4,000 barrels were dipped from the Allegheny river and was used for lubricating oil and for making lampblack.

The occurrence of oil in the drift gravels beneath the superficial clays south of Titusville has already been mentioned (see page 49). The oil here was pumped from shallow wells, dug only a few feet into the gravel. (*a*)

SECTION 9.—YIELD OF WELLS.

The average duration of the profitable production of an oil-well is very uniformly estimated at five years, but this period is subject to very great variations. The wells in the Colorado district, northeast of Titusville, have been pumped about twelve years, and have yielded constantly enough to more than pay expenses. In the White Oak district of West Virginia the Scott and Scioto wells, drilled in 1865, were being pumped in 1880. On the contrary, the Cole creek portion of the Bradford field had all been drilled over since 1879, and some of the wells were abandoned before June 4, 1881, while at the same date wells were flowing near Tarport, in the same field, that were drilled in 1875. As a general rule, it may be said that the nearer the wells are to each other on a given piece of property the sooner they will become unprofitable.

As an illustration: On Triumph hill eight wells were drilled in a group, two on the edge of the belt and six nearer the center. As each well was drilled it commenced to yield at the rate those previously drilled were yielding at that time. The first well was drilled in 1866, and yielded an average daily production for the first six months of 70 barrels, the second six months 41 barrels, the second year 35 barrels; it then fell off gradually until it reached 5 to 7 barrels, where it remained for two or three years; it then continued to fall, until for the three years preceding 1881 the yield was only about 1 barrel a day. The eight wells were pumped with sucker-rods by one engine. The six central wells were 9 or 10 rods apart. The sand in the center of the Triumph belt is more than 100 feet thick.

The Economites drilled two wells on their tract upon the hill east of Tidioute 300 feet apart. They started at 100 barrels a day and held it three months, then ran down to 25 barrels in two years, and during the two years following ran down to 200 barrels a week and held about that yield for two years. Two wells were drilled in

a In the summer of 1881 quite an excitement was occasioned in Titusville by the discovery of oil saturating gravel beneath the soil of gardens along the creek. Several hundred barrels were pumped and dipped from holes or pits dug over an area of several acres. It was supposed to have been the leakage from loading racks during the Pithole development.

positions *a* and *b*. They started at 125 barrels each, and in eighteen months ran down to zero. The rigs were then changed to the other side of the engines at *a'* and *b'* and the wells were redrilled. They were

a *a'*

drilled deeper into the sand the second time, and were cased with $5\frac{5}{8}$-inch instead of $3\frac{1}{4}$-inch casing. These second wells started off at 75 barrels a day and lasted ten years. The first wells were drilled

b' *b*

by a man who had a hobby that 10 feet in the sand is sufficient, but the second wells were drilled through 25 or 30 feet of sand.

The yield of some single wells has been enormous. One half of the Empire well was sold for $900, and it afterward yielded $12,000 in six days. Its owners saved 3,500 barrels a day and sold it for 10 cents a barrel. The owners of the land were unable to furnish barrels, and the royalty was put into pits dug in gravel. Well No. 4, on the Jacob and John Hemphill farm, Donegal township, Butler county, Pennsylvania, struck by McKinney Brothers in September, 1873, has produced about 110,000 barrels, and is still (1881) producing six barrels daily. The farm upon which this well is located is among the most prolific oil properties ever developed, twelve wells thereon producing over 750,000 barrels. The Divner well, No. 1, Divner farm, Butler county, Pennsylvania, has yielded about 200,000 barrels, and six years after being struck produced 13 barrels a day. The Boss well, on the J. A. Parker farm, in Armstrong county, Pennsylvania, produced about 80,000 barrels. The amount yielded by any one well in the Bradford district is much smaller, from 20,000 to 25,000 barrels being probably the highest yield.

SECTION 10.—FLOODING.

The proximity of other outlets appears to determine the duration of the flow of oil-springs or wells. The spring in the island of Zante is known to have flowed two thousand years. The Beatty well, in Wayne county, Kentucky, drilled in 1819, is still flowing, there being no other well near it. The American well yielded oil in large quantities from 1830 to 1860, but after the drilling of other wells in the neighborhood the yield fell off, and finally ceased altogether. It is therefore impossible for any producer controlling a small area to preserve his oil beneath the surface. The lateral flow of oil and water through the oil-sand has been repeatedly demonstrated. Jonathan Watson, in his experience, had known water to run into a well when the seed-bag was removed from another one-half mile distant, and in another instance red paint was put into one well and pumped out of another at about the same distance.

J. F. Carll, in Report III, *Geological Survey of Pennsylvania*, page 258, says:

The National well No. 1 was struck in February, 1866. It was very near the northwesterly edge of a large and well-stored pool, and passed through rather an inferior oil rock as compared with that afterward found on the axis of the belt. Still it had a sufficiently free connection with the supplying reservoir to furnish a delivery of about 85 barrels per day, and it maintained its production with wonderful constancy for two years, having only declined to about 60 barrels in that time. In the summer of 1868 wells were drilled on the center of the deposit from which it had been deriving its supply. Some of these wells produced as much as 150 barrels per day. The effect on the National was immediately apparent. Its production dropped off rapidly and dwindled down to 10 barrels or less a day. * * * Harmonia well No. 1 was on the thriving northerly edge of the Pleasantville belt. The main body of oil and the best sand-rock, as afterward demonstrated, lay to the south. It started with a small yield, and at the end of a fortnight was pumping about 30 barrels per day. Gradually increasing its production, as if enlarging and cleaning out the passages leading into the supplying reservoir, it finally commenced to flow, and ran up to 125 barrels, where it remained until wells of larger flow were drilled on the center of the belt and relieved the gas pressure, when pumping had to be resumed. After this it soon fell down to an unremunerative production and was abandoned.

The early method of drilling with the well full of water prevented the escape of the oil and gas until the water was pumped out; when the rock is pierced with a hole drilled dry "the effect is similar to the sudden liberation of the safety-valve of a boiler under a full head of steam, * * * "the boiling, foaming mass is driven upward against the forces of gravity", and sometimes shoots high above the top of the derrick. The equilibrium which had been maintained for ages throughout the communicating portions of the rock is suddenly destroyed in the immediate proximity of the well by this sudden rush up the drill-hole, and material gaseous at the ordinary temperature and pressure, but fluid under the enormous pressure maintained in the oil-rock, expands and evaporates as it rushes to the surface. This action goes forward, slowly reducing the pressure upon all the communicating portions of rock, until the pressure on the oil filling the rock is only equal to that of the column filling the drill-hole. The pump is now used to lift the fluid from the drill-hole, the oil being still under the pressure of the gas ascending between the tubing and casing. The rock is still full of oil, and the pumping goes on until the pressure of the gas is scarcely sufficient to send any of it to the surface, when a gas-pump is applied at the casing-head to one of the lateral tubes and the pressure of the atmosphere removed. Still, after all this has been done, there is oil remaining in the rock. As before intimated, the oil and gas mutually dissolve each other and form a homogeneous mass, "the gas being as thoroughly incorporated with the oil as gas is with water in a bottle of soda-water." The effects of "flooding" or allowing water to enter the rock partially exhausted of its oil has been the subject of much controversy. Some producers imagine that if the rock is properly flooded the oil can be driven toward certain points and removed to advantage, but experience has proved such operations extremely hazardous.

J. F. Carll has discussed this subject in great detail, and I am greatly indebted to his report and private conversations for information on this subject. He says: (*a*)

The first intimation of the flooding of a district is given by an increased production from the wells affected by it. Old wells improve gradually, running up from 5 to 10 or 20 or even 50 barrels. After pumping in this way for some time, the oil quickly fails, and they yield

a J. F. Carll, Report III, p. 265.

only a few barrels of salt or brackish water. * * * In some districts the movement is quite rapid, and wells are invaded and "watered out" in quick succession; in others it is so slow that large quantities of oil are obtained from those which are favorably located to receive a "benefit". Flooding a well is sometimes a very profitable way of closing up its career, inasmuch as it thus yields more in a few months than it otherwise would in years, and when the water reaches it the owner knows at once what it betokens and stops work, thus saving the time and money usually expended in fruitless efforts to reclaim a well failing through natural decline. * * * In judging of the probable effects of the introduction of water into any particular oil district several things are to be considered. (1) *The time of flooding*, whether early in the progress of development, while yet a large percentage of oil remains unexhausted, or at a later period, after the supply has suffered from long-continued depletion. (2) *The structure of the rock*, whether regular and homogeneous throughout, or composed of fine sand interbedding and connected and irregular layers of gravel, sometimes lying near the top and at others near the bottom. (3) *The shape of the area being flooded.* (4) *The position of the point at which water is admitted* in relation to the surrounding wells still pumping oil. (5) *The height* (which governs the pressure) *of the column of water* obtaining admittance. (6) *The duration of the water supply.* It will readily be seen that a *temporary flooding* of comparatively *fresh territory*, such as frequently occurred in early days along Oil creek, from the drilling of new wells without casing or the overhauling of old ones when the seed-bag was attached to the tubing in the primitive way, must necessarily be quite a different affair from one caused by a *permanent deluge* through unplugged and abandoned wells *in nearly exhausted territory.* In the former case the flood may be checked before much water has accumulated in the rock, and then the oil-flow can be reclaimed after a few days of persistent pumping; in the latter, the recovery of the oil is very uncertain, because from its long-continued extraction a greater capacity has been given to the rocks for storing water, and this being supplied from scattered and obscure sources, there is little probability that it can be shut off, although the most thorough and systematic attempts may be made to check it.

The effect of flooding upon adjacent wells is illustrated by the following incident related of the Oil Creek district: A and B owned wells 200 feet apart. A's pumped about 10 barrels a day and B's 30. B wished to pump his, but A thought his would not pay and stopped, when B soon found he could get only water. B offered A $10 per day to pump his well ten days. At the end of ten days A refused to pump, then B offered him $25 a day for twenty-five days, at the end of which time B offered A $30 a day to pump his well an indefinite period, and A consented. In the mean time the oil in B's well increased gradually until it reached 75 barrels a day, and the operation proved profitable.

This flooding of oil territory has been proved of such importance that the legislature of Pennsylvania has affixed a penalty to any neglect to "plug" abandoned wells. The plugging consists in filling them with sand. A moment's reflection will show that the owner of oil territory must have it drilled or it will be exhausted by his neighbors drilling a cordon of wells around his property. After it is drilled, the wells must flow until the pressure of gas is exhausted, or, as has been known in several cases, the casing and tubing will be thrown out of the well. A case is on record where the casing-head was anchored down with chains and the flow of oil arrested, yet the gas pressure tore away the fastenings and threw the casing out through the top of the derrick. After the oil has stopped flowing, if the well-owner does not pump, his neighbor's pumps will drain his territory, and if he "pulls out", the law compels him to fill his well with sand and ruin it forever, to prevent the public injury resulting from letting down surface water into the oil-sand. There is therefore no other alternative presented to the unfortunate possessor of oil territory but to drill and produce, whatever the price of oil may be.

CHAPTER VIII.—TRANSPORTATION AND STORAGE OF PETROLEUM.

SECTION 1.—EARLY HISTORY OF TRANSPORTATION.

But few facts have come within my notice respecting the transportation of petroleum among the primitive peoples that have used it. In Burmah it is placed in jars and transported in them about the country. The breakage of the jars and muck occasioned by the leakage is mentioned by Major Symes as one of the disagreeable adjuncts of the production in the neighborhood of Rangoon.

In this country the Seneca oil of the early days was transported in barrels or packed in bottles. Dr. Haggard, of Burkesville, Kentucky, very graphically described to me the incidents attending the trip which he took to Louisville with the first barrel of oil that was ever sent away from the American well. The odor of the oil was so pronounced that it attracted a great deal of disagreeable attention along the road, and many criticisms more emphatic than elegant were made by the passers-by and inhabitants along the route.

During the first years of the excitement oil was transported in 40 and 42 gallon barrels, made of oak and hooped with iron. Its penetrating character led those interested to coat the barrels on the inside with a stiff solution of hot glue, which forms a continuous lining, is elastic, and is not attacked by the oil. (*a*) Great difficulty has always been experienced in the transportation of crude oil in barrels, due to the fact that such oil invariably contains a trace of water, usually as much as 1 per cent., which, acting on the glue, causes the barrels to leak, and consequently a loss of oil. To remedy this difficulty, and also to decrease the labor of handling the oil, early in 1866, or possibly in 1865, tank-cars were introduced upon railroads entering the oil regions. Those first introduced consisted of an ordinary flat car, upon which were placed two wooden tanks shaped like tubs, each holding about 2,000 or 4,000 gallons to a car.

While this change in methods of transportation was taking place on the railroads, a corresponding one had grown up in river carriage. The difficulty of moving such enormous quantities of material by teams was almost insurmountable. Aside from its enormous weight and bulk, the very magnitude of the transportation, carried on as it was over roads badly and recently constructed, left them during a large portion of the year in an almost impassable condition. The mud was often limitless in extent and depth, through which waded the long trains of teams to Oil City and other points of shipment.

The following appears in Henry's *Early and Later History of Petroleum*, page 287:

> Arrangements were made with the mill-owners at the headwaters of Oil creek for the use of their surplus water at stated intervals The boats were towed up the creek by horses—not by a tow-path, but *through the stream*—to the various points of loading, and when laden they were floated off upon a pond-freshet. As many as 40,000 barrels were brought out of the creek on one of these freshets, but the average was between 15,000 and 20,000. At Oil City the oil was transferred to larger boats. At one time over 1,000 boats, 30 steamers, and about 4,000 men were engaged in this traffic. Great loss occurred from collisions and jams. During the freshet of May, 1864, a jam occurred at Oil City, which resulted in the loss of from 20,000 to 30,000 barrels of oil.

Bulk barges were also introduced on the Allegheny and Ohio rivers. These were constructed with more or less care, many of those first employed being of inadequate strength and too easily broken up in the vicissitudes of river travel. As now constructed, they are made 130 by 22 by 16 feet, in eight compartments, with water-tight bulkheads, and hold 2,200 barrels. They are still used to convey oil from the lower Allegheny to the refineries at Mingo, Wheeling, Marietta, and Parkersburg, and also to float the production from Burning Springs down the Little Kanawha to Parkersburg.

In 1871 the wooden-tank car gave place to the boiler-iron cylinder car of the present time. These are now used in transporting crude, illuminating, and lubricating oils and other petroleum products; also residuum and spent acid. They are much safer and stronger than wooden tanks, and the railroad companies require shippers to use them. The tanks are of different sizes, holding 3,856, 3,873, 4,568, and 5,000 gallons each. The heads are made of $\frac{5}{16}$-inch flange iron, the bottom of $\frac{1}{4}$-inch, and the top of $\frac{3}{16}$-inch tank iron, and they weigh about 4,500 pounds. They are about 24 feet 6 inches long and 66 inches in diameter. Those made at present hold from 4,500 to 5,000 gallons each.

Light iron tanks on wheels are used for carting the petroleum from Boyd's creek to Glasgow, Kentucky, where it reaches a railroad.

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a The barrels are first thoroughly washed, usually with a jet of steam, dried, and heated. Hot glue is then put in and distributed over the whole surface. Then by a tube a pressure of about 20 pounds per square inch is applied through the bung, and the glue is forced into the pores of the wood.—*Chem. News*, xvi, 221.

SECTION 2.—PIPE-LINES.

A wonderful revolution has taken place in the transportation of petroleum through the use of pipe-lines. The *Bradford Era* gives the following account by C. L. Wheeler:

He said in substance that the first suggestion of a pipe-line for transporting oil, so far as he knew, was made to him by General S. D. Karns at Parkersburg, West Virginia, in November, 1860. Mr. Karns said that as soon as he could raise the money he would lay a six-inch gas-pipe from Burning Springs to Parkersburg and let the oil gravitate to the Ohio river, a distance of 36 miles. For some reason this line was never laid. Some years after, Mr. Wheeler was unable to recall the exact date, a Mr. Hutchinson, inventor of the rotary pump which bears his name, conceived the idea of forcing oil through pipes, and explained his plan to John Dalzell and the narrator in the latter's office in Titusville. Subsequently Hutchinson's plans became a reality, the first pipe-line being laid from the Sherman well to the terminus of the railroad at Miller farm, a distance of about 3 miles. The inventor's idea of the hydraulic pressure of a column of that length was certainly very exalted, and he took elaborate pains to prevent the breaking of pipes. At intervals of 50 or 100 feet were air chambers like those on pumps, 10 inches in diameter, for the purpose of equalizing the pressure. These queer protuberances gave the line the appearance of a fence with ornamental posts and excited great curiosity. The weak point, however, was the jointing, which, as the pipes were of cast-iron and imperfectly finished at their ends, was very defective, and the leakage from this cause was so great that little, if any, oil ever reached the end of the line. It was a success theoretically, but a mechanical failure. Thus the expectations of easy and cheap transportation for crude oil raised by the building of the first pipe-line were ruthlessly dashed to the ground and the inventor discontinued his experiments in despair.

The first successful pipe-line was put down by Samuel Van Syckle, of Titusville, in 1865, and extended from Pithole to Miller's farm, a distance of four miles. In the fall of 1865 Henry Harley began the construction of a pipe-line from Benninghoff run to Shaffer farm, and finished it the following spring. Meantime the firm of Abbot & Harley had secured control of the Van Syckle line, and they afterward purchased enough of the Western Transportation Company's stock to control the charter and organized under it. The two lines thus consolidated were brought into successful operation under the name of the "Allegheny Transportation Company".

After the doubters were silenced by the prospect of success, the enterprise met with the most determined opposition from the army of teamsters and roustabouts, who supposed their interests were invaded by the use of pipe-lines. Mr. Harley was threatened with personal violence, his oil-tanks were burned, attempts were made to destroy the pipe-line by breaking the joints, and personal violence was offered to the men employed upon it. A few detectives, employed as teamsters, soon effected the arrest of the ringleaders, and the opposition ceased. (*a*)

At the present time the pipe-lines not only form a complete network throughout the oil regions, but there are trunk lines which extend from the oil regions to Pittsburgh, Cleveland, Buffalo, New York, and Williamsport. These trunk lines transport the oil of large areas to those cities under a high pressure, delivering thousands of barrels daily. They are laid for miles through the forest-covered hills and valleys of northern Pennsylvania and southern New York, across hills and rivers, on the surface of the ground or only slightly covered. These main lines are 6-inch pipe tested to a pressure of 2,000 pounds to the square inch and joined with couplings, into which the lengths of pipe are screwed, as are ordinary gas or water pipes.

Each well has a tank, usually of wood, holding an average of perhaps 250 barrels. With these well tanks are connected 2-inch pipes, converging toward a central point, to which there is fall enough to cause the oil to descend. Occasionally wells are so situated that the oil has to be forced by a pump over a hill.

The lines are provided with cocks and gates for opening and closing connections, and the large corporations constantly employ a corps of men in laying and taking up pipe as connections are made with new wells or broken with others. It is impossible to compute or estimate accurately the vast length of these 2-inch pipe connections. Wells are connected and left to flow for months or years, with only an occasional visit of the owner or agent. Only that proportion of the producing interest controlled by firms or corporations of strict business habits really know approximately how many miles of pipe they own, and therefore an accurate enumeration was found to be impossible; but it is safe to say that there are thousands of miles of 2-inch pipe laid for transporting oil not owned by the pipe-line companies. These lines run everywhere through the streets of towns, across fields and door-yards, under and over and beside roads, and terminate at pumping stations, at racks, or in storage-tanks. There are also racks and storage-tanks on the main lines.

The pumping stations are located at central points in the valleys. These stations consist of permanent buildings, a boiler-house and a pump-house, which contain the necessary steam-power and a steam- and oil-pump combined in one. Many of these pumps are of the Worthington pattern, and are very powerful machines, forcing the oil rapidly through great distances and in vast quantities, not only over the hills that are encountered in the course of the line, but against the friction of the pipe conveying the oil; an element in the problem of vast importance when it is remembered that the friction increases enormously as the flow of the oil is increased in rapidity. The friction on the 108 miles of 6-inch pipe between Rixford and Williamsport, Pennsylvania, is found to be equal to a column of oil 700 feet in height; that is to say, if the pipe were laid on a uniform descending grade of 700 feet between the two points and filled with oil, the friction or the adhesion between the oil and iron would prevent the oil from flowing For these reasons the pressure carried on these pumps is frequently from 1,200 to 1,500 pounds to the square inch.

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a Henry's *Early and Later History of Petroleum.*

The racks are used for loading oil from pipe-lines into tank-cars, and are so arranged that any number of cars, from one to an entire train, can be loaded at the same time. They are constructed after the following general plan: The line is brought alongside the railroad track, and perpendicular branches are brought up just as far apart as the length of a tank-car. A platform is erected of a convenient height, and each perpendicular branch-pipe is provided with a stop-cock and an elbow above it. To this elbow is attached an adjustable pipe, usually of tin, long enough to reach the man-hole of the tank-car as it stands upon the track. To load a train it is run upon the track in front of the rack, the man-hole plates are all removed, the adjustable pipes placed in position to discharge the oil into the tanks, and the oil turned on. In this way as many cars as the rack will hold, perhaps 20, holding 2,000 barrels of oil, can be loaded in an hour and a half.

The storage-tanks are situated at convenient points for construction and use in filling and emptying. Standing on the hill south of Kendall, and looking north up the Tuna valley toward Limestone, I counted about 60 of these huge storage-tanks in sight. They are placed upon the ground without any foundation, the surface being carefully leveled to receive them. The following table shows the relative capacity, dimensions, and weight of the different sizes:

Capacity.	Diameter.	Height.	Weight and value.	Sizes of iron.
Barrels.	*Feet.*	*Feet.*		
37,065.66	95.4	29	90 tons; value, $9,000; 5 cents per pound.	54 plates, No. 6, sketch.
				34 plates, No. 00, rectangular.
				68 plates, No. 0, rectangular.
				34 plates, No. 3, rectangular.
				34 plates, No. 4, rectangular.
				34 plates, No. 5, rectangular.
				200 plates, No. 6, rectangular.
				34 plates, No. 7, rectangular.
31,000.00	86.0	30	80 tons; value, $8,000; 5 cents per pound.	48 plates, No. 6, sketch.
				32 plates, No. 0, rectangular.
				32 plates, No. 1, rectangular.
				32 plates, No. 2, rectangular.
				32 plates, No. 3, rectangular.
				32 plates, No. 4, rectangular.
				32 plates, No. 5, rectangular.
				165 plates, No. 6, rectangular.
26,000.00	87.0	$24\frac{5}{12}$	66 tons; value, $7,260; $5\frac{1}{2}$ cents per pound.	46 plates, No. 6, sketch.
				31 plates, No. 1, rectangular.
				31 plates, No. 2, rectangular.
				31 plates, No. 3, rectangular.
				31 plates, No. 4, rectangular.
				31 plates, No. 5, rectangular.
				169 plates, No. 6, rectangular.
22,000.00	85.0	22	53 tons; value, $5,830; $5\frac{1}{2}$ cents per pound.	54 plates, No. 7, sketch.
				26 plates, No. 2, rectangular.
				26 plates, No. 3, rectangular.
				26 plates, No. 4, rectangular.
				26 plates, No. 5, rectangular.
				26 plates, No. 6, rectangular.
				156 plates, No. 7, rectangular.
16,000.00	70.0	24	45 tons; value, $5,400; 6 cents per pound.	38 plates, No. 7, sketch.
				50 plates, No. 3, rectangular.
				25 plates, No. 4, rectangular.
				25 plates, No. 5, rectangular.
				25 plates, No. 6, rectangular.
				82 plates, No. 7, rectangular.
				25 plates, No. 8, rectangular.
10,000.00	60.0	$20\frac{8}{12}$	38 tons; value, $5,320; 7 cents per pound.	38 plates, No. 6, sketch.
				40 plates, No. 4, rectangular.
				40 plates, No. 5, rectangular.
				80 plates, No. 6, rectangular.
				20 plates, No. 7, rectangular.
5,900.00	45.0	20	15 tons; value, $2,100; 7 cents per pound.	20 plates, No. 8, sketch.
				15 plates, No. 5, rectangular.
				30 plates, No. 6, rectangular.
				15 plates, No. 7, rectangular.
				44 plates, No. 8, rectangular.

The following specifications, used by the United Lines in making contracts, will give a very good idea of their construction:

UNITED PIPE-LINES.—SPECIFICATIONS FOR 35,000-BARREL TANKS.

DIMENSIONS.—Tank to be 93 feet in diameter and 30 feet high, and be composed of 7 rings.

SHEETS.—The first ring to be of No. 00 (Birmingham gauge), weighing 13.64 pounds per square foot. The second ring to be of No. 0 (Birmingham gauge), weighing 12.04 pounds per square foot. The third ring to be of No. 1 (Birmingham gauge), weighing 11.40 pounds per square foot. The fourth ring to be of No. 2 (Birmingham gauge), weighing 10.40 pounds per square foot. The fifth ring to be of No. 3 (Birmingham gauge), weighing 9.55 pounds per square foot. The sixth ring to be of No. 4 (Birmingham gauge), weighing 8.83 pounds per square foot. The seventh ring to be of No. 6 (Birmingham gauge), weighing 8.15 pounds per square foot. The bottom to be of No. 6 (Birmingham gauge), with 5 sketch plates, weighing 8.15 pounds per square foot.

ANGLE-IRON.—The bottom angle-iron to be 4 by 4 by ½. The top angle-iron to be 2 by 2 by ⅜.

RIVETS.—The bottom angle-iron and first ring to be riveted with ⅝-inch rivets; the second and third rings with ½-inch rivets driven hot, and the remaining rings with ⅜-inch rivets driven cold. The vertical seams of the first, second, third, and fourth rings to be double-riveted.

ROOF.—The roof to be conical, with a rise of at least 5 feet 6 inches to the center (1.2 inches to the foot), and to be covered with No. 20 iron, painted on both sides, and riveted to the top angle-iron. The ends of the rafters supporting the roof must not rest on the angle-iron, but upon posts placed next to the shell of the tank inside.

MAN-HOLE.—The man-hole to be of wrought-iron throughout, and 20 inches in diameter, and be placed 10 inches from the bottom of the first ring in the sheet adjoining that in which the outlet-valve is placed.

HATCHES.—There shall be two hatches in the roof, each 2½ by 3 feet, provided with suitable covers. One of the hatches shall be directly over the outlet-valve; the position of the other to be determined by the superintendent of the United Pipe-Lines.

SWING-PIPES.—There shall be two swing-pipes, one of 6¼-inch casing, for oil, and one of 1½-inch pipe, for water; each pipe to be 30 feet long, and to have 50 feet of chain fastened to it by clamps; the chain for the 6¼-inch pipe to be $\frac{5}{16}$-inch, and the chain for the 1½-inch pipe to be ¼-inch.

FLANGES.—The flange for the pipes to be of wrought-iron, and securely riveted to the tank; the flange for the 6¼-inch pipe to be at least 1¼ inches thick where the thread is cut.

VALVES AND CONNECTIONS.—The oil-valve to be a 6-inch iron body, brass-mounted, flanged gate-valve. The connections for the oil swing-pipe to consist of one 6-inch nipple (8 threads to inch), with 10 inches of thread on one end and ordinary thread on other end. One 6-inch elbow (8 threads to inch). One 6-inch elbow (8 threads to inch) on one end, and 6¼ casing-thread on other end. One 6-inch nipple 18 inches long, ordinary threads both ends (8 threads to inch). The water-valve to be a 1½-inch iron body screwed gate-valve. The water connections to be one 1½-inch nipple, with 6 inches of thread on one end and ordinary thread on the other. One 1½ nipple 6 inches long, with ordinary thread, both ends. Two 1½-inch elbows.

WINDLASS.—There shall be a windlass over one of the hatches to raise the swing-pipes.

STAIRS.—The stairs to be substantially constructed and furnished with a gate. The tank to be carefully painted with red paint, and to be completed in every part in a thorough and workmanlike manner.

The standard tank adopted by the United Pipe-Lines is the second on the list, practically holding 30,000 barrels of oil, and over 20,000,000 barrels of oil are stored in these tanks of various sizes. (a) The oil is subject to depreciation in value from evaporation and by leakage through the roof of the tank, by which it is converted into an emulsion locally known as "B. S.", from which the water will not separate until the emulsion is heated. These tanks are also constantly exposed to danger of fire from lightning and other accidental causes.

SECTION 3.—CONCERNING IRON-TANK FIRES.

The following discussion of the subject of tank fires is mainly abridged from an elaborate discussion of the subject by William T. Scheide, superintendent of the United Pipe-Lines:

A few of the tanks have roofs of No. 12 iron riveted and calked, but the majority have a conical, wooden roof, covered with No. 20 iron. The plate-iron roofs are more expensive, and do not remain water-tight. Iron roofs, when sunken and covered with water, are especially bad, owing to changes in the form of the shell, due to changes in the temperature, and also to filling and emptying the tank. The roof adopted is wooden, with a pitch of 1.2 inches to the foot from the center, supported on posts set inside the tank and covered with No. 20 iron, nailed to the wood and securely riveted to the shell.

Such a tank, containing 80 tons of iron, and resting upon 5,800 square feet of earth, upon which it is pressed by more than 4,000 tons of oil, would seem to be safe from lightning. The danger comes from the liability of the gas that is continually rising from the oil to be lighted from the bolt. Mr. Scheide thinks the roofs are tight enough to prevent the escape of gas, and that the firing takes place inside; but this is scarcely possible from the manner of their construction, and it is probable that the firing is due to the ignition, either within or without the tank, of an explosive mixture of gas and air. Mr. Scheide considers that the introduction of the spark can take place by following the pipes and leaping across some air space, as the tanks and pipes of the whole region are connected in a network.

These pipes are connected with the tanks in either of two ways:

1. They run up the sides and over the top of the tank, bending into the hatchway, in which case they are held to the shell of the tank by an iron band, fastened to the roof (making a connection), and extending 12 or 15 inches through the hatch into the tank. If such a pipe were struck, and the entire bolt was not conducted to the earth through and over which it passes, the residue would leap through the mixed air and gases over the oil and

a April, 1882, 27,000,000 barrels.

fire them. To provide against this such pipes are now being bolted to a flange on the shell, and do not project through it. This arrangement is necessary for station tanks, where it is required to see the flow of oil in order to judge whether the pipe is intact.

2. As the majority of tanks are storage rather than station tanks, they are not so arranged. Oil is pumped into these through a pipe that enters through a flange at the bottom. To provide against the collection and freezing of water which settles from the oil about the outlet valve, the pipe is continued through the shell by what is called a "swing-pipe", the end of which is intended to be constantly above the surface of the oil. In this case, as in the other, the residuum of a charge might leap from the pipe to the shell and fire the tank. This swing-pipe is raised and lowered by a chain, one end of which is fastened to the pipe, and the other to a windlass placed above one of the hatches, the chain passing through the roof. Mr. Scheide suggests that such tanks be disconnected from the pipes, but remarks that the ground becomes very dry beneath them, and hence they are not in as complete connection as might at first be supposed. At the same time no such isolated tank has ever been burned. Continuing, he says:

The great majority of tanks lost by lightning have been station tanks with pipes running over the roof; but there have been tanks burned where the only pipe connection was through the shell near the bottom, the spark evidently going from the end of the swing-pipe. Well tanks of wood (usually 16 feet in diameter and 8 feet high) are quite frequently destroyed, though not more frequently in proportion to their number than iron tanks. There is always a 2-inch pipe leading over the top of these tanks and resting against the derrick over the well. This derrick, being 70 or 80 feet high, is very liable to be struck. The noteworthy point about these fires is that the pipe that leads to the tank has its other end connected with the tubing and casing in the well, and is thus afforded the most perfect earth connection conceivable. The firing in these cases is due, first, to the presence of an explosive mixture formed by the mingling of the gas from the fresh oil and the air; and, second, to the residual discharge from the end of the pipe. Either the mixture without the discharge or the discharge without the mixture would be harmless.

When a tank is fired, the roof is always blown off if there are several feet of gas space between it and the oil. There have been instances where this explosion was sufficiently intense to blow the tank to pieces. When, as has been the case this year, the tank is practically full, the explosion only starts the roof, and the fire may be, and occasionally is, extinguished by covering the rents with wet blankets, or by turning in steam. Usually, however, a tank once fairly aflame has to burn, and attention is directed exclusively to saving adjoining property. In a country as broken as this it is difficult to find sufficient ground to separate the tanks widely without going to unwarranted expense, so that from 200 to 300 feet is considered a fair interval between them. Very many are much closer than this.

A tank once fairly on fire will burn from 6 to 8 inches an hour, and will not endanger neighboring tanks (unless high wind carries the flames over them) for several hours. The danger comes usually from the "overflow"—the most extraordinary phenomenon attending an oil fire. After a period varying, in a full tank, from 5 to 12 hours, or even a little more, and when the oil has burned down about 5 feet, the tank suddenly and without any previous notice throws out in a grand flow from 8 to 12 feet (8,000 to 12,000 barrels) of burning oil. To prepare for this flood all our energies are directed until it comes. Ditches are dug and embankments thrown up between the burning tank and other property, and, if possible, the ditches are made to open into fields, where the oil can burn rapidly and without further damage.

The oil burns on the ground or on water with incredible rapidity, and will not run very far from the tank. When the flow ceases, it loses its limpidity, as its lighter parts are consumed, and when carried forward by water the flames die out in a comparatively short distance, leaving the surface covered with thick, dark-green, unconsumed oil.

At certain intervals after the first flow there will be smaller flows, and in from twenty-four to thirty-six hours the tank will be quite burned out.

The cause of these overflows is uncertain. They are probably owing, in part at least, to the heating of the subjacent oil, but not wholly.

At the Custer fire our superintendent went completely around within five minutes of the flow, and as far as he could reach the tank was quite cool to the hand.

The theories offered to account for the overflow are chiefly, first, heating the sides of the tank causes the oil to boil; second, currents of air caused by the fire itself; and, third, that, as the more volatile parts of the oil burn first, the burning surface will, after a time, become thick enough to seriously impede the free flow of gas from the oil beneath, and this obstruction becomes sufficient to permit or cause the accumulation of a quantity of gas so considerable as when it is suddenly relieved to cause the overflow. It is certain that the force excited is very great. At Custer the flow was made with such vehemence as to extinguish the flames in the tank, and for several minutes the oil left in the tank was not burning, only catching again from the fire outside.

To shorten the time during which the tank burns we "shoot" it with small cannon or rifles. Through the holes thus made a considerable quantity of oil escapes, and though the area and intensity of the fire is increased the time of danger is lessened. When spouting from holes made by rifle-balls the oil burns with an exceedingly brilliant, pure white flame, almost comparable to the electric light. Another object in shooting is to lessen the overflow by reducing the volume of unburned oil in the tank. The flames of a burning tank take a whirling motion, tending toward the center of the tank; when there is no wind the column of flame and smoke covers about two-thirds of the surface of the tank, the strong rotary movement drawing the flames from the circumference. The combustion is naturally very imperfect, and the column is chiefly dense black smoke, through which the flames, in great brilliant jets of fire, burst continually.

In a private communication of later date Mr. Scheide says:

1. We think lightning-rods are an advantage; we rodded nearly all the tanks last summer, and the result (if it was the result) indicates the advantage. Seven tanks were fired; three had no rods, and four had. But one of the four was a station tank undergoing repairs to the roof, and we think the evidence is that the discharge came from the pipe. As at least 90 per cent. of the tanks were rodded, the showing of last summer we think favorable. The rod is an inch-round iron rod 25 feet long, screwed into two iron bands (4 inches by $\frac{1}{8}$ inch), which cross each other at the apex of the roof and run radially to the circumference, where they are carefully riveted to the top angle-iron, and so to the shell. The idea is that the shell may help discharge itself as far as possible above the roof, and the spark thus kept out of the vicinity of the escaping gas. The bands are further fastened to the roofing iron (previously scraped and cleared) by screws.

2. All recent tanks have been built without swing-pipes. An arrangement devised by one of our men keeps the water out of the gate-valve, through which the tank is filled and emptied. We are now lowering the swing-pipes in all other tanks on the bottom of the tank, there to remain until fall. I think this is quite important.

3. The ground (electrical) connections of the tanks we find on test to be very much better than expected. We have had every tank in the field tested for its electrical connection with the earth and with the rods. Owing to the extreme difficulty in obtaining a perfect "ground" to test to, our results are only approximate, but a vast majority of the tanks show an average earth resistance of not exceeding 6 ohms. Their true resistance is probably much less. We were unable to get any resistance in the rod connections. We were prepared with no less resistance coil than one-hundredth of an ohm, and none of the rod connections gave as much resistance as that coil.

4. We have increased the distance between the tanks: 350 feet from shell to shell is now the minimum distance, and the average is 400 feet.

5. We are confident we can prevent the overflow if we can draw the oil out of the burning tank fast enough. A 3½-inch cannon seems about the best instrument for the purpose, but we are experimenting with a machine that seems to promise well, which will cut a 6-inch hole without any jar to the tank, and be operated by power from a safe distance. About a dozen 3½-inch shots will empty a tank fast enough to prevent an overflow.

6. We have given a great deal of thought to the matter of extinguishing fires. We conclude thus far that this can only be done while the roof is yet comparatively whole (it is often several hours before the roof disappears), and by steam or carbonic acid. We think steam the surest, as it can be generated more steadily. We have a large "gas-engine", with a capacity of 2,000 cubic feet per charge, but experimental tests have not encouraged us. We tried it also at an actual fire, but it was not in first-class order, having been partly broken in transit. We have built a number of 30-horse boilers and fitted them for rapid steaming with oil fuel, which we think will prove effective. We expect to have at least two of these boilers at a burning tank, with steam on, in an hour and a half at most from when it was struck, having organized very thoroughly a fire department at each of our tankage points completely supplied with every tool and machine necessary at an oil fire.

The burning of a large oil-tank at night is described as one of the grandest spectacles that can be witnessed. Considering the fact that whenever a thunder-storm passes over the oil regions it is quite probable that one or more tanks will burn, and also the seeming recklessness with which these vast reservoirs of combustible material are located in and near large towns, escape from terrible disaster seems providential. There have been several serious warnings. Red Rock station, on the Olean and Bradford narrow-gauge railroad, was burned in November, 1879. A wooden 250-barrel tank having taken fire from a lantern, the oil from this small tank ran down the valley and struck a large iron one. The flames being as high as the tank, soon set its contents on fire. The tank of oil began to burn about 7 p. m., and continued to burn quietly until 4 a. m., when it overflowed. The burning oil streamed over the sides, and, running down the main street, set the town on fire. The tank fire at Summit City was witnessed by a large company on the hill above, who were waiting for the overflow. A man fired into it with a Winchester rifle, around the circumference and at about the same height from the ground, making a fountain of fire as the jets ignited successively. Finally the oil poured over the sides all around, and a column of flame ascended at least 300 feet in height, and spread out in a horizontal sheet, like an umbrella. A gentleman beneath this sheet of flame and several hundred feet from the tank had his hat scorched.

Hair-breadth escapes from destruction are often recorded. A tank near Tarport was fired by lightning in the summer of 1880. The explosion split the cover across from side to side and set the oil on fire, the flames streaming out of the man-hole in the cover. Wet blankets were placed over the hole at first without success, but finally, by doubling them and putting wet carpets along the crack in the cover, the flames were smothered and the tank saved. On another occasion a 250-barrel wooden well tank, 16 feet in diameter and 8 feet high, nearly full of oil, and covered with loose boards, was fired by a thunderbolt. A workman near by wet his coat and thrashed out the flames. His employer gave him $50, but told him not to risk his life another time for so small a value. These may be taken as examples of hundreds of similar incidents.

It may not be out of place here to remark that very disastrous fires have sometimes resulted from the ignition of gas at the well head when the oil-rock is perforated. One of the most disastrous fires of this kind on record occurred in 1861 on the John Buchanan farm, on the east side of Oil creek. The well was at the mouth of a small ravine formed by the waters of a spring, which, spreading out, had formed a small marsh. The well had first been drilled to the first sand and afterward put down deeper, and must have poured forth a stream of 3,000 barrels a day, as the marsh was immediately flooded with oil. The catastrophe is thus described by an eye-witness:

Just after supper on the evening of April 17, 1861, Mr. H. R. Rouse, Mr. Perry, Mr. Buel, myself, and others were in the sitting-room of Anthony's hotel, when a laborer on the fatal well hurried into the room to say that a monstrous vein of oil had been struck and barrels were wanted to preserve it. All ran to the well with the exception of myself, and I, not seeing the man who attended to the distribution of barrels, started in the opposite direction for teams to haul the necessary packages. I had completed my errand, and was on a full run for the well, with less than 20 rods to make, when an explosion occurred which nearly took me from my feet. On the instant an acre of ground, with two wells and their tankage, a barn, and a large number of barrels of oil were in flames, and from the circumference of this circle of fire could be seen the unfortunate lookers-on of a moment before rushing out enveloped in a sheet of flame that extended far above their heads, and which was fed by the oil thrown upon their clothing by the explosion. * * * The well burned three days before it could be extinguished, which was finally done by smothering it with manure and earth. Its appearance while burning was grand. From the driving-pipe, 6 inches in diameter, to the height of 60 or 70 feet arose a solid column of oil and gas, burning brilliantly. Above this hovered an immense cloud of black smoke, which would seize sections of the ascending flames, and rolling over and over, first exposing to the view cloud and then flame, would rise a hundred feet higher before the flame would fade out. From the main column below millions of individual drops of oil would shoot off at an angle, and then turning the arc of a circle drop burning to the ground, presenting all the hues of the rainbow, making a scene like enchantment, the whole accompanied by a roar hardly inferior to that made by Niagara Falls. (a)

Mr. Henry R. Rouse, one of the owners of this well, was among those fatally burned. On other occasions a fountain of oil projected high into the air has burned continually for weeks before the flames could be smothered.

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a Henry's *Early and Later History of Petroleum*, p. 338.

Oil in transit in tank-cars has also occasioned terrific fires. Travel stopped ten hours on the Central railroad of New Jersey in 1876 by the burning of oil cars. The following telegraphic dispatch illustrates the extent of such disasters:

PORT JERVIS, NEW YORK, *October* 5—3 p. m.—The fire broke out at 1.40 p. m., and is burning fiercely. There are fifteen cars in the train, which are exploding one after the other. No one dares approach within a hundred feet of the train. Rails will have to be laid for a distance of nineteen car-lengths before trains can pass.

The following is from *Stowell's Petroleum Recorder*, June, 1880:

The greatest oil fire on record occurred in Titusville, Pennsylvania, on the 11th of June, 1880. It continued three days, and was caused by lightning striking a large iron tank filled with crude oil on a hill south of the city, from which the burning fluid rolled down the declivity, consuming refineries, tanks of crude oil, tanks of benzine, tanks of distillate, houses, stables, and bridges; burning some 200,000 barrels of oil, 8 or 10 iron tanks, 2 refineries, 2 bridges, 20 or 30 dwellings, and everything that could be burned in its resistless course to the creek below. The estimated loss was $500,000.

The United Pipe-Lines mutually insure their patrons against losses by fire and other accidents. The following notice will illustrate the manner in which the assessments are made after any accident which involves a loss of oil:

GENERAL OFFICE UNITED PIPE-LINES,
Oil City, Pennsylvania, August 30, 1880.

The patrons of the United Pipe-Lines are hereby notified that all credit balances upon the books of the United Pipe-Lines at the close of business August 28, and all outstanding acceptances issued on and before that date, are subject to an assessment of twenty-one one-hundredths ($\frac{21}{100}$) of 1 per cent. in pipeage paid oil, on account of loss by fire, on August 28, 1880, of tank United register No. 738, located at Babcock, on the Erie railroad, McKean county, Pennsylvania.

WILLIAM T. SCHEIDE, *General Manager*.

SECTION 4.—CONCERNING THE STORAGE OF OIL AND ACCUMULATED STOCK.

The legislature of Pennsylvania has required the incorporated pipe-lines whose certificates are negotiable paper to publish a monthly statement of their condition. The following abstract of a report made in conformity to the requirements of that law affords a sufficient illustration of its operation:

STATEMENT OF THE TIDE-WATER PIPE COMPANY, LIMITED.

(Made in compliance with the act of assembly approved May 22, 1878.)

First. Quantity of crude petroleum which was in the actual and immediate custody of said company at the beginning of the month of March, 1881, 1,594,900.68 barrels.

Quantity of crude petroleum which was in the actual and immediate custody of said company at the close of the month of March, 1881, showing where the same was located or held, describing in detail the location and designation of each tank or place of deposit, and the name of its owner, viz:

Designation of tank.			Name of owner.	Location.	Barrels and hundredths of barrels of 42 gallons each.
Wood or iron.	Marked.	Numbered.			
Iron	Tide-Water Pipe Company, limited	2	Tide-Water Pipe Company, limited	Otto township, McKean county, Pennsylvania	25,238.86
Iron	do	12	Knapp's Creek Oil Company, limited	do	23,803.26
Iron	do	15	Hoyt & Emerson *et al*	do	25,608.53
*	* *	(*)	* *	* * *	1,459,695.10
Wood		1	do	Gibson's Point, Philadelphia, Pennsylvania	438.29
Iron	Tide-Water Pipe Company, limited	63	do	do	3,119.68
Iron	do	66	do	Thurlow, Delaware county, Pennsylvania	29,884.66
Iron	do	67	do	do	28,114.48
				Total fluid in tanks	1,595,902.86
				Less sediment and surplus	33,903.97
				Net amount of oil in tanks	1,561,998.89
Contained in 138 tank-cars in transit. Capacity, 106.66 barrels each				Between Williamsport, Pennsylvania, and Bayonne, New Jersey.	14,719.08
Contained in 28 tank-cars in transit. Capacity, 106.66 barrels each				Between Williamsport and Philadelphia, Pennsylvania.	2,986.48
Contained in 41 tank-cars in transit. Capacity, 106.66 barrels each				Between Philadelphia and Thurlow, Pennsylvania.	4,373.06

Miles of pipe.	Inside diameter.	Capacity per mile.	Total capacity.	Estimated contents.		
	Inches.	*Barrels.*	*Barrels.*	*Barrels.*		
93.95	2.067	21.914	2,058.82	1,029.41		
27.68	3.067	48.247	1,335.48	1,335.48		
14.93	4.026	83.137	1,241.24	1,241.24		
108.24	6.065	188.672	20,421.86	18,379.67		
2.04	7.982	326.790	666.65	666.65	Total	23,112.29
0.62	12.025	741.677	459.84	459.84	Total barrels	1,607,189.80

Second. Quantity of crude petroleum which was received by said company during the month of March, 1881, 159,874.51 barrels.

Third. Quantity of crude petroleum which was delivered by said company during the month of March, 1881, 145,699.68 barrels.

Fourth. Quantity of crude petroleum for the delivery or custody of which said company was liable to other corporations, companies, associations, or persons at the close of the month of March, 1881, 1,607,189.80 barrels.

Fifth. Amount of such liability which was represented by outstanding certificates, accepted orders, or other vouchers, 1,325,400 barrels.

Amount of such liability which was represented by credit balances, 281,789.80 barrels.

Sixth. All the provisions of the act above referred to have been faithfully observed and obeyed during the said month of March, 1881.

No refined petroleum was in the custody of said company during the month of March, 1881, nor was said company liable during the month for the delivery of any refined petroleum.

D. B. STEWART.
B. F. WARREN.

COMMONWEALTH OF PENNSYLVANIA,
County of Crawford :

Before me, a notary public within and for said county, duly authorized by law to administer oaths, personally came D. B. Stewart, having charge of the books and accounts of the Tide-Water Pipe Company, limited, and B. F. Warren, having charge of the pipes and tanks of said company, who, being each duly sworn, depose and say that they are familiar and acquainted with the business and condition of said company and with the facts set forth in the above report, and that the statements made therein are true to the best of their knowledge, information, and belief.

Subscribed and sworn before me this 9th day of April, 1881.

JOHN O'NEILL, *Notary Public.*

At the close of the census year the accumulation of gross stocks in the tanks of the United lines, according to their published statement, was 10,306,078.79 barrels, and of this 454,193.73 barrels was estimated to be "sediment and surplus". At the same time the tide-water pipe-line report gross stocks in tanks at 978,183.30 barrels and 18,657 barrels "water and sediment". Concerning this surplus Mr. Scheide writes:

Our "surplus" is the amount in which our gross stocks exceed our liabilities of all kinds, and we estimate that it is large enough to enable us to deliver all the oil we owe with a safe limit. We keep it at from 3½ to 4 per cent. of our liabilities by monthly purchases. Every year we make a careful inspection of the contents of our tanks. By an instrument called a "thief" we can take samples from any depth in the tank through four gauge-hatches in the roof. These samples, when not clearly merchantable oil, are carefully heated in white-glass bottles having leveled bottoms. The heat completely separates the oil from the water, dirt, and paraffine, which last settles in time into a compact mass at the bottom. There being a clear line of separation, the percentage of oil in the sample is thus readily obtained. In our calculations of the value of our "B. S." we usually make a further reduction of from 10 to 50 per cent. to cover the expense of the separation. This can only be determined by experts. In addition to the annual inspection, there are two experts engaged every day in inspecting the tanks to see whether the water or "B. S." is accumulating, which is about the only way we have of finding small leaks in the roof. It is impossible to give any idea as to how fast "B. S." is formed. The quantity formed differs in the widest manner in adjacent tanks; with rain carefully excluded, its formation, after that naturally in the oil (there is a small percentage in almost all fresh oil) had settled, would be commercially insignificant. We have enormously reduced its formation by the careful attention we have for two years been giving our tank roofs. I think that 3 per cent. is an ample surplus on a stock exceeding 20,000,000 barrels, but the percentage would have to increase rapidly if the stock was materially reduced.

The total net stock in tanks June 1, 1880, was estimated to be 11,737,890 barrels, exclusive of the Franklin pipe-line, the Smith's Ferry Transportation Company, and the West Virginia Transportation Company, all of which handle oils that do not enter the general trade, and also exclusive of the oil in well tanks throughout the Pennsylvania region. The condition in which much of this vast quantity of oil actually is can only be determined when it is drawn out of the tanks, in which some of it has been stored for years, although the larger portion of it is not allowed to remain more than two or three years without being changed. Oil soon loses the more volatile portion by evaporation, and increases in density, becoming more difficult to refine, but in other respects remains unchanged in quality. "Formerly, when stills were run slowly, and the product desired was the greatest possible percentage of illuminating oil, age was an advantage, and for many years oil of 45° gravity and under was worth one-half cent a gallon more than lighter oil; indeed, by a rule of the New York produce exchange, no oil of over 47° was merchantable except at a cut. For several years the greatly increased value of the other products of distillation has completely changed this rule." The oils in the tanks are therefore kept as new as possible.

William T. Scheide, in a private communication, says:

Oil is steamed in winter to free it from snow and ice and in cases to make it more limpid, as oil from very "gassy" territory thickens rapidly in the cold and will not run through any long line without warming. Orders are that the oil shall not be heated above 80° or 90° F., and not run warmer than 65° to 70°; but these figures are, no doubt, frequently exceeded. There is a great loss in this steaming, both to the producer because of the evaporation and to the pipe-line because of the condensed steam held in the oil. Many merely blow steam in and do not usually heat with a coil, as they should. The United Lines deduct from the amount shown by the gauge one-tenth of 1 per cent. for each degree F. that the temperature of the oil run stands above the temperature of the oil in three iron tanks at either Tarport or Oil City (according as the run is made in the upper or lower country), which are held untouched for this purpose.

B. F. Warren, of the Tide-Water Pipe Company, has made a very careful study of the effects of steaming oil, and has reached some conclusions, which are embraced in the following communication:

Inclosed find a tabulated statement of some results which I obtained in experiments in the field with steamed oil. You will notice some wide variations and apparent discordance in the results. These are mainly due to the imperfections of the tanks. You will understand that the tanks are of wood, and the action of steam is apt to make them leak, so much so that we almost invariably are obliged to "drive hoops" on tanks at the end of the steaming season. Some careful laboratory work gave me a rate of increase for each degree of heat from 40° to 80° F. at 0.000465; below 40° the rate of increase or decrease was noticeably less, although not measurably so, with the facilities which I was possessed; above 80° the rate seems to increase rapidly.

COMPARATIVE RESULTS OF STEAMING OIL, FROM TESTS MADE IN THE BRADFORD OIL-FIELD.

Number of tank.	Owner.	District.	Cold. Temperature.	Cold. Gauge.			Steamed. Temperature.	Steamed. Gauge.			Increase of temperature.	Increase of volume in barrels.	Water and B. S.	Net increase.	Rate of increase for each degree.
			Deg. F.	Ft.	In.	Barrels.	Deg. F.	Ft.	In.	Barrels.	Deg. F.				Deg. F.
292	....	Bradford........	30.7	6	11⅝	235.52	77.0	7	4⅝	248.91	46.3	13.39	9.62	1.64	0.00020
811	W. Chambers..........	West Branch...	37.8	6	11⅝	229.59	103.8	7	1	234.41	66.0	4.82	9.41	4.82	0.00036
30	——— Robbins.........	Dallas	26.0	6	11	223.58	86.0	7	4	235.91	60.0	12.33	1.25	10.08	0.00072
48	Ford & Weaver........	....do	31.0	5	6	181.58	80.0	5	9½	190.66	49.0	9.08	....	....	....
380	Knapps Creek Comp'y.	Rixford.........	28.0	7	2	236.92	85.0	7	6	246.90	57.0	9.98	9.26	0.72	0.00006
459	Larmonth.............	Dallas	26.0	7	1	229.72	100.0	7	7	245.70	74.0	15.98	2.50	12.52	0.00074
677	D. A. Wray............	Coleville........	40.0	14	6¼	761.36	63.0	14	10¾	778.13	23.0	16.77	19.51	....	....
703	Evans & Houtz........	....do	33.0	4	10½	169.91	94.0	5	1	176.89	61.0	6.98	....	....	....
740	Evans & Thompson....	Bordell	34.0	10	7	549.59	84.0	11	0½	571.38	50.0	21.79	5.94	15.85	0.00058
838	......do	....do	30.0	10	8½	537.34	90.0	11	4	565.10	60.0	27.76	11.95	18.71	0.00055
969	Union Oil Company....	....do	32.0	6	7⅝	214.80	82.0	6	11½	224.11	50.0	9.31	5.58	3.73	0.00035
970	......do	....do	40.0	6	9¼	216.03	85.0	7	0¼	223.22	45.0	7.19	....	....	0.00074
1025	......do	....do	32.0	5	11	199.76	85.0	6	3	210.22	53.0	10.46	4.57	5.99	0.00056
1027	......do	....do	40.0	6	8¾	209.97	90.0	7	0¼	218.29	50.0	8.32	2.38	5.94	0.00060
1059	......do	....do	40.0	6	9¾	243.62	85.0	7	0	250.32	45.0	6.70	....	....	0.00061
1060	......do	....do	28.0	7	4¼	263.12	85.0	7	9	277.71	57.0	14.59	2.87	11.72	0.00078
1064	......do	....do	30.0	7	0½	252.66	100.0	7	7	271.96	70.0	19.30	0.75	18.55	0.00106
1065	......do	....do	34.0	7	1½	255.77	88.0	7	3¾	262.50	54.0	6.73	4.48	2.25	0.00020
1074	......do	....do	34.0	7	3½	259.88	80.0	7	6¾	269.44	46.0	9.56	0.68	8.88	0.00074
1075	......do	....do	40.0	6	3	222.75	85.0	6	6	231.66	45.0	8.91	1.49	7.42	0.00074
1076	......do	....do	42.0	6	3	223.23	90.0	6	6¾	234.37	48.0	11.14	3.71	7.43	0.00064
1076	......do	....do	40.0	7	3½	260.36	92.0	7	7¼	271.27	52.0	10.91	0.70	10.21	0.00075
	Average	....	......	......	......	....	....	......	......	....	....	....	....	....	0.00058

Number of tank.	Owner.	District.	Cooling. Temperature.	Cooling. Gauge.			Temperature.	Decrease of volume in barrels.	Rate of decrease for each degree.	Gauge when run.		Remarks.
			Deg. F.	Ft.	In.	Barrels.	Deg. F.		Deg. F.	Ft.	In.	
292	....	Bradford........	43.0	7	2	241.88	34.0	7.03	0.00085	7	2	
811	W. Chambers..........	West Branch...	90.7	6	11$\frac{15}{16}$	230.08	13.0	4.33	0.00150	7	1	The small increase and large decrease of these tanks would seem to indicate a leak in tank.
30	——— Robbins.........	Dallas	68.0	6	11½	224.83	18.0	11.08	0.00273	6	11	
48	Ford & Weaver........	....do	66.0	5	8½	188.07	14.0	2.59	0.00096	5	8½	Water not drawn.
380	Knapps Creek Comp'y.	Rixford.........	70.0	7	1	234.41	12.5	2.51	0.00085	6	9¼	Contained an excessive amount of water.
459	Larmonth.............	Dallas	68.0	7	5	239.72	32.0	5.98	0.00078	7	4	
677	D. A. Wray............	Coleville........	60.0	14	10¼	776.28	3.0	1.85	0.00081	14	5	
703	Evans & Houtz........	....do	70.0	5	0	174.10	24.0	2.79	0.00066	5	0	Water not drawn.
740	Evans & Thompson....	Bordell	70.0	10	11	565.45	14.0	5.93	0.00075	10	9½	
838	......do	....do	71.0	11	2	557.84	19.0	7.26	0.00070	10	11	
969	Union Oil Company....	....do	62.0	6	10½	221.63	20.0	2.48	0.00056	6	8½	
970	......do	....do	65.0	6	11½	221.43	20.0	1.79	0.00042	6	11½	Water not drawn.
1025	......do	....do	67.0	6	2	207.61	18.0	2.61	0.00070	6	0¼	
1027	......do	....do	68.0	6	11	215.32	22.0	2.97	0.00060	6	10	
1059	......do	....do	60.0	6	11¼	248.09	25.0	2.23	0.00040	6	11¼	Water not drawn.
1060	......do	....do	58.0	7	7¼	272.69	27.0	5.02	0.00067	7	6¼	
1064	......do	....do	72.0	7	5½	267.61	28.0	4.35	0.00060	7	5½	Water not drawn.
1065	......do	....do	54.0	7	0½	251.28	34.0	11.22	0.00130	6	10½	Tank probably leaked some.
1074	......do	....do	60.0	7	5¾	266.50	20.0	2.94	0.00060	7	5¾	Water not drawn.
1075	......do	....do	64.0	6	4½	227.21	21.0	4.45	0.00090	6	4	
1076	......do	....do	66.0	6	5½	230.60	24.0	3.71	0.00066	6	4¼	
1076	......do	....do	78.0	7	6¼	268.48	14.0	2.79	0.00060	7	6	
	Average	....	......	......	......	....	....	....	0.00085	......	......	

NOTE.—The quality of the oil does not appear to be affected by steaming. Except in two cases the gravity was not sensibly changed; in one case the gravity was increased from 43 to 40°, in the other decreased from 40 to 42.5° Baumé. The variation between the apparent increase and decrease is due to the fact that all oil at temperatures below 40° F. contains varying proportions of water when it comes from the wells, and will not settle until the temperature is raised. There is also a portion of the oil destroyed by the action of steam, forming so-called B. S.

The problems in hydraulics presented in the construction and management of pipe-lines, particularly those lines that may be denominated trunk lines out of the oil regions, are many and intricate, and required great courage on the part of those who projected the first line to meet and surmount them. These men had only the quite different problems and experience met in laying pipes for water to guide them. These problems dealt with a homogeneous fluid, flowing through pipes, laid permanently on curves of large diameter, flowing slowly under a low pressure and delivered slowly. This water pressure seldom exceeded from 40 to 50 pounds per square inch. The pipe-line problems dealt with a fluid varying in density with the temperature, flowing easily in summer and with difficulty in winter through pipes of small diameter, laid hurriedly and frequently changed, often on sharp curves or at right angles, for rapid movement and delivery, and at high pressures to compensate in part for the friction due to long distances and rapid transmission and small diameter of pipe, as well as at much greater elevations than are found in water-mains. The pipes used in pipe-lines are all tested to 2,000 pounds per square inch. The small sizes, 2-inch, 3-inch, and 4-inch, are worked under a pressure of 1,600 pounds, and the 5-inch and 6-inch at 1,000 pounds per square inch.

Elaborate governmental and other experiments have been made in Europe with reference to the storage and transportation of petroleum and its products. These have been mainly directed toward storing the oil under water, either in barrels or submerged cisterns, or toward a method of solidifying the petroleum or its products. The most successful plan for storing oil in submerged cisterns appears to be that of Ckiandi, an engineer of Marseilles, and consists of a cistern of masonry, provided with an inverted bell resembling a gasometer, beneath which the oil is held over water. (*a*) At Saint Ouen, near Paris, floating reservoirs of iron of an approximate capacity of 100 barrels have been used for a long time. Fourteen of these reservoirs were constructed in 1877, with a total capacity of 900,000 gallons. They were made of $\frac{3}{16}$- to $\frac{1}{4}$-inch iron, and weighed in the aggregate 151 tons. (*b*)

The so-called process for solidifying petroleum has been very widely noticed. It consists in producing with the petroleum a little water and saponaria root, an emulsion which is considered harmless for transportation. To recover the oil a little pure carbolic acid or strong acetic acid is added, and the constituents again separate. As *saponaria* is a product of the Levant and a drug of considerable value, this and other similar methods are rendered too expensive if their inconvenience was not an insurmountable obstacle to their employment. Such experiments furnish curious but impracticable results.

Concerning the proposed transportation of oil in bulk, the following from the *Oil and Drug News* presents the latest aspect of the question:

The report from Philadelphia that the steamer Vaderland, of the Red Star line, had been purchased by a number of capitalists for the purpose of transporting petroleum in bulk has attracted considerable attention at the various commercial exchanges. The transportation of oil in bulk is not entirely an experiment. A number of sailing vessels have already been fitted up for this purpose, and have, to a certain extent, demonstrated the practicability of the idea. This is the first time, however, that a steamer has been constructed solely with the view of transporting safely large quantities of petroleum in bulk. The advantages of the system are, first, that it enables a steamer to carry a much greater amount of petroleum than it could if stored in barrels; and, second, it saves the expense of the barrels, each one of which costs exactly as much as the refined oil it contains. Not only this, but it also saves the expense of returning the barrels from Europe for use again.

Inquiry among petroleum men and shipping merchants in this city elicited the general opinion that the idea is not considered practicable. Said one well-known oil inspector: "It is my opinion that the system will not work. It has been tried three times on sailing vessels during the past eight years, and each time the vessel was lost. The captain of one of them, who was saved from the wreck of his vessel, said to me that the difficulty was that the oil seemed to move quicker than water, and in rough weather, when the vessel was pitched forward, the oil would rush down and force the vessel into the waves much the same as improperly stored bulk grain does sometimes in stormy weather. It may be that by stowing the oil in small compartments it could be transported with safety, but I doubt it. Besides, what is the advantage of the system any way? The vessel must return in ballast, and it might as well bring back barrels, which under the present system are used over and over again, but under the proposed method would not be needed in the export trade."

Messrs. Slocovich & Co., the well-known shipping merchants, state that about eight years ago one of their vessels was fitted up with tanks for transporting oil in bulk. She proceeded on her journey and was never heard from. Her loss was undoubtedly due to her mode of carrying petroleum. Another shipping merchant stated that he believed the idea to be impracticable. It might be possible to make the tanks strong enough to prevent the escape of the vapor of the oil, but all previous experiments had proven failures, and there was no reason to suppose that this would succeed. An experiment to transport molasses in bulk has been tried within two or three years, and two vessels were fitted up for the purpose to run between Cuba and Boston. The experiment, however, proved a failure, and the project had been abandoned. The Vaderland is an iron screw steamship, built at Yarrow-on-Tyne, in England, in 1872, and was extensively repaired last year. Her capacity for cargo is 2,001 tons. She is owned in Antwerp.

The "oil in bulk" movement does not meet with favor among practical exporters. They say that it cannot be carried out successfully. It would seem, however, that oil might be transported in vessels in that way as well as grain, and the day will no doubt come when a means to that end will be devised.

SECTION 5.—STATISTICS OF THE TRANSPORTATION OF OIL DURING THE CENSUS YEAR.

Statistics have been received from the following-named pipe-lines that were engaged in business during the whole of the census year:

United Pipe Lines.
Tide-Water Pipe Company, limited.
West Virginia Transportation Company.
Franklin Pipe Line.
Smith's Ferry Transportation Company.
Octave Oil Company Pipe Line.

a *Engineering*, xv, 279. *b* *London Inst. Civ. Engineers*, 1, 200. *Nouv. Ann. de la Construction* (3), ii, 83.

Fox Farm Pipe Line.
Shæffer and Charley Runs Pipe Line.
Tidioute and Titusville Pipe Line.
T. C. Joy.

There were also four other pipe-line companies doing business at the beginning of the census year that went out of business during that year, of which such statistics are incorporated with those of the other lines as can be obtained from their printed statements. These lines are:

Pennsylvania Transportation Company.
Church Run Pipe Line.
Cherry Tree Run Pipe Line.
Emlenton Pipe Line.

Beside these lines, there were a number of small private lines, particularly in the lower country, of which no reports are published, and from which it was impossible to obtain statistics, except at an unwarranted expenditure of time and labor, if, indeed, they could be obtained at all. These statistics, if obtained, would not materially change the significance of the figures here presented.

The total amount of capital invested in the ten pipe-lines above mentioned was $6,347,930, and the total amount paid in wages during the year was $769,641. The greatest number of hands employed by them during the census year was 1,381; the average number 1,107, of whom 1,098 were males above sixteen years, 6 were females above fifteen years, and 3 were children.

The hours of labor constituting a day were in general ten, but some of the operations of pipe-lines require constant oversight, and therefore in some instances the labor is performed by men who work in "tours" of twelve hours each, extending from twelve o'clock at midday to twelve o'clock at night, and from twelve o'clock at night to twelve o'clock at midday.

The ten lines in operation at the end of the year were in operation throughout the year.

The average wages of skilled workmen varied from $1.75 to $3.33 per day and from $70 to $75 per month; that of ordinary laborers from $1.25 to $2.50 per day.

A marked difference in the rate of wages is found to exist in different sections of the oil-producing country. This difference is no doubt determined to some extent by the magnitude of the operations of the lines and the responsibility attaching to the labor performed.

The total amount expended for fuel by these ten lines (not including the value of a vast quantity of natural gas, of which no account was taken) was $127,058. The total amount received for transporting (piping) oil was $1,381,328. The total number of boilers used was 216, having an estimated horse-power of 4,301; of pumps on main lines, with a diameter of cylinder varying from 3 to 34½ inches, and a length of stroke varying from 4 to 36 inches, 383; of pumps used in collecting oil (for the most part small portable pumps), 511; of iron tanks, 646, with a total capacity of 12,958,385 barrels; and of wooden tanks, 383, with a total capacity of 239,587 barrels.

The total miles of pipe controlled by pipe-lines was:

	Miles.
12-inch pipe, several hundred feet.	
6-inch pipe	121.66
5-inch pipe	7.75
4-inch pipe	123.73
3-inch pipe	289.65
2½-inch pipe	16.00
2-inch pipe	1,716.23
1½-inch pipe	2.78
1-inch pipe	9.05
Total miles of pipe	2,286.85

	Barrels.
The stock of oil on hand in tanks and pipes June 1, 1879, was	6,753,909.02
In the other four lines	28,795.33
Total	6,782,704.35
The amount run into these lines during the census year was	22,516,676.27
Into the other four lines	370,110.96
Total	22,886,787.23
The stock on hand in tanks and pipes May 31, 1880, was	11,239,555.73
In the other four lines	18,022.31
	11,257,578.04
The amount transported through the pipes during the year was	18,411,913.54

There were 36 racks belonging to these lines, at which 561 tank-cars could be loaded at one time, and 287 tanks on cars, having an aggregate capacity of 30,230 barrels.

CHAPTER IX.—PETROLEUM IN COMMERCE.

SECTION 1.—COMMERCIAL VARIETIES.

Few persons are aware that there is more than one variety of petroleum, and those who know that some petroleums are relatively heavy and are used for lubrication suppose the light oils to be of one definite quality. The petroleum of Oil creek in early days was known to be inferior for many purposes to the amber oil of the lower Allegheny. During the first ten years of its development the oil produced in Pennsylvania was practically one thing, and the light oils of West Virginia and southern Ohio were not particularly different. The wonderful expansion of the lower Allegheny field, which commenced in 1872, was accompanied by a corresponding decline in the Oil Creek district in such a manner that the bulk of the production was shifted from the green oil of Oil creek to the amber oil of Armstrong and Butler counties. It was soon discovered that this amber oil was of superior quality for refining purposes, so superior, in fact, that refiners would secure it if possible. When, in 1876, the production of the Bradford district assumed importance, it was discovered that it was the least valuable variety of petroleum for refining yet discovered in large quantities. The price of oil from these different sections has, however, been uniformly the same, irrespective of quality, and has been the ruling price in commerce.

At the same time the heavy oil of Mecca has been sold at from ten to twenty times the price obtained for the light oils of other districts. Those of Belden, Ohio, and West Virginia have been graded according to their density and the effects of cold upon them. The Smith's Ferry oils have been sold for about three times the value of the light oils, and the Franklin oil at five to six times the value of the same.

The West Virginia Transportation Company divides the oil which it handles, which embraces the larger portion of the production of West Virginia and a part of that of Washington county, Ohio, into seven grades, as follows:

A, 37.1° Baumé and lighter.
B, 33° to 37° Baumé, inclusive.
C, 31.6° to 32.9° Baumé, inclusive.
D, 30.6° to 31.5° Baumé, inclusive.
E, 29.6° to 30.5° Baumé, inclusive.
F, 28.6° to 29.5° Baumé, inclusive.
G, 28.5° and heavier.

Grades from C to G, inclusive, are also separated into "cold-test" and "weak" oils, zero being the standard.

In order to establish these grades an inspector is appointed, who stands between the producers and the transportation company or the purchasers. These oils are for the most part quite dense, and their value varies greatly with the density; the more dense they are the greater the amount of water which they will hold mechanically and the more difficult it is to separate it. The inspector has an office near the central portion of Volcano, and has there instruments for accurately estimating the specific gravity, the water or other sediment, and the temperature at which it will thicken above zero, Fahrenheit, in accordance with the following directions:

In receiving and making delivery of oils shipped by the company, the water and sediment contained therein shall be determined by mixing an average sample with an equal quantity of benzine, and subject the mixture to 120° F., in a graduated glass vessel, for not less than 6 hours; after which the mixture cools and settles, not less than two hours for light grade, three hours for A grade, four hours for B grade, six hours for C grade, eight hours for D grade, and eighteen hours for heavier grades.

The inspector certifies to the amount of water in the oil upon the back of the receipt issued by the company. This company has also incurred the expense of a very elaborate research upon the coefficient of dilation of oils of different density for each degree of temperature from 0° to 130° F., with the unit at 60°. The compilation was made by Mr. Julius Schubert, of Parkersburg, West Virginia.

The tables, through the kind permission of M. C. C. Church, esq., secretary of the company, are given on pages 111-115. In relation to them Mr. Schubert writes:

In regard to the expansion table you mentioned in your letter, please let me state that the experiments were made according to a method given by Gay-Lussac, and the formula used for the calculations was also given by the same author.

$$\frac{1 + kt}{1 + at} = \frac{P - p}{P}$$

Where—

P = weight of the fluid before heating it.
p = weight of the fluid after heating and after the apparent expansion has been removed.
t = change of temperature.
k = coefficient of expansion of the glass = 0.000026.
a = coefficient of expansion of the fluid.

The glass used was a liter-bottle with a narrow neck. Instead of finding p, the apparent expansion P—p was directly ascertained by weighing the amount of oil taken out of the bottle. A small pipette was used for removing the oil, and in order to avoid cleaning the pipette so often the following expansion was added to the first one: $(P-p)+(P-p_1)+(P-p_2)+(P-p_3)$, etc.

For every 10° of temperature the expansion of the oil was weighed. The heating was done in a large water-bath very slowly, and the temperature of the water held for some time at the point of the test, so as to be sure that the fluid inside the bottle had reached the same temperature as the water surrounding it.

In the calculation of the table, as sufficient for all practical purposes, I took the coefficient of expansion to be equal or the same during 10° of temperature. As, for instance, in 30° Baumé oil the table shows:

0° temperature,	0.980330 volume,	when it should be	0.980330 volume.	
	293		287	
1° temperature,	0.980623 volume,	when it should be	0.980617 volume.	
	293		289	
2° temperature,	0.980916 volume,	when it should be	0.980906 volume.	
	293		290	
3° temperature,	0.981209 volume,	when it should be	0.981196 volume.	
	293		291	
4° temperature,	0.981502 volume,	when it should be	0.981487 volume.	
	293		292	
5° temperature,	0.981795 volume,	when it should be	0.981779 volume.	
	293		294	
6° temperature,	0.982088 volume,	when it should be	0.982073 volume.	
	293		295	
7° temperature,	0.982381 volume,	when it should be	0.982368 volume.	
	293		296	
8° temperature,	0.982674 volume,	when it should be	0.982664 volume.	
	293		297	
9° temperature,	0.982967 volume,	when it should be	0.982961 volume.	
	293		299	
10° temperature,	0.983260 volume,	when it should be	0.983260 volume.	
	306		300	
11° temperature,	0.983566 volume,	when it should be	0.983560 volume.	
	306		301	
12° temperature,	0.983872 volume,	when it should be	0.983861 volume.	

I deemed it necessary to call your attention to this fact.

From these experiments it appears that the expansions of the oils increase very perceptibly with the rise of the temperature and also with the decrease of specific gravity; that is, lighter oils expand more readily than heavier oils. The cold-test oils do not seem to differ in this respect from oils which do not stand the cold.

These tables have been found sufficiently accurate for all practical purposes, and are very valuable in handling the great variety of oils produced in that region.

On pages 116 to 133, inclusive, will be found another set of tables, compiled by Dr. S. A. Lattimore, of the University of Rochester, New York, for the use of the Vacuum Oil Company of Rochester, and kindly furnished by those gentlemen for publication. These tables show first the quantity of oil in gallons corresponding to a given weight of oil of different degrees of Baumé's hydrometer, all computed for 60° of temperature. By the use of the first set of tables the volume of a gallon of oil at any temperature between zero and 130° F. can be ascertained if the specific gravity is known at 60° F., while by the use of the second set the number of gallons in a barrel or car of petroleum can be ascertained by weighing if the specific gravity is known at 60° F.

The temperature at which natural petroleums will congeal or become partially solid is an important item in their value for purposes of lubrication, the oils of the Mecca and Franklin districts being particularly valuable in this respect. Great diversity of quality in this particular is observed in the oils of West Virginia, wells in immediate proximity furnishing oils as unlike as possible. The cause of this difference has never been properly investigated, and is only a matter of conjecture; at the same time it is one of the most important questions connected with the heavy-oil trade. Many of the wells of eastern Kentucky yield heavy oils of remarkable and uniformly excellent quality in this respect.

SECTION 2.—THE MANAGEMENT OF PIPE-LINES.

The bulk of the petroleum trade at the present time is conducted through the pipe-lines and their certificates. The entire product of the Belden and the Mecca districts is handled in barrels in small lots. A considerable portion of the Franklin heavy oil and a small part of that of West Virginia is also handled in the same manner. A smaller proportion of the medium and light oils of West Virginia and southern Ohio, as also of the Smith's Ferry district, is sold by the producers direct to the refiners in barrels, and an insignificant proportion of the product of the Oil creek and upper and lower Allegheny districts finds a market in the same way. Such oil is usually rolled upon a frame over a tank, and is emptied from the barrels into the tank. Hence it is called dump oil. Many thousands of barrels of this oil are gathered in the older and nearly exhausted portions of the oil-fields by middlemen, who divide with the producers the cost of piping, paying them about 10 cents per barrel more than the market price. These middlemen dispose of the oil in car-load lots, and usually have a rack for loading one or more cars. A still larger though insignificant portion of the light-oil product is brought out to the railroad by private pipe-lines and is loaded into cars at private racks in small lots of a few car-loads each. This line of business is usually carried on along Oil creek and the Allegheny river between Titusville, Tidioute, and Brady's bend.

The method of handling petroleum by the pipe-lines is substantially the same for all located within the region producing light oils, with perhaps this exception: that while the smaller companies are incorporated and are legally "common carriers", their business is conducted more like that of private individuals, while that of the United Pipe Lines and the Tide-Water Pipe Company is of a more general public nature and interest. The following description of the method of business adopted by the United Pipe Lines will therefore apply to all of the incorporated pipe-line companies: When oil is received from a well into the lines of the company, the amount is ascertained by a joint measurement made by the representative of the owner of the well and the pipe-line, and is passed to the credit of the former on the books of the company, less 3 per cent., to cover losses to points of delivery. Such oil is held in the custody of the line, subject to the order of the owner, precisely like a deposit in bank, and is transferable on a written order. Upon the signature by the owner of a proper order for the whole or any part of his credit balance, whether such balance is obtained by transfer or production, such order will be marked "accepted" by an authorized agent of the company, and thereafter is known in the trade as an "acceptance" or "certificate", and, like a certified check, is negotiable. As the oil exchanges only deal in certificates of the value of 1,000 barrels, they are, so far as is possible, made of that amount; but those for less amounts are sold to the refiners for immediate use, and do not pass into the speculative trade. All persons holding credit balances are entitled, upon payment of proper charges, to have their oil loaded into cars or barges or delivered into tanks, to be disconnected from the lines. All oil, when received from the wells, at once loses its identity and becomes part of the common stock of the line; no holder of a credit balance can therefore claim the identical oil that entered the line from his tank or well.

Producers' credit balances are held free of storage for thirty days, after which time, unless the owner have tankage upon the line, they are chargeable at the rate of 1¼ cents per barrel per month, equal to $12 50 per 1,000 barrels, until removed or transferred. All credit balances obtained by transfer, unless protected by tankage, are subject to the same storage charge until removed. As all the tankage is now practically owned by the lines, this charge is now substantially uniform on all certificates, equal to $150 on 1,000 barrels for one year.

Parties owning iron tanks can have them connected with the line by signing contracts which entitle them to carry oil either in credit balances or certificates, free of storage, to the capacity of their tank, subject to a shrinkage charge of one-fourth per cent. per month, payable in oil. The capacity of such tank is subject to the owner, and can only be temporarily used by the company. Upon demand by the owner of a credit balance for the delivery of his oil, a pipeage charge of 20 cents per barrel must be paid. The term "shipper" is applied in the trade to parties removing oil from the custody of the line. The Tide-Water Pipe Company insures the oil of its patrons; but the United lines mutually insure, as has been before mentioned, and assess the loss upon the holders of certificates.

Since the Tide-Water Pipe Company successfully laid their line from Rixford to Williamsport (now being carried through to Chester, Pennsylvania) another trunk line has been laid to Jersey City. These lines have not made public their charges for conveying oil out of the oil region. The united lines gather oil into tanks and at convenient points of shipment, but do not convey it out of the oil region. The income of these corporations is made up of pipeage fees and storage fees, the former being paid when the oil is removed from the line, and the latter at least once in six months. The term "old oil", used in the exchanges, refers to certificates of pipe-lines on which storage charges have not been paid up to date. Thus, if A holds a certificate of the United Pipe Lines on which storage charges had been paid up to any given previous date, and B bought from him on exchange 1,000 barrels of United oil, storage paid, and A should offer him said certificate, B would say, "That is 'old oil', A; you will have to freshen it." So A would go to the pipe-line office and pay the storage on the certificate up to the date of the transaction, and it would be termed "fresh oil". The line attaches a slip to the certificate showing the date to which storage has been paid.

SECTION 3.—BROKERAGE.

The issuing of certificates by the pipe companies has made speculation in oil, brokerage, and oil exchanges possible to an extent vastly beyond an actual trade in the oil itself. The broker buys or sells for others and charges about $2 50 per thousand barrels for his services. On a market without much fluctuation he also agrees to deliver to customers at a stipulated price a certain amount of oil either on demand or at a fixed time, and receives therefor an amount somewhat less than the storage fees; but he does not purchase until the demand for it is made. If oil falls mean time, he profits; if it rises, he loses; and if the price remains unchanged, he profits to the extent of the money paid him in lieu of storage money that would be paid the pipe company if he purchased the oil. The speculator in oil, therefore, who buys "futures" signs a contract with his broker and pays him his brokerage fees as a buyer and some sum less than $150 per year per thousand barrels of oil. The speculator, who buys certificates if he does not own tankage, pays his broker's fees as a buyer, and also $150 per year per thousand barrels, together with whatever sum may be required to purchase oil to pay the assessments for losses by fire or other accident, and interest on the amount invested. If he owns tankage, in lieu of the $150 per thousand barrels for storage he pays $30 for evaporation and the interest on $260 (the cost of a thousand barrels of tankage), which should be estimated at not less than 20 per cent., together with the other expenses above mentioned.

The fluctuations in the price of petroleum during the census year rendered a speculative investment in the article an object of exciting interest. June 1, 1879, was Sunday. The market opened on the 2d at $74\frac{5}{8}$ cents per barrel. It continued to fall, with little disposition to rally, until on the 17th it closed at $64\frac{5}{8}$; and after fluctuating between 65 and 68 for four days, it reached 75, and dropped to $69\frac{5}{8}$ on the 25th. It hovered about 70 until the 9th of August, when it began to fall, reaching $64\frac{5}{8}$ on the 27th. A slight rally held it at about 66 until the 7th of September, when an upward movement began, reaching $96\frac{1}{4}$ on October 9. It remained near 91 until the 10th of November, when it again moved upward, reaching \$1 $27\frac{1}{2}$ on the 21st, closing that day at \$1 $22\frac{1}{2}$. On the following day it ranged between \$1 $22\frac{1}{2}$ and \$1 $10\frac{5}{8}$, closing at \$1 $18\frac{1}{2}$, from which it rallied, reaching on the 2d of December \$1 $28\frac{1}{8}$. Between the 10th and 18th it ranged between \$1 $27\frac{1}{2}$ and \$1 10, and fluctuated greatly between \$1 18 and \$1 09 from this time to January 15, 1880, when it went down in three days to \$1 05, and steadily declined, with scarce a rally, till, on March 9, it touched $85\frac{5}{8}$. It hovered between 85 and 90 till April 6, when it again commenced to decline, reaching $71\frac{1}{4}$ on the 21st. On the 5th of May it closed at $72\frac{1}{2}$, and by the 26th had again reached the latitude of $93\frac{3}{4}$, closing on the 31st at $98\frac{3}{4}$. It will thus be seen that the certificates of oil in tank were worth that year from $64\frac{5}{8}$ cents to \$1 $28\frac{1}{8}$ per barrel, and this variation of almost 100 per cent. occurred between August 27 and December 2, an interval of only sixty-eight days. If a man wants a quantity of oil for refining the transaction becomes one of the simplest possible. He buys certificates to the amount required, and calls upon the pipe company to deliver the oil whenever he chooses to provide tanks, cars, or barges to receive it, and after the pipeage of 20 cents per barrel is paid the company delivers the oil.

The price of Franklin first-sand oil averaged during the census year $3 82 per barrel of 42 gallons; that of second-sand crude for the same time varied very slightly from that of third-sand oil. The price of Mecca oil ranged from $7 to $9 per barrel; Smith's Ferry amber oil averaged $1 50 per barrel. The price of West Virginia oils varied from $1 per barrel for light to $9 per barrel for the heaviest oils produced.

The business of the West Virginia Transportation Company, though far smaller in bulk, is much more intricate in detail than that of the large companies controlling the vast interests of the Pennsylvania oil regions. As already mentioned, their oil is so variable in character that its quality has to be determined by an inspector. The following is a copy of the certificate used by this company, and the rules of the company printed upon the back of it:

Dept. C, No. 2694. THE WEST VIRGINIA TRANSPORTATION COMPANY,
Parkersburg, W. Va., August 8, 1881.

Received from Excelsior well, West Va. O. & O. L. Co., tract for account of royalty, under and subject to the charges, terms, and conditions on the back of this receipt, as a part thereof, No. —— barrels (of 40 gallons each) of $32\frac{3}{10}°$ crude oil, for transportation through pipe-line in bulk with C grade ($31\frac{6}{10}$ to $32\frac{5}{10}$ gravity) to our tanks at Volcano, West Virginia, and for delivery by oil of like grade, or gravity, in lots of 500 barrels or over at Parkersburg, West Virginia, (unavoidable delays excepted), to the order of Geo. Washington, at the rate of 35 cents per barrel, including therein all charges for inspecting, grading, and measuring said oil, and certifying in the receipt therefor the amount, grade, and gravity, and liability under and by reason of said certificate.

THE WEST VIRGINIA TRANSPORTATION CO.,
By M. C. C. CHURCH, *Secretary.*

Attest: CHAS. A. BUKEY.

(Stamped across the face :) Canceled August 1, 1881.
(On the margin :) Not negotiable unless signed by the secretary of the company.

FORM NO. 5.

The terms and conditions upon which the within mentioned oil is held by the West Virginia Transportation Company are as follows:

In receiving the within oil, the water and sediment contained therein, as per the following inspector's certificate, have been first deducted, and the following percentages of oil have been reserved to cover losses for evaporation and waste in receiving, transporting, and delivering the same; the within receipt, therefore, covers the net amount only. On light and A grades two and one-half per cent.; on B and C grades two per cent.; and on heavier oils one and one-half per cent. (See below for variation in case of local and special shipments.)

I certify that I have inspected the within oil, and that it contained ½ per cent. of water and sediment at the time of shipment.

HENRY CASKIN, *Inspector.*

The company shall not be responsible or liable for loss by fire or unavoidable accidents; but any such loss shall be assessed, *pro rata*, upon the total amount of outstanding certificates of oil, of like grade of the within, held by the company at the time such loss may occur.

The company shall have a lien upon all the within mentioned oil for all charges mentioned in this receipt. These charges shall be made upon the net quantity of oil received by the West Virginia Transportation Company (said quantity being mentioned in the face of this receipt), and the computation thereof to be made from the date of this receipt.

The following percentages of the net amount of oil received shall be deducted to cover losses by evaporation when held in tankage, to wit: On light and A grades, one per cent. per month or part of a month; on B and C grades, three-fourths of one per cent. per month or part of a month; on heavier oils, one-half of one per cent. per month or part of a month.

Monthly statements of the company's oil account will be made; and any gains arising from the above reservations, on account of waste and evaporation, will be returned, *pro rata*, in certificate oil, to shippers, to July 1 of each and every year during the continuance of this arrangement.

Freight and other charges are due and payable on receipt of the oil in the company's tankage at Volcano and Cochran's, West Virginia, and at Petrolia, Ohio. If said charges are not settled within fifteen days from the date of this receipt, storage will be charged at the rate of 2 cents per barrel per month or part of a month from said date. If the oil is not removed within three months from the date aforesaid, the company shall have right to remove and store the same at the expense of the consignee, and the right to sell said oil, or such part thereof as may be necessary, at public auction to the highest bidder, to pay the advances made and charges due to it, together with the costs of sale. Such sale to be made upon the premises of the company upon at least ten days' notice by advertising in newspapers published at Parkersburg, West Virginia, and Marietta, Ohio.

In receiving and making delivery of oils shipped by the company, the water and sediment contained therein shall be determined by mixing an average sample with an equal quantity of benzine, and subject the mixture to 120° F., in a graduated glass vessel, for not less than 6 hours, after which the mixture cools and settles not less than two hours for light grade, 3 hours for A grade, 4 hours for B grade, 6 hours for C grade, 8 hours for D grade, and 18 hours for heavier grades.

No allowance made on account of condition in making delivery of the within oil.

Note.—The foregoing applies to regular shipments, to wit: Shipments net by pipe-line to Parkersburg, West Virginia, or to Petroleum, West Virginia, or to Petrolia, Ohio, or to Cochran's, West Virginia.

SPECIAL SHIPMENTS.—The company will take special shipments of oil, in lots of 500 barrels or over, under the conditions expressed herein, except as modified as follows: First. Tankage shall be furnished at the point of destination and possession retained by the company until the final delivery of the shipment. Second. The company delivers all the oil, water, and sediment received by it and guarantees that the loss of actual oil shall not exceed the above reservations. Third. Special shipment certificates will be issued and charges will be made upon the gross amount of oil, water, and sediment received for transportation.

Note.—Special shipments are shipments by pipe-line, in gross, to Parkersburg, West Virginia, or to Petroleum, West Virginia.

LOCAL SHIPMENTS.—The company will take local shipments of oil, in lots of not less that 50 barrels, charging therefor at the rate of 10 cents per barrel. Local shipments to be under the same conditions in other respects as expressed above for special shipments.

Note.—Local shipments are shipments made in gross, and are confined to points in the Volcano oil district. When regular shipments are stopped *in transitu* they become local shipments, and charges will be made on the gross amount received at the well, and not on the net amount, as per face of regular shipment certificates. In all such cases said certificates must be surrendered and canceled and local shipment certificates issued for the gross amount at the well, as aforesaid; the delivery as to amount to be made, however, according to the terms of the regular shipment certificates surrendered.

The acceptance and retention of this receipt shall be regarded as an agreement on the part of the owner of said oil to all its terms and conditions, which shall be equally binding on all subsequent holders hereof.

Deliver to the order of ———.

The charges for pipeage from the wells in Volcano district to Parkersburg, West Virginia, are 35 cents per barrel of 40 gallons each; to the Baltimore and Ohio railroad, 30 cents; to Cochran's Landing, Ohio river, 30 cents; and local shipments to points within the oil districts, 10 cents. From Cow run, Ohio, to Petrolia, on the Ohio river, the rate is 30 cents. If oil remains in their tankage over 15 days, the charge for storage is 2 cents per barrel per month or part of a month from date, unless the freight charges are paid when storage is remitted. So far as the principal and general use of the certificates of this company is concerned, they become what they indicate—mere mediums between the consignor and consumer or refiner. Sometimes, however, they are used by the producers as collateral security for their notes in the local banks. In some instances also they have been purchased by investors as a speculation and held for a rising market, but such cases are exceptional.

SECTION 4.—PETROLEUM AS AN ARTICLE OF FOREIGN COMMERCE.

The foreign trade in petroleum centers in New York, Philadelphia, and Baltimore, with a very large proportion of the whole in New York. The exports consist of crude petroleum, the different varieties of illuminating oil, naphtha, and residuum. This trade is largely controlled by the New York produce exchange. The following rules, which indicate the general methods upon which the business is conducted, are taken from their report for 1879:

CRUDE PETROLEUM.

RULE 4. Crude petroleum shall be understood to be pure, natural oil, neither steamed nor treated, free from water, sediment, or any adulteration, of the gravity of 43° to 48° Baumé.

RULE 5. When crude petroleum is sold in bulk, the quantity shall be ascertained by tank measurement at the time of delivery.

RULE 6. Crude petroleum in barrels shall be sold by weight at the rate of 6½ pounds net to the gallon.

RULE 7. In the absence of any stipulation, crude petroleum, when sold in barrels, shall be understood to mean, so far as regards packages, such packages as were originally refined petroleum barrels, whose last contents was crude petroleum, refined petroleum, or naphtha.

RULE 8. When contracts for crude petroleum call for second-hand refined petroleum barrels (*i. e.*, barrels whose last contents have been refined petroleum or naphtha) the sellers shall have the privilege of substituting new barrels, but they shall be glued.

RULE 9. The weighing and verification of crude petroleum shall be governed by the rules applicable thereto under the head of refined petroleum.

REFINED PETROLEUM.

RULE 10. Refined petroleum shall be standard white, or better, with a burning test of 110° F. or upward, and of a specific gravity not below 45° Baumé.

RULE 11. The burning test of refined petroleum shall be determined by the use of the Saybolt electric instrument, and shall be operated in arriving at a result as follows: In 110° and upward the flashing points, after the first flash (which will generally occur between 90° and 95°), shall be taken at 95°, 100°, 104°, 108°, 110°, 112°, and 115°; in 120° and upward, after first flash, at 100°, 105°, 110°, 115°, 118°, 120°, 122°, and 125°; in 130° and upward, every 5° until burning point is reached.

RULE 12. When refined petroleum is sold in bulk, the quantity shall be ascertained by measurement on the decks of the tank-boats.

RULE 13. Refined petroleum shall be delivered in blue, well-painted barrels, with white heads. Barrels shall be well glued and filled within 1 or 2 inches of the bung.

RULE 14. Refined petroleum in barrels shall be sold by weight at the rate of 6½ pounds net to the gallon.

RULE 15. The tares of refined petroleum in barrels shall be weighed by half pounds and gross weight by pounds.

RULE 16. The gross weight of packages for refined petroleum shall be not less than 360 pounds nor more than 415 pounds, and the actual gross weight shall be plainly marked thereon.

RULE 17. Barrels shall be made of well-seasoned white-oak timber, and shall be hooped not lighter than as follows: Either with six iron hoops, the head hoop 1¾ inches wide, No. 16 gauge, English standard, the quarter hoop 1½ inches wide, No. 17 gauge, and the bilge-hoop 1¾ inches wide, No. 16 gauge; or with eight iron hoops, the head-hoop 1¾ inches wide, No. 17 gauge, the collar-hoop 1½ inches wide, No. 17 gauge, the quarter-hoop 1½ inches wide, No. 18 gauge, and the bilge-hoop 1½ inches wide, No. 18 gauge. But all old barrels of which the gross weight is less than 395 pounds may be hooped with six iron hoops 1½ inches wide, excepting the chine hoop, which shall be 1¾ inches wide.

RULE 18. Buyers may test, at their own expense, the correctness of the gross weight or gauge of the whole or part of any lot delivered, and the average shortage found on a portion of not less than 10 per cent. shall be taken as the average amount to be deducted from the lot.

RULE 19. The tare shall be plainly marked upon each barrel before it is filled. Buyers may test the accuracy of the tare so marked to the extent of 5 per cent. of the lot, and the average difference between the tare thus ascertained and the marked tare on the barrels tested shall be accepted as the average difference on the entire lot. Any excess of tare so discovered shall be allowed buyer.

NAPHTHA.

RULE 20. Naphtha shall be water-white and sweet, and of gravity of from 68° to 73° Baumé.

RULE 21. When naphtha is sold in bulk, the quantity shall be ascertained by measurement on the decks of the tank-boats.

RULE 22. Naphtha in barrels shall be sold by weight at the rate of 5¾ pounds net to the gallon.

RULE 23. Barrels containing naphtha shall be painted blue, with white heads, and be well glued.

RULE 24. Naphtha shall be weighed, and may be tested by the buyer, as provided in the foregoing rules relating to refined petroleum.

RESIDUUM.

RULE 25. Residuum shall be understood to be the refuse from the distillation of crude petroleum, free from coke and water and from any foreign impurities, and of gravity from 16° to 21° Baumé.

RULE 26. Residuum, when sold in barrels, shall be sold by weight, at the rate of 7½ pounds net per gallon.

RULE 27. Residuum shall be weighed, and may be tested by the buyer, as provided in the foregoing rules relating to refined petroleum.

EMPTY BARRELS.

RULE 28. Unless otherwise stipulated, empty barrels shall be understood to have last contained either refined petroleum or naphtha.

RULE 29. Barrels shall be classified according to the use for which they are fitted, as follows:

First class shall include all barrels which, if properly coopered, would be fit to carry refined petroleum or naphtha.

Second class shall include barrels which are unfit for refined petroleum or naphtha, but which would, if properly coopered, be fit for crude petroleum.

Third class shall include such barrels as are unfit for either crude, refined petroleum, or naphtha, but which can be used for residuum, if properly coopered.

RULE 30. When barrels which would otherwise be first class have been injured by sand, mold, or water, they shall be placed in the second class.

RULE 32. When barrels have been filled with crude petroleum, and steamed out after shipment to Europe and used for refined oil, such packages shall be placed in the second class.

RULE 33. All empty barrels must have six hoops, and be delivered in form, shooks or staves not being a good delivery.

CONTRACTS AND DELIVERIES.

RULE 35. All deliveries and contracts for delivery of petroleum and its products under these rules shall be of the production of the United States, unless otherwise specified.

RULE 36. All settlements of contracts for refined petroleum and naphtha shall be on the following basis: In barrels, on 50 gallons; in bulk, on 45 gallons. All settlements of contracts for crude petroleum shall be on the following basis: In barrels, on 48 gallons; in bulk, on 42 gallons.

RULE 37. All cooperage shall be in prime shipping order. Tar and pitch barrels shall be excluded, except for residuum.

RULE 38. When the capacity of the vessel exceeds or falls short of the amount specified in the contract, including the margin, then the specified amount shall be delivered. In determining the capacity of the vessel, barrels of 50 net gallons capacity in case of refined petroleum and naphtha, barrels of 48 net gallons capacity in case of crude petroleum, and barrels of 45 net gallons capacity in case of residuum shall be the basis for settlement.

The inspection of petroleum and its products for export is an important business in New York city, Philadelphia, and Baltimore. Mr. A. Bourgougnon has read before the American Chemical Society several papers relating to this inspection. He refers to the fact that the petroleum of the New York market is a mixture of oils from a great many wells, and remarks that the specific gravity of the New York crude oil ranges from 0.790 to 0.800 = 48° to 46° B. at 15° C.

The coefficient of expansion of the crude oil varies from 0.00082 to 0.00086, according to the gravity of the oil. For the products of distillation the following can be generally adopted:

Under 0.700 gravity at 15° C	0.00090
0.700 to 0.750 gravity at 15° C	0.00085
0.750 to 0.800 gravity at 15° C	0.00080
0.800 gravity at 15° C	0.00070

The knowledge of these coefficients is important, as it aids in calculating the empty space which must be allowed in the vessels containing the oil. This space will be—

$$V. K. 50,$$

V representing the volume of the oil, K the coefficient of expansion, and 50 the number of degrees of temperature through which the oil may change.

Generally the inspectors examine the density, the odor, and how the oil feels with the fingers, and make a fractional distillation in tenth parts, giving a report stating that the oil does not contain more than 17 per cent. of naphtha. He states further that the separation of the distillate into hundredths instead of tenths is much to be preferred, as the proportion of naphtha can then be determined with exactness; "and this determination is very important to the buyer, since the crude oil is taxed in foreign countries according to the quantity of naphtha contained in it."

The crude oil of the New York market will generally furnish from 12 to 15 per cent. of naphtha at 0.700 specific gravity, 9 to 12 per cent. of benzine at 0.730 specific gravity, and about 60 per cent. of burning oil at 0.795 specific gravity. The residuum contains 2½ per cent. of dry paraffine, calculated for the quantity of oil submitted to distillation. (*a*)

In another communication he thus describes an ingeniously contrived instrument for determining the amount of naphtha of 0.700 gravity in crude petroleum:

I employ an instrument made on the same principle and of the same shape as an hydrometer, which I call a *naphthometer*. To make the graduation of this instrument I proceed as follows: The specific gravity of commercial naphtha being 0.700 at 15° C., it is first necessary to have such naphtha. This naphtha being at a temperature of 15° C., the naphthometer is immersed in it, and on the stem at the point of intersection of the liquid the number 15 is written. The same naphtha is brought to a temperature of 20° C., and on the stem, as above, the number 20 is written; the temperature of the naphtha is again increased to 25° C., and the number 25 is written on the stem at the point of intersection, and so on, in order that the temperature indicated by the thermometer (when immersed in naphtha of 0.700 at 15° C.) will be always in accordance with the figures marked on the stem. For example, if I have a sample of naphtha of which the density is 0.700 at 15° C., but supposing that the actual temperature be 20° C., the naphthometer will indicate 20 both by the thermometer and on the stem at the point of intersection with the liquid. Now, to determine the percentage of naphtha in crude petroleum, I distill, say 300 c.c., and collect the distillate in a glass cylinder divided into c.c., in which glass the naphthometer has been previously placed. The temperature of the distillate, and if, *e. g.*, the temperature be 25° C., the distillation is continued until the point marked 25 on the stem intersects with the liquid. At this moment the naphtha has a specific gravity of 0.700 at 15° C., as I have verified by several experiments. Removing the naphthometer from the jar, cooling to 15° C., and reading the number of c.c. obtained, and dividing by 3, I obtain finally the percentage of naphtha at 0.700 density and at the temperature of 15° C. contained in the crude oil. (*b*)

The increase in the bulk of petroleum and of all its products, due to an increase of temperature, occasions a great deal of trouble in measuring these articles in bulk. In barrels and small packages the difficulty is obviated by weighing. Preisser, of Rouen, in 1840, investigated a case in which a certain amount of oil (seed and fish) was stored in winter and measured in summer, when an excess was discovered, and the parties storing were charged with fraud. He found that the oil increased in volume at a certain ratio for each degree of temperature. (*c*) M. Henri St. Claire Deville first stated that American petroleum increases in bulk 0.01 for every 10° C. Later it has been discovered that the ratio of expansion varies with the specific gravity of the oil and also with the temperature. The table on pages 111 to 115, inclusive, has been computed for the specific gravity of crude oil up to 45° B.

a 7. Am. Chem., vii, 81. *b* *Ibid.*, p. 123. c *Jour. F. Inst.*, xxix, 130.

This does not embrace illuminating oils or naphthas, but is approximately correct for the dense oils below 45°. Mr. Gustavus Pile offers the following suggestion of a method of universal application to crude petroleum and all petroleum products: (*a*)

I was asked a short time ago by a gentleman in the coal-oil trade to furnish him with some sort of apparatus with which he could readily estimate the number of gallons of oil there would be in a tank gauged at any temperature if the temperature were reduced to 60° F. The rate of expansion of most of the petroleum products being considerable, the difference in measurement at various temperatures often becomes too great to be unnoticed. In the case of benzine of 68° B., the expansion from 30° to 90° F. amounted to 50 parts in a 1,000. The solution of this problem appears to be best made by observing the specific gravity as it would stand at different temperatures, and calculating from the variation in the gravity the amount of expansion in bulk. If we have gauged a tank holding oil and find it to hold, at 90° temperature, 12,000 gallons, and desire to know how much that would measure if reduced to 60° temperature, we must first note the gravity at the two temperatures, 60° and 90°, and the calculation will then be as follows: Say the gravity at 90° = 0.7900 and at 60° = 0.8025. The gravity at 90° is to be divided by the gravity at 60°, thus $\frac{7900}{8025}$, which will give the measure at 60° of one gallon, and by multiplying this by 12,000, $\frac{7900}{8025} + 12,000 = 11,812$ gallons, we have the measure at 60° of the whole amount. The difference of 188 gallons between the measure at 60° and that at 90° expresses the expansion caused by that increase of temperature.

In order to obtain correct results by this method, it would be necessary to use hydrometers made with a specific gravity scale and with the degrees sufficiently far apart to be able to read to single degrees, or also to use a specific gravity bottle, which, of course, will always give the best result.

I am not acquainted with any method that may be in use among dealers, but the plan here suggested will give accurate conclusions, and where it is found necessary to be particular can be used with confidence.

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a Oil and Drug News.

TABLE OF EXPANSION OF THE WEST VIRGINIA NATURAL OILS.

[*GRAVITIES* 28° *TO* 45°, *FROM ZERO TO* 130° *F., WITH THE UNIT AT* 60° *TEMPERATURE.*]

Calculated by JUL. SCHUBERT, *Engineer.*

The expansion of the West Virginian natural oils is, as the following table shows, by no means very small, and has in a large number of cases worked to the disadvantage of both producers and dealers. It therefore became desirable to have the expansion of the oils established, and carefully conducted experiments, according to the rule laid down by Professor Gay-Lussac for testing the expansion of liquids, and calculations made corresponding to the formula of the same author, have furnished the following table.

The coefficient of expansion of the glass entering into the calculation has been adopted as being 0.000026.

The expansion of the oils increases with the temperature and varies with the gravity. The higher oils expand faster than the heavier oils within the same change of temperature. It became necessary, therefore, to establish the scale of expansion for each gravity from 28° to 45°.

As the gravity is measured at 60° temperature, the unit for the volume of the oil has also been taken at 60° F.

The quantity of oil at 60° temperature should be the guide in all business transactions with the West Virginian natural oils.

RULES FOR USE OF THE TABLE.—In order to find the quantity of oil at 60° temperature: Divide the quantity of the oil by the figure found in the table corresponding both to gravity and temperature of the oil.

For instance: 75.63 barrels of 35° oil, measured at a temperature of 26°, would be:

$$\frac{75.63}{0.987394} = 76.59 \text{ barrels of } 35° \text{ oil at } 60°.$$

Or, 81.34 barrels of 33° oil, measured at a temperature of 88°, would be:

$$\frac{81.34}{1.011566} = 80.41 \text{ barrels of } 33° \text{ oil at } 60° \text{ temperature.}$$

TABLE OF EXPANSION OF THE WEST VIRGINIA NATURAL OILS.

Degrees of temperature. (*F.*)	DEGREES OF GRAVITY.								
	28°.	29°.	30°.	31°.	32°.	33°.	34°.	35°.	36°.
Zero.	0.980810	0.980570	0.980330	0.980060	0.979770	0.979470	0.979170	0.978870	0.978570
1	0.981095	0.980859	0.980623	0.980357	0.980071	0.979776	0.979481	0.979186	0.978891
2	0.981380	0.981148	0.980916	0.980654	0.980372	0.980082	0.979792	0.979502	0.979212
3	0.981665	0.981437	0.981209	0.980951	0.980673	0.980388	0.980103	0.979818	0.979533
4	0.981950	0.981726	0.981502	0.981248	0.980974	0.980694	0.980414	0.980134	0.979854
5	0.982235	0.982015	0.981795	0.981545	0.981275	0.981000	0.980725	0.980450	0.980175
6	0.982520	0.982304	0.982088	0.981842	0.981576	0.981306	0.981036	0.980766	0.980496
7	0.982805	0.982593	0.982381	0.982139	0.981877	0.981612	0.981347	0.981082	0.980817
8	0.983090	0.982882	0.982674	0.982436	0.982178	0.981918	0.981658	0.981398	0.981138
9	0.983375	0.983171	0.982967	0.982733	0.982479	0.982224	0.981969	0.981714	0.981459
10	0.983660	0.983460	0.983260	0.983030	0.982780	0.982530	0.982280	0.982030	0.981780
11	0.983958	0.983762	0.983566	0.983340	0.983095	0.982850	0.982605	0.982360	0.982115
12	0.984256	0.984064	0.983872	0.983650	0.983410	0.983170	0.982930	0.982690	0.982450
13	0.984554	0.984366	0.984178	0.983960	0.983725	0.983490	0.983255	0.983020	0.982785
14	0.984852	0.984668	0.984484	0.984270	0.984040	0.983810	0.983580	0.983350	0.983120
15	0.985150	0.984970	0.984790	0.984580	0.984355	0 984130	0.983905	0.983680	0.983455
16	0.985448	0.985272	0.985096	0.984890	0.984670	0.984450	0.984230	0.984010	0.983790
17	0.985746	0.985574	0.985402	0.985200	0.984985	0.984770	0.984555	0.984340	0.984125
18	0.986044	0.985876	0.985708	0.985510	0.985300	0.985090	0.984880	0.984670	0.984460
19	0.986342	0.986178	0.986014	0.985820	0.985615	0.985410	0.985205	0.985000	0.984795
20	0.986640	0.986480	0.986320	0.986130	0.985930	0.985730	0.985530	0.985330	0.985130
21	0.986952	0.986796	0.986640	0.986454	0.986259	0.986064	0.985869	0.985674	0.985479
22	0.987264	0.987112	0.986960	0.986778	0.986588	0.986398	0.986208	0.986018	0.985828
23	0.987576	0.987428	0.987280	0.987102	0.986917	0.986732	0.986547	0.986362	0.986177
24	0.987888	0.987744	0.987600	0.987426	0.987246	0.987066	0.986886	0.986706	0.986526
25	0.988200	0.988060	0.987920	0.987750	0.987575	0.987400	0.987225	0.987050	0.986875
26	0.988512	0.988376	0.988240	0.988074	0.987904	0.987734	0.987564	0.987394	0.987224
27	0.988824	0.988692	0.988560	0.988398	0.988233	0.988068	0.987903	0.987738	0.987573
28	0.989136	0.989008	0.988880	0.988722	0.988562	0.988402	0.988242	0.988082	0.987922
29	0.989448	0.989324	0.989200	0.989046	0.988891	0.988736	0.988581	0.988426	0.988271
30	0.989760	0.989640	0.989520	0.989370	0.989220	0.989070	0.988920	0.988770	0.988620
31	0.990086	0.989970	0.989854	0.989709	0.989564	0.989419	0.989274	0.989129	0.988984
32	0.990412	0.990300	0.990188	0.990048	0.989908	0.989768	0.989628	0.989488	0.989348
33	0.990738	0.990630	0.990522	0.990387	0.990252	0.990117	0.989982	0.989847	0.989712
34	0.991064	0.990960	0.990856	0.990726	0.990596	0.990466	0.990336	0.990206	0.990076
35	0.991390	0.991290	0.991190	0.991065	0.990940	0.990815	0.990690	0.990565	0.990440
36	0.991716	0.991620	0.991524	0.991404	0.991284	0.991164	0.991044	0.990924	0.990804
37	0.992042	0.991950	0.991858	0.991743	0.991628	0.991513	0.991398	0.991283	0.991168
38	0.992368	0.992280	0.992192	0.992082	0.991972	0.991862	0.991752	0.991642	0.991532
39	0.992694	0.992610	0.992526	0.992421	0.992316	0.992211	0.992106	0.992001	0.991896
40	0.993020	0.992940	0.992860	0.992760	0.992660	0.992560	0.992460	0.992360	0.992260
41	0.993361	0.993285	0.993209	0.993114	0.993019	0.992924	0.992829	0.992734	0.992639
42	0.993702	0.993630	0.993558	0.993468	0.993378	0.993288	0.993198	0.993108	0.993018
43	0.994043	0.993975	0.993907	0.993822	0.993737	0.993652	0.993567	0.993482	0.993397
44	0.994384	0.994320	0.994256	0.994176	0.994096	0.994016	0.993936	0.993856	0.993776
45	0.994725	0.994665	0.994605	0.994530	0.994455	0.994380	0.994305	0.994230	0.994155
46	0.995066	0.995010	0.994954	0.994884	0.994815	0.994744	0.994674	0.994604	0.994534
47	0.995407	0.995355	0.995303	0.995238	0.995173	0.995108	0.995073	0.994978	0.994913
48	0.995748	0.995700	0.995652	0.995592	0.995532	0.995472	0.995412	0.995352	0.995292
49	0.996089	0.996045	0.996001	0.995946	0.995891	0.995836	0.995781	0.995726	0.995671
50	0.996430	0.996390	0.996350	0.996300	0.996250	0.996200	0.996150	0.996100	0.996050
51	0.996787	0.996751	0.996715	0.996670	0.996625	0.996580	0.996535	0.996490	0.906445
52	0.997144	0.997112	0.997080	0.997040	0.997000	0.996960	0.996920	0.996880	0.996840
53	0.997501	0.997473	0.997445	0.997410	0.997375	0.997340	0.997305	0.997270	0.997235
54	0.997858	0.997834	0.997810	0.997780	0.997750	0.997720	0.997690	0.997660	0.997630
55	0.998215	0.998195	0.998175	0.998150	0.998125	0.998100	0.998075	0.998050	0.998025
56	0.998572	0.998556	0.998540	0.998520	0.998500	0.998480	0.998460	0.998440	0.998420
57	0.998929	0.998917	0.998905	0.998890	0.998875	0.998860	0.998845	0.998830	0.998815
58	0.999286	0.999278	0.999270	0.999260	0.999250	0.999240	0.999230	0.999220	0.999210
59	0.999643	0.999639	0.999635	0.999630	0.999625	0.999620	0.909615	0.999610	0.999605
60	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
61	1.000374	1.000378	1.000382	1.000387	1.000392	1.000397	1.000402	1.000407	1.000412
62	1.000748	1.000756	1.000764	1.000774	1.000784	1.000794	1.000804	1.000814	1.000824
63	1.001122	1.001134	1.001146	1.001161	1.001176	1.001191	1.001206	1.001221	1.001236
64	1.001496	1.001512	1.001528	1.001548	1.001568	1.001588	1.001608	1.001628	1.001648
65	1.001870	1.001890	1.001910	1.001935	1.001960	1.001985	1.002010	1.002035	1.002060

TABLE OF EXPANSION OF THE WEST VIRGINIA NATURAL OILS—Continued.

DEGREES OF GRAVITY.									Degrees of temperature. (F.)
37°.	38°.	39°.	40°.	41°.	42°.	43°.	44°.	45°.	
0.978210	0.977850	0.977490	0.977130	0.976770	0.976390	0.976020	0.975660	0.975240	Zero.
0.978537	0.978183	0.977829	0.977475	0.977121	0.976747	0.976383	0.976029	0.975616	1
0.978864	0.978516	0.978168	0.977820	0.977472	0.977104	0.976746	0.976398	0.975992	2
0.979191	0.978849	0.978507	0.978165	0.977823	0.977461	0.977109	0.976767	0.976368	3
0.979518	0.979182	0.978846	0.978510	0.978174	0.977818	0.977472	0.977136	0.976744	4
0.979845	0.979515	0.979185	0.978855	0.978525	0.978175	0.977835	0.977505	0.977120	5
0.980172	0.979848	0.979524	0.979200	0.978876	0.978532	0.978198	0.977874	0.977496	6
0.980499	0.980181	0.979863	0.979545	0.979227	0.978889	0.978561	0.978243	0.977872	7
0.980826	0.980514	0.980202	0.979890	0.979578	0.979246	0.978924	0.978612	0.978248	8
0.981153	0.980847	0.980541	0.980235	0.979929	0.979603	0.979287	0.978981	0.978624	9
0.981480	0.981180	0.980880	0.980580	0.980280	0.979960	0.979650	0.979350	0.979000	10
0.981821	0.981527	0.981233	0.980939	0.980645	0.980331	0.980027	0.979733	0.979390	11
0.982162	0.981874	0.981586	0.981298	0.981010	0.980702	0.980404	0.980116	0.979780	12
0.982503	0.982221	0.981939	0.981657	0.981375	0.981073	0.980781	0.980499	0.980170	13
0.982844	0.982568	0.982292	0.982016	0.981740	0.981444	0.981158	0.980882	0.980560	14
0.983185	0.982915	0.982645	0.982375	0.982105	0.981815	0.981535	0.981265	0.980950	15
0.983526	0.983262	0.982998	0.982734	0.982470	0.982186	0.981912	0.981648	0.981340	16
0.983867	0.983609	0.983351	0.983093	0.982835	0.982557	0.982289	0.982031	0.981730	17
0.984208	0.983956	0.983704	0.983452	0.983200	0.982928	0.982666	0.982414	0.982120	18
0.984549	0.984303	0.984057	0.983811	0.983565	0.983299	0.983043	0.982797	0.982510	19
0.984890	0.984650	0.984410	0.984170	0.983930	0.983670	0.983420	0.983180	0.982900	20
0.985245	0.985011	0.984777	0.984543	0.984309	0.984055	0.983811	0.983577	0.983304	21
0.985600	0.985372	0.985144	0.984916	0.984688	0.984440	0.984202	0.983974	0.983708	22
0.985955	0.985733	0.985511	0.985289	0.985067	0.984825	0.984593	0.984371	0.984112	23
0.986310	0.986094	0.985878	0.985662	0.985446	0.985210	0.984984	0.984768	0.984516	24
0.986665	0.986455	0.986245	0.986035	0.985825	0.985595	0.985375	0.985165	0.984920	25
0.987020	0.986816	0.986612	0.986408	0.986204	0.985980	0.985766	0.985562	0.985324	26
0.987375	0.987177	0.986979	0.986781	0.986583	0.986365	0.986157	0.985959	0.985728	27
0.987730	0.987538	0.987346	0.987154	0.986962	0.986750	0.986548	0.986356	0.986132	28
0.988085	0.987899	0.987713	0.987527	0.987341	0.987135	0.986939	0.986753	0.986536	29
0.988440	0.988260	0.988080	0.987900	0.987720	0.987520	0.987330	0.987150	0.986940	30
0.988810	0.988636	0.988462	0.988288	0.988114	0.987920	0.987736	0.987562	0.987359	31
0.989180	0.989012	0.988844	0.988676	0.988508	0.988320	0.988142	0.987974	0.987778	32
0.989550	0.989388	0.989226	0.989064	0.988902	0.988720	0.988548	0.988386	0.988197	33
0.989920	0.989764	0.989608	0.989452	0.989296	0.989120	0.988954	0.988798	0.988616	34
0.990290	0.990140	0.989990	0.989840	0.989690	0.989520	0.989360	0.989210	0.989035	35
0.990660	0.990516	0.990372	0.990228	0.990084	0.989920	0.989766	0.989622	0.989454	36
0.991030	0.990892	0.990754	0.990616	0.990478	0.990320	0.990172	0.990034	0.989873	37
0.991400	0.991268	0.991136	0.991004	0.990872	0.990720	0.990578	0.990446	0.990292	38
0.991770	0.991644	0.991518	0.991392	0.991266	0.991120	0.990984	0.990858	0.990711	39
0.992140	0.992020	0.991900	0.991780	0.991660	0.991520	0.991390	0.991270	0.991130	40
0.992525	0.992411	0.992297	0.992183	0.992069	0.991936	0.991812	0.991698	0.991565	41
0.992910	0.992802	0.992694	0.992586	0.992478	0.992352	0.992234	0.992126	0.992000	42
0.993295	0.993193	0.993091	0.992989	0.992887	0.992768	0.992656	0.992554	0.992435	43
0.993680	0.993584	0.993488	0.993392	0.993296	0.993184	0.993078	0.992982	0.992870	44
0.994065	0.993975	0.993885	0.993795	0.993705	0.993600	0.993500	0.993410	0.993305	45
0.994450	0.994366	0.994282	0.994198	0.994114	0.994016	0.993922	0.993838	0.993740	46
0.994835	0.994757	0.994679	0.994601	0.994523	0.994432	0.994344	0.994266	0.994175	47
0.995220	0.995148	0.995076	0.995004	0.994932	0.994848	0.994766	0.994694	0.994610	48
0.995605	0.995539	0.995473	0.995407	0.995341	0.995264	0.995188	0.995122	0.995045	49
0.995990	0.995930	0.995870	0.995810	0.995750	0.995680	0.995610	0.995550	0.995480	50
0.996391	0.996337	0.996283	0.996229	0.996175	0.996112	0.996049	0.995995	0.995932	51
0.996792	0.996744	0.996696	0.996648	0.996600	0.996544	0.996488	0.996440	0.996384	52
0.997193	0.997151	0.997109	0.997067	0.997025	0.996976	0.996927	0.996885	0.996836	53
0.997594	0.997558	0.997522	0.997486	0.997450	0.997408	0.997366	0.997330	0.997288	54
0.997995	0.997965	0.997935	0.997905	0.997875	0.997840	0.997805	0.997775	0.997740	55
0.998396	0.998372	0.998348	0.998324	0.998300	0.998272	0.998244	0.998220	0.998192	56
0.998797	0.998779	0.998761	0.998743	0.998725	0.998704	0.998683	0.998665	0.998644	57
0.999198	0.999186	0.999174	0.999162	0.999150	0.999136	0.999122	0.999110	0.999096	58
0.999599	0.999593	0.999587	0.999581	0.999575	0.999568	0.999561	0.999555	0.999548	59
1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	60
1.000418	1.000424	1.000430	1.000436	1.000442	1.000449	1.000456	1.000463	1.000470	61
1.000836	1.000848	1.000860	1.000872	1.000884	1.000898	1.000912	1.000926	1.000940	62
1.001254	1.001272	1.001290	1.001308	1.001326	1.001347	1.001368	1.001389	1.001410	63
1.001672	1.001696	1.001720	1.001744	1.001768	1.001796	1.001824	1.001852	1.001880	64
1.002090	1.002120	1.002150	1.002180	1.002210	1.002245	1.002280	1.002315	1.002350	65

TABLE OF EXPANSION OF THE WEST VIRGINIA NATURAL OILS—Continued.

Degrees of temperature. (F.)	Degrees of gravity.								
	28°.	29°.	30°.	31°.	32°.	33°.	34°.	35°.	36°.
66	1.002244	1.002268	1.002292	1.002322	1.002352	1.002382	1.002412	1.002442	1.002472
67	1.002618	1.002646	1.002674	1.002709	1.002744	1.002779	1.002814	1.002849	1.002884
68	1.002992	1.003024	1.003056	1.003096	1.003136	1.003176	1.003216	1.003256	1.003296
69	1.003366	1.003402	1.003438	1.003483	1.003528	1.003573	1.003618	1.003663	1.003708
70	1.003740	1.003780	1.003820	1.003870	1.003920	1.003970	1.004020	1.004070	1.004120
71	1.004131	1.004175	1.004219	1.004274	1.004329	1.004384	1.004439	1.004495	1.004550
72	1.004522	1.004570	1.004618	1.004678	1.004738	1.004798	1.004858	1.004920	1.004980
73	1.004913	1.004965	1.005017	1.005082	1.005147	1.005212	1.005277	1.005345	1.005410
74	1.005304	1.005360	1.005416	1.005486	1.005556	1.005626	1.005696	1.005770	1.005840
75	1.005695	1.005755	1.005815	1.005890	1.005965	1.006040	1.006115	1.006195	1.006270
76	1.006086	1.006150	1.006214	1.006294	1.006374	1.006454	1.006534	1.006620	1.006700
77	1.006477	1.006545	1.006613	1.006698	1.006783	1.006868	1.006953	1.007045	1.007130
78	1.006868	1.006940	1.007012	1.007102	1.007192	1.007282	1.007372	1.007470	1.007560
79	1.007259	1.007335	1.007411	1.007506	1.007601	1.007696	1.007791	1.007895	1.007990
80	1.007650	1.007730	1.007810	1.007910	1.008010	1.008110	1.008210	1.008320	1.008420
81	1.008058	1.008142	1.008226	1.008331	1.008437	1.008542	1.008647	1.008763	1.008869
82	1.008466	1.008554	1.008642	1.008752	1.008864	1.008974	1.009084	1.009206	1.009318
83	1.008874	1.008966	1.009058	1.009173	1.009291	1.009406	1.009521	1.009649	1.009767
84	1.009282	1.009378	1.009474	1.009594	1.009718	1.009838	1.009958	1.010092	1.010216
85	1.009690	1.009790	1.009890	1.010015	1.010145	1.010270	1.010395	1.010535	1.010665
86	1.010098	1.010202	1.010306	1.010436	1.010572	1.010702	1.010832	1.010978	1.011114
87	1.010506	1.010614	1.010722	1.010857	1.010999	1.011134	1.011269	1.011421	1.011563
88	1.010914	1.011026	1.011138	1.011278	1.011426	1.011566	1.011706	1.011864	1.012012
89	1.011322	1.011438	1.011554	1.011699	1.011853	1.011998	1.012143	1.012307	1.012461
90	1.011730	1.011850	1.011970	1.012120	1.012280	1.012430	1.012580	1.012750	1.012910
91	1.012155	1.012279	1.012404	1.012559	1.012725	1.012880	1.013035	1.013212	1.013378
92	1.012580	1.012708	1.012838	1.012998	1.013170	1.013330	1.013490	1.013674	1.013846
93	1.013005	1.013137	1.013272	1.013437	1.013615	1.013780	1.013945	1.014136	1.014314
94	1.013430	1.013566	1.013706	1.013876	1.014060	1.014230	1.014400	1.014598	1.014782
95	1.013855	1.013995	1.014140	1.014315	1.014505	1.014680	1.014855	1.015060	1.015250
96	1.014280	1.014424	1.014574	1.014754	1.014950	1.015130	1.015310	1.015522	1.015718
97	1.014705	1.014853	1.015008	1.015193	1.015395	1.015580	1.015705	1.015984	1.016186
98	1.015130	1.015282	1.015442	1.015632	1.015840	1.016030	1.016220	1.016446	1.016654
99	1.015555	1.015711	1.015876	1.016071	1.016285	1.016480	1.016675	1.016908	1.017122
100	1.015980	1.016140	1.016310	1.016510	1.016730	1.016930	1.017130	1.017370	1.017590
101	1.016422	1.016587	1.016762	1.016967	1.017193	1.017399	1.017644	1.017851	1.018077
102	1.016864	1.017034	1.017214	1.017424	1.017656	1.017868	1.018078	1.018332	1.018564
103	1.017306	1.017481	1.017666	1.017881	1.018119	1.018337	1.018552	1.018813	1.019051
104	1.017748	1.017928	1.018118	1.018338	1.018582	1.018806	1.019026	1.019294	1.019538
105	1.018190	1.018375	1.018570	1.018795	1.019045	1.019275	1.019500	1.019775	1.020025
106	1.018632	1.018822	1.019022	1.019252	1.019508	1.019744	1.019974	1.020256	1.020512
107	1.019074	1.019269	1.019470	1.019709	1.019971	1.020213	1.020448	1.020737	1.020999
108	1.019516	1.019716	1.019926	1.020166	1.020434	1.020682	1.020922	1.021218	1.021486
109	1.019958	1.020163	1.020378	1.020623	1.020807	1.021151	1.021396	1.021609	1.021973
110	1.020400	1.020610	1.020830	1.021080	1.021360	1.021620	1.021870	1.022180	1.022460
111	1.020860	1.021075	1.021300	1.021556	1.021842	1.022108	1.022363	1.022680	1.022967
112	1.021320	1.021540	1.021770	1.022032	1.022324	1.022596	1.022856	1.023180	1.023474
113	1.021780	1.022005	1.022240	1.022508	1.022806	1.023084	1.023349	1.023680	1.023981
114	1.022240	1.022470	1.022710	1.022984	1.023288	1.023572	1.023842	1.024180	1.024488
115	1.022700	1.022935	1.023180	1.023460	1.023770	1.024060	1.024335	1.024680	1.024995
116	1.023160	1.023400	1.023650	1.023936	1.024252	1.024548	1.024828	1.025180	1.025502
117	1.023620	1.023865	1.024120	1.024412	1.024734	1.025036	1.025321	1.025680	1.026009
118	1.024080	1.024330	1.024590	1.024888	1.025216	1.025524	1.025814	1.026180	1.026516
119	1.024540	1.024795	1.025060	1.025364	1.025698	1.026012	1.026307	1.026680	1.027023
120	1.025000	1.025260	1.025530	1.025840	1.026180	1.026500	1.026800	1.027180	1.027530
121	1.025478	1.025743	1.026019	1.026335	1.026681	1.027007	1.027313	1.027700	1.028057
122	1.025956	1.026226	1.026508	1.026830	1.027182	1.027514	1.027826	1.028220	1.028584
123	1.026434	1.026709	1.026997	1.027325	1.027683	1.028021	1.028339	1.028740	1.029111
124	1.026912	1.027192	1.027486	1.027820	1.028184	1.028528	1.028852	1.029260	1.029638
125	1.027390	1.027675	1.027975	1.028315	1.028685	1.029035	1.029365	1.029780	1.030165
126	1.027868	1.028158	1.028464	1.028810	1.029186	1.029542	1.029878	1.030300	1.030692
127	1.028346	1.028641	1.028953	1.029305	1.029687	1.030049	1.030391	1.030820	1.031219
128	1.028824	1.029124	1.029442	1.029800	1.030188	1.030556	1.030904	1.031340	1.031746
129	1.029302	1.029607	1.029931	1.030295	1.030689	1.031063	1.031417	1.031860	1.032273
130	1.029780	1.030090	1.030420	1.030790	1.031190	1.031570	1.031930	1.032380	1.032800

TABLE OF EXPANSION OF THE WEST VIRGINIA NATURAL OILS—Continued.

DEGREES OF GRAVITY.									Degrees of temperature. (F.)
37°.	38°.	39°.	40°.	41°.	42°.	43°.	44°.	45°.	
1.002508	1.002544	1.002580	1.002616	1.002652	1.002694	1.002736	1.002778	1.002820	66
1.002926	1.002968	1.003010	1.003052	1.003094	1.003143	1.003192	1.003241	1.003290	67
1.003344	1.003392	1.003440	1.003488	1.003536	1.003592	1.003648	1.003704	1.003760	68
1.003762	1.003816	1.003870	1.003924	1.003978	1.004041	1.004104	1.004167	1.004230	69
1.004180	1.004240	1.004300	1.004360	1.004420	1.004490	1.004560	1.004630	1.004700	70
1.004616	1.004682	1.004748	1.004814	1.004880	1.004957	1.005034	1.005112	1.005189	71
1.005052	1.005124	1.005196	1.005268	1.005340	1.005424	1.005508	1.005592	1.005678	72
1.005488	1.005566	1.005644	1.005722	1.005800	1.005891	1.005982	1.006076	1.006167	73
1.005924	1.006008	1.006092	1.006176	1.006260	1.006358	1.006456	1.006558	1.006656	74
1.006360	1.006450	1.006540	1.006630	1.006720	1.006825	1.006930	1.007040	1.007145	75
1.006796	1.006892	1.006988	1.007084	1.007180	1.007292	1.007404	1.007522	1.007634	76
1.007232	1.007334	1.007436	1.007538	1.007640	1.007759	1.007878	1.008004	1.008123	77
1.007668	1.007776	1.007884	1.007992	1.008100	1.008226	1.008352	1.008486	1.008612	78
1.008104	1.008218	1.008332	1.008446	1.008560	1.008693	1.008826	1.008968	1.009101	79
1.008540	1.008660	1.008780	1.008900	1.009020	1.009160	1.009300	1 009450	1.009590	80
1.008995	1.009121	1.009247	1.009373	1.009499	1.009646	1.009793	1.009951	1.010099	81
1.009450	1.009582	1.009714	1.009846	1.009978	1.010132	1.010286	1.010452	1.010608	82
1.009905	1.010043	1.010181	1.010319	1.010457	1.010618	1.010779	1.010953	1.011117	83
1.010360	1.010504	1.010648	1.010792	1.010936	1.011104	1.011272	1.011454	1.011626	84
1.010815	1.010965	1.011115	1.011265	1.011415	1.011590	1.011765	1.011955	1.012135	85
1.011270	1.011426	1.011582	1.011738	1.011894	1.012076	1.012258	1.012456	1.012644	86
1.011725	1.011887	1.012049	1.012211	1.012373	1.012562	1.012751	1.012957	1.013153	87
1.012180	1.012348	1.012516	1.012684	1.012852	1.013048	1.013244	1.013458	1.013662	88
1.012635	1.012809	1.012983	1.013157	1.013331	1.013534	1.013737	1.013959	1.014171	89
1.013090	1.013270	1.013450	1.013630	1.013810	1.014020	1.014230	1.014460	1.014680	90
1.013564	1.013750	1.013937	1.014123	1.014309	1.014526	1.014743	1.014981	1.015209	91
1.014038	1.014230	1.014424	1.014616	1.014808	1.015032	1.015256	1.015502	1.015738	92
1.014512	1.014710	1.014911	1.015109	1.015307	1.015538	1.015769	1.016023	1.016267	93
1.014986	1.015190	1.015398	1.015602	1.015806	1.016044	1.016283	1.016544	1.016796	94
1.015460	1.015670	1.015885	1.016095	1.016305	1.016550	1.016795	1.017065	1.017325	95
1.015934	1.016150	1.016372	1.016588	1.016804	1.017056	1.017308	1.017586	1.017854	96
1.016408	1.016630	1.016859	1.017081	1.017303	1.017562	1.017821	1.018107	1.018383	97
1.016882	1.017110	1.017346	1.017574	1.017802	1.018068	1.018334	1.018628	1.018912	98
1.017356	1.017590	1.017833	1.018067	1.018301	1.018574	1.018847	1.019149	1.019441	99
1.017830	1.018070	1.018320	1.018560	1.018800	1.019080	1.019360	1.019670	1.019970	100
1.018324	1.018570	1.018827	1.019073	1.019320	1.019607	1.019894	1.020212	1.020520	101
1.018818	1.019070	1.019334	1.019586	1.019840	1.020134	1.020428	1.020754	1.021070	102
1.019312	1.019570	1.019841	1.020099	1.020360	1.020661	1.020962	1.021296	1.021620	103
1.019806	1.020070	1.020348	1.020612	1.020880	1.021088	1.021496	1.021838	1.022170	104
1.020300	1.020570	1.020855	1.021125	1.021400	1.021715	1.022030	1.022380	1.022720	105
1.020794	1.021070	1.021362	1.021638	1.021920	1.022242	1.022564	1.022922	1.023270	106
1.021288	1.021570	1.021869	1.022151	1.022440	1.022769	1.023098	1.023464	1.023820	107
1.021782	1.022070	1.022376	1.022664	1.022960	1.023296	1.023632	1.024006	1.024370	108
1.022276	1.022570	1.022883	1.023177	1.023480	1.023823	1.024166	1.024548	1.024920	109
1.022770	1.023070	1.023390	1.023690	1.024000	1.024350	1.024700	1.025090	1.025470	110
1.023284	1.623590	1.023917	1.024224	1.024541	1.024899	1.025256	1.025654	1.026042	111
1.023798	1.024110	1.024444	1.024758	1.025082	1.025448	1.025812	1.026218	1.026614	112
1.024312	1.024630	1.024971	1.025292	1.025623	1.025997	1.026368	1.026782	1.027186	113
1.024826	1.025150	1.025498	1.025826	1.026164	1.026546	1.026924	1.027346	1.027758	114
1.025340	1.025670	1.026025	1.026360	1.026705	1.027095	1.027480	1.027910	1.028330	115
1.025854	1.026190	1.026552	1.026894	1.027246	1.027644	1.028036	1.028474	1.028902	116
1.026368	1.026710	1.027079	1.027428	1.027787	1.028193	1.028592	1.029038	1.029474	117
1.026882	1.027230	1.027606	1.027962	1.028328	1.028742	1.029148	1.029602	1.030046	118
1.027306	1.027750	1.028138	1.028496	1.028869	1.029291	1.029704	1.030166	1.030618	119
1.027910	1.028270	1.028660	1.029030	1.029410	1.029840	1.030260	1.030730	1.031190	120
1.028444	1.028811	1.029208	1.029585	1.029973	1.030411	1.030839	1.031317	1.031785	121
1.028978	1.029352	1.029756	1.030140	1.030536	1.030982	1.031418	1.031904	1.032380	122
1.029512	1.029893	1.030304	1.080695	1.031099	1.031553	1.031997	1.032491	1.032975	123
1.030046	1.030434	1.030852	1.031250	1.031662	1.032124	1.032576	1.033078	1.033570	124
1.030580	1.030975	1.031400	1.031805	1.032225	1.032695	1.033155	1.033665	1.034165	125
1.031114	1.031516	1.031948	1.032360	1.032788	1.033266	1.033734	1.034252	1.034760	126
1.031648	1.032057	1.032496	1.032915	1.033351	1.033837	1.034313	1.034839	1.035355	127
1.032182	1.032598	1.033044	1.033470	1.033914	1.034408	1.034892	1.035426	1.035950	128
1.032716	1.033139	1.033592	1.034025	1.034477	1.034979	1.035471	1.036013	1.036545	129
1.033250	1.033680	1.034140	1.034580	1.635040	1.035550	1.036050	1.036600	1.037140	130

TABLES FOR THE RAPID AND EXACT COMPUTATION OF THE NUMBER OF GALLONS CONTAINED IN ANY GIVEN WEIGHT OF OIL OR OTHER LIQUID LIGHTER THAN WATER, WITHOUT MEASURING OR GAUGING.

ARRANGED WITH SPECIAL REFERENCE TO THE WANTS OF THE PETROLEUM TRADE.

By S. A. LATTIMORE, A. M., *Professor of Chemistry in the University of Rochester, New York.*

INSTRUCTIONS FOR THE USE OF THE TABLES.—Ascertain the net weight of the oil or other fluid by the balance. The gravity is to be next accurately ascertained by means of a correct hydrometer, the temperature of the fluid being 60° F. and the line of the scale just below the surface being taken. Turn to the page on which that gravity is given. In the first column find the number of pounds. Opposite this number, in the column for the proper gravity, will be found the corresponding number of gallons, tenths and hundredths. If the exact number of pounds does not occur, take the nearest smaller number, then the number next less than the remainder, and so on, until the sum of these several numbers is the exact number of pounds required.

EXAMPLE.

In 2,384 pounds of oil of 45° B., how many gallons?

	Gallons.
2,000 pounds	300.08
300 pounds	45.01
80 pounds	12.00
4 pounds	0.60
2,384 pounds	357.69

An additional series of tables is given embracing the more common gravities of petroleum products and the range of the number of gallons ordinarily contained in a single cask. Find the page for the required gravity, and opposite the net weight will be found the exact number of gallons contained in the cask.

DEGREES OF BAUMÉ'S HYDROMETER.

Pounds.	15°.	16°.	17°.	18°.	19°.	20°.	21°.	22°.	23°.	24°.	25°.	26°.	27°.	28°.
	Gallons.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
1	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14
2	0.25	0.25	0.25	0.25	0.26	0.26	0.26	0.26	0.26	0.26	0.27	0.27	0.27	0.27
3	0.37	0.38	0.38	0.38	0.38	0.39	0.39	0.39	0.39	0.40	0.40	0.40	0.40	0.41
4	0.50	0.50	0.50	0.51	0.51	0.52	0.52	0.52	0.53	0.53	0.53	0.54	0.54	0.54
5	0.62	0.63	0.63	0.63	0.64	0.64	0.65	0.65	0.66	0.66	0.66	0.67	0.67	0.68
6	0.75	0.76	0.76	0.76	0.77	0.77	0.78	0.78	0.79	0.79	0.80	0.80	0.81	0.81
7	0.87	0.88	0.88	0.89	0.89	0.90	0.91	0.91	0.92	0.92	0.93	0.94	0.94	0.95
8	1.00	1.00	1.01	1.02	1.02	1.03	1.04	1.04	1.05	1.06	1.06	1.07	1.08	1.08
9	1.12	1.13	1.13	1.14	1.15	1.16	1.17	1.17	1.18	1.20	1.20	1.20	1.21	1.22
10	1.24	1.25	1.26	1.27	1.28	1.29	1.30	1.30	1.31	1.32	1.33	1.34	1.35	1.35
20	2.49	2.50	2.52	2.54	2.56	2.57	2.58	2.61	2.62	2.64	2.66	2.68	2.69	2.71
30	3.73	3.76	3.78	3.81	3.83	3.86	3.88	3.91	3.94	3.96	3.99	4.01	4.04	4.06
40	4.97	5.01	5.04	5.08	5.11	5.15	5.18	5.21	5.25	5.28	5.31	5.35	5.38	5.42
50	6.22	6.26	6.30	6.34	6.39	6.43	6.47	6.52	6.56	6.60	6.64	6.69	6.73	6.77
60	7.46	7.51	7.56	7.61	7.67	7.72	7.77	7.82	7.87	7.92	7.97	8.03	8.08	8.13
70	8.70	8.76	8.82	8.88	8.94	9.00	9.06	9.12	9.18	9.24	9.30	9.36	9.42	9.48
80	9.95	10.01	10.08	10.15	10.22	10.29	10.36	10.43	10.49	10.56	10.63	10.70	10.77	10.84
90	11.19	11.27	11.34	11.42	11.50	11.58	11.65	11.73	11.81	11.98	11.96	12.04	12.12	12.19
100	12.43	12.52	12.61	12.69	12.78	12.86	12.95	13.03	13.12	13.21	13.29	13.38	13.46	13.55
200	24.87	25.04	25.21	25.38	25.55	25.72	25.84	26.07	26.24	26.41	26.57	26.75	26.92	27.10
300	37.30	37.55	37.81	38.07	38.33	38.58	38.84	39.10	39.36	39.62	39.86	40.13	40.38	40.64
400	49.73	50.07	50.42	50.76	51.11	51.45	51.79	52.13	52.47	52.82	53.15	63.50	53.85	54.19
500	62.16	62.59	63.02	63.45	63.88	64.31	64.74	65.16	65.59	66.03	66.45	66.88	67.30	67.74
1,000	124.32	125.18	126.05	126.90	127.76	128.61	129.47	130.33	131.18	132.05	132.87	133.76	134.61	135.48
2,000	248.65	250.36	252.09	253.80	255.53	257.22	258.94	260.66	262.37	264.10	265.73	267.52	269.22	270.96
3,000	372.97	375.54	378.13	380.69	383.29	385.84	388.42	390.99	393.55	396.15	398.60	401.28	403.83	406.43
4,000	497.29	500.71	504.18	507.59	511.05	514.45	517.89	521.31	524.73	528.20	531.47	535.03	538.45	541.91
5,000	621.61	625.89	630.23	634.49	638.81	643.06	647.36	651.64	655.92	600.25	664.34	668.79	673.06	677.39
10,000	1,243.22	1,251.78	1,260.46	1,268.99	1,277.63	1,286.12	1,294.72	1,303.29	1,311.84	1,320.50	1,328.67	1.337.58	1,346.11	1,354.78
20,000	2,486.45	2,503.57	2,520.92	2,637.97	2,555.26	2,572.24	2,589.43	2,606.58	2,623.07	2,641.00	2,657.35	2,675.15	2,692.22	2,709.56

DEGREES OF BAUMÉ'S HYDROMETER—Continued.

Pounds.	29°.	30°.	31°.	32°.	33°.	34°.	35°.	36°.	37°.	38°.	39°.	40°.	41°.	42°.
	Gallons.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
1	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15
2	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.29	0.29	0.29	0.29	0.29	0.29
3	0.41	0.41	0.41	0.42	0.42	0.42	0.43	0.43	0.43	0.43	0.43	0.44	0.44	0.44
4	0.55	0.55	0.56	0.56	0.56	0.56	0.57	0.57	0.57	0.58	0.58	0.58	0.59	0.59
5	0.68	0.69	0.69	0.69	0.70	0.70	0.71	0.71	0.72	0.72	0.72	0.73	0.73	0.74
6	0.82	0.82	0.83	0.83	0.84	0.84	0.85	0.85	0.86	0.86	0.87	0.88	0.88	0.89
7	0.95	0.96	0.97	0.97	0.98	0.98	0.99	1.00	1.00	1.01	1.01	1.02	1.03	1.03
8	1.09	1.10	1.10	1.11	1.12	1.13	1.13	1.14	1.15	1.15	1.16	1.17	1.17	1.18
9	1.23	1.24	1.24	1.25	1.26	1.27	1.27	1.28	1.29	1.30	1.30	1.30	1.32	1.33
10	1.36	1.37	1.38	1.39	1.40	1.40	1.41	1.42	1.43	1.44	1.45	1.46	1.47	1.47
20	2.73	2.74	2.76	2.78	2.80	2.81	2.83	2.85	2.87	2.88	2.90	2.92	2.93	2.95
30	4.09	4.12	4.14	4.17	4.19	4.22	4.25	4.27	4.30	4.32	4.35	4.37	4.40	4.42
40	5.45	5.49	5.52	5.56	5.59	5.63	5.66	5.69	5.73	5.76	5.80	5.83	5.86	5.90
50	6.82	6.86	6.90	6.94	6.99	7.03	7.07	7.12	7.16	7.20	7.24	7.29	7.33	7.37
60	8.18	8.23	8.28	8.33	8.39	8.44	8.49	8.54	8.60	8.64	8.69	8.75	8.80	8.85
70	9.53	9.60	9.66	9.72	9.78	9.84	9.91	9.96	10.03	10.08	10.14	10.20	10.26	10.32
80	10.81	10.97	11.04	11.11	11.18	11.25	11.33	11.39	11.46	11.52	11.59	11.66	11.73	11.80
90	12.27	12.35	12.42	12.50	12.58	12.66	12.73	12.81	12.89	12.96	13.04	13.12	13.20	13.27
100	13.63	13.72	13.80	13.89	13.98	14.06	14.15	14.23	14.33	14.40	14.49	14.58	14.66	14.75
200	27.27	27.44	27.61	27.78	27.95	28.12	28.30	28.47	28.65	28.81	28.98	29.16	29.32	29.50
300	40.90	41.15	41.42	41.67	41.93	42.19	42.45	42.70	42.98	43.21	43.46	43.73	43.98	44.24
400	54.53	54.87	55.22	55.56	55.91	56.25	56.60	56.93	57.30	57.62	57.95	58.31	58.65	58.99
500	68.16	68.59	69.02	69.45	69.88	70.31	70.74	71.17	71.63	72.02	72.44	72.89	72.31	73.74
1,000	136.33	137.18	138.05	138.91	139.77	140.62	141.48	142.34	143.26	144.04	144.88	145.77	146.61	147.48
2,000	272.65	274.36	276.10	277.81	279.54	281.24	282.97	284.67	286.51	288.09	289.76	291.55	293.23	294.96
3,000	408.97	411.54	414.14	416.71	419.30	421.87	424.44	427.02	429.78	432.12	434.64	437.31	439.84	442.44
4,000	545.30	548.72	552.19	555.62	559.07	562.49	565.92	569.36	573.04	576.16	579.52	583.09	586.46	589.82
5,000	681.63	685.90	690.24	694.52	698.84	703.11	707.41	711.68	716.29	720.24	724.41	728.86	733.07	737.40
10,000	1,363.25	1,371.81	1,380.49	1,389.05	1,397.68	1,406.21	1,414.83	1,423.36	1,432.58	1,440.47	1,448.81	1,457.73	1,466.15	1,474.80
20,000	2,726.50	2,743.63	2,760.98	2,778.10	2,795.36	2,812.42	2,829.65	2,846.73	2,865.16	2,880.93	2,897.63	2,915.45	2,932.29	2,949.59

Pounds.	43°.	44°.	45°.	46°.	47°.	48°.	49°.	50°.	51°.	52°.	53°.	54°.	55°.	56°.
	Gallons.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
1	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.16
2	0.30	0.30	0.30	0.30	0.30	0.31	0.31	0.31	0.31	0.31	0.31	0.32	0.32	0.32
3	0.45	0.45	0.45	0.45	0.46	0.46	0.46	0.46	0.47	0.47	0.47	0.47	0.48	0.48
4	0.59	0.60	0.60	0.60	0.61	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.64	0.64
5	0.74	0.75	0.75	0.76	0.76	0.76	0.77	0.77	0.78	0.78	0.79	0.79	0.79	0.80
6	0.89	0.89	0.90	0.91	0.91	0.92	0.92	0.93	0.93	0.94	0.94	0.95	0.95	0.96
7	1.04	1.04	1.05	1.06	1.06	1.07	1.07	1.08	1.09	1.09	1.10	1.10	1.11	1.12
8	1.19	1.19	1.20	1.21	1.21	1.22	1.23	1.24	1.24	1.25	1.26	1.26	1.27	1.28
9	1.34	1.34	1.35	1.36	1.37	1.37	1.38	1.39	1.40	1.40	1.41	1.42	1.43	1.44
10	1.48	1.49	1.50	1.51	1.52	1.53	1.53	1.54	1.55	1.56	1.57	1.58	1.59	1.59
20	2.97	2.98	3.00	3.02	3.04	3.05	3.07	3.09	3.10	3.12	3.14	3.16	3.17	3.19
30	4.45	4.47	4.50	4.53	4.55	4.58	4.60	4.63	4.66	4.68	4.71	4.73	4.76	4.78
40	5.93	5.96	6.00	6.04	6.07	6.11	6.14	6.17	6.21	6.24	6.28	6.31	6.35	6.38
50	7.41	7.45	7.50	7.55	7.59	7.63	7.67	7.72	7.76	7.80	7.85	7.89	7.03	7.97
60	8.90	8.94	9.00	9.05	9.11	9.16	9.21	9.26	9.31	9.36	9.41	9.47	9.52	9.57
70	10.38	10.43	10.50	10.56	10.62	10.68	10.74	10.80	10.86	10.92	10.98	11.04	11.10	11.16
80	11.87	11.92	12.00	12.07	12.14	12.21	12.28	12.35	12.42	12.48	12.55	12.62	12.69	12.76
80	13.35	13.41	13.50	13.59	13.66	13.74	13.81	13.89	13.97	14.04	14.12	14.20	14.28	14.35
100	14.83	14.91	15.00	15.09	15.18	15.26	15.35	15.43	15.52	15.61	15.69	15.78	15.86	15.95
200	29.67	29.81	30.00	30.18	30.36	30.52	30.70	30.87	31.04	31.21	31.38	31.56	31.73	31.90
300	44.50	44.72	45.01	45.27	45.53	45.79	46.04	46.30	46.56	46.82	47.07	47.33	47.59	47.85
400	59.34	59.62	60.02	60.36	60.71	61.05	61.39	61.74	62.08	62.42	62.76	63.11	63.45	63.80
500	74.17	74.53	75.02	75.45	75.88	76.31	76.74	77.17	77.60	78.03	78.45	78.89	79.31	79.75
1,000	148.34	149.05	150.04	150.91	151.77	152.62	163.48	154.34	155.20	156.05	156.91	157.77	158.63	159.49
2,000	296.67	298.11	300.08	391.82	303.56	305.24	306.95	308.69	310.40	312.10	313.81	315.55	317.25	318.98
3,000	445.02	447.16	450.13	452.73	455.30	457.85	460.43	463.03	465.60	468.15	470.72	473.32	475.88	478.47
4,000	593.35	596.22	600.17	603.64	607.07	610.47	613.91	617.38	620.80	624.20	627.63	631.09	634.51	637.96
5,000	741.60	745.27	750.21	754.55	758.84	763.09	767.38	771.72	776.01	780.25	784.54	788.87	793.13	797.45
10,000	1,483.37	1,490.53	1,500.42	1,509.09	1,517.68	1,526.18	1,534.75	1,543.45	1,552.02	1,560.50	1,569.07	1,577.74	1,586.27	1,594.90
20,000	2,966.74	2,981.07	3,000.84	3,018.18	3,035.56	3,052.36	3,069.51	3,086.90	3,104.05	3,121.00	3,138.14	3,155.47	3,172.53	3,189.70

DEGREES OF BAUMÉ'S HYDROMETER—Continued.

Pounds.	57°.	58°.	59°.	60°.	61°.	62°.	63°.	64°.	65°.	70°.	75°.	80°.	85°.
	Gallons.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
1	0.16	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.18	0.18	0.18
2	0.32	0.32	0.32	0.32	0.33	0.33	0.33	0.33	0.33	0.34	0.35	0.36	0.37
3	0.48	0.48	0.49	0.49	0.49	0.49	0.50	0.50	0.50	0.51	0.53	0.54	0.55
4	0.64	0.65	0.65	0.65	0.66	0.66	0.66	0.67	0.67	0.69	0.70	0.72	0.74
5	0.80	0.81	0.81	0.82	0.82	0.82	0.83	0.83	0.84	0.86	0.88	0.99	0.92
6	0.96	0.97	0.97	0.98	0.98	0.99	1.00	1.00	1.00	1.03	1.86	1.08	1.11
7	1.12	1.13	1.13	1.14	1.15	1.15	1.16	1.16	1.17	1.20	1.23	1.26	1.29
8	1.28	1.29	1.30	1.30	1.31	1.31	1.32	1.33	1.34	1.37	1.41	1.44	1.48
9	1.44	1.45	1.46	1.47	1.47	1.48	1.49	1.50	1.50	1.54	1.58	1.62	1.66
10	1.60	1.61	1.62	1.63	1.64	1.65	1.65	1.66	1.67	1.72	1.76	1.80	1.84
20	3.21	3.22	3.24	3.24	3.28	3.29	3.31	3.33	3.34	3.43	3.52	3.60	3.69
30	4.81	4.84	4.86	4.89	4.91	4.94	4.96	4.99	5.02	5.14	5.28	5.40	5.53
40	6.41	6.45	6.48	6.52	6.55	6.59	6.62	6.65	6.69	6.86	7.03	7.20	7.37
50	8.02	8.06	8.10	8.15	8.19	8.23	8.27	8.32	8.36	8.57	8.79	9.00	9.22
60	9.62	9.67	9.72	9.77	9.83	9.88	9.93	9.99	10.03	10.29	10.55	10.80	11.06
70	11.22	11.28	11.34	11.40	11.46	11.53	11.58	11.64	11.69	12.00	12.31	12.60	12.90
80	12.83	12.90	12.95	13.03	13.10	13.16	13.24	13.31	13.38	13.72	14.07	14.41	14.75
90	14.43	14.51	14.58	14.66	14.74	14.82	14.89	14.97	15.05	15.43	15.83	16.21	16.59
100	16.03	16.12	16.21	16.29	16.38	16.47	16.55	16.64	16.72	17.15	17.59	18.01	18.44
200	32.07	32.24	32.41	32.58	32.76	32.93	33.10	33.27	33.44	34.30	35.17	36.01	36.87
300	48.10	48.36	48.61	48.87	49.13	49.40	49.65	49.90	50.16	51.44	52.76	54.02	55.31
400	64.14	64.48	64.82	65.16	65.51	65.86	66.20	66.54	66.88	68.59	70.34	72.03	73.74
500	80.17	80.60	81.03	81.46	81.89	82.33	82.75	83.17	83.60	85.74	87.93	90.04	92.18
1,000	160.34	161.21	162.05	162.91	163.78	164.66	165.49	166.35	167.20	171.48	175.86	180.07	184.36
2,000	320.69	322.41	324.11	323.82	327.56	329.31	330.99	332.69	334.40	342.95	351.72	360.14	368.71
3,000	481.03	483.60	486.16	488.73	491.34	493.97	496.48	499.03	510.60	514.43	527.58	540.21	553.06
4,000	641.37	644.82	648.21	651.64	655.11	658.62	661.98	665.38	668.81	685.91	703.44	720.28	737.42
5,000	801.72	806.02	810.27	814.56	818.89	823.28	827.47	831.73	836.01	857.38	879.30	900.35	921.77
10,000	1,603.44	1,612.05	1,620.54	1,629.12	1,637.79	1,646.55	1,654.94	1,663.45	1,672.02	1,714.77	1,758.59	1,800.70	1,843.55
20,000	3,206.87	3,224.09	3,241.07	3,238.24	3,275.57	3,293.10	3,309.88	3,326.90	3,344.03	3,429.53	3,517.18	3,601.40	3,687.11

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL.

15° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
288	35.8	318	39.5	348	43.3	378	47.0	408	50.7
289	35.9	319	39.7	349	43.4	379	47.1	409	50.9
290	36.1	320	39.8	350	43.5	380	47.3	410	51.0
291	36.2	321	39.9	351	43.6	381	47.4	411	51.1
292	36.3	322	40.0	352	43.8	382	47.5	412	51.2
293	36.4	323	40.2	353	43.9	383	47.6	413	51.3
294	36.6	324	40.3	354	44.0	384	47.8	414	51.5
295	36.7	325	40.4	355	44.1	385	47.9	415	51.6
296	36.8	326	40.5	356	44.3	386	48.0	416	51.7
297	36.9	327	40.7	357	44.4	387	48.1	417	51.8
298	37.1	328	40.8	358	44.5	388	48.3	418	52.0
299	37.2	329	40.9	359	44.6	389	48.4	419	52.1
300	37.3	330	41.0	360	44.8	390	48.5	420	52.2
301	37.4	331	41.2	361	44.9	391	48.6	421	52.3
302	37.6	332	41.3	362	45.0	392	48.7	422	52.5
303	37.7	333	41.4	363	45.1	393	48.9	423	52.6
304	37.8	334	41.5	364	45.3	394	49.0	424	52.7
305	37.9	335	41.7	365	45.4	395	49.1	425	52.8
306	38.1	336	41.8	366	45.5	396	49.2	426	53.0
307	38.2	337	41.9	367	45.6	397	49.4	427	53.1
308	38.3	338	42.0	368	45.8	398	49.5	428	53.2
309	38.4	339	42.2	369	45.9	399	49.6	429	53.3
310	38.5	340	42.3	370	46.0	400	49.7	430	53.5
311	38.7	341	42.4	371	46.1	401	49.9	431	53.6
312	38.8	342	42.5	372	46.3	402	50.0	432	53.7
313	38.9	343	42.6	373	46.4	403	50.1	433	53.8
314	39.0	344	42.8	374	46.5	404	50.2	434	53.9
315	39.2	345	42.9	375	46.6	405	50.4	435	54.0
316	39.3	346	43.0	376	46.8	406	50.5	436	54.2
317	39.4	347	43.1	377	46.9	407	50.6	437	54.3

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

20° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
260	36.0	310	39.9	340	43.7	370	47.6	400	51.5
281	36.1	311	40.0	341	43.9	371	47.7	401	51.6
282	36.3	312	40.1	342	44.0	372	47.8	402	51.7
283	36.4	313	40.3	343	44.1	373	48.0	403	51.8
284	36.5	314	40.4	344	44.3	374	48.1	404	52.0
285	36.7	315	40.5	345	44.4	375	48.2	405	52.1
286	36.8	316	40.6	346	44.5	376	48.4	406	52.2
287	36.9	317	40.8	347	44.6	377	48.5	407	52.4
268	37.0	318	40.9	348	44.8	378	48.6	408	52.5
289	37.2	319	41.0	349	44.9	379	48.7	409	52.6
290	37.3	320	41.2	350	45.0	380	48.9	410	52.7
291	37.4	321	41.3	351	45.1	381	49.0	411	52.9
292	37.6	322	41.4	352	45.3	382	49.1	412	53.0
293	37.7	323	41.5	353	45.4	383	49.3	413	53.1
294	37.8	324	41.7	354	45.5	384	49.4	414	53.3
295	37.9	325	41.8	355	45.7	385	49.5	415	53.4
296	38.1	326	41.9	356	45.8	386	49.6	416	53.5
297	38.2	327	42.1	357	45.9	387	49.8	417	53.6
298	38.3	328	42.2	358	46.0	388	49.9	418	53.8
299	38.5	329	42.3	359	46.2	389	50.0	419	53.9
300	38.6	330	42.4	360	46.3	390	50.2	420	54.0
301	38.7	331	42.6	361	46.4	391	50.3	421	54.2
302	38.8	332	42.7	362	46.6	392	50.4	422	54.3
303	39.0	333	42.8	363	46.7	393	50.6	423	54.4
304	39.1	334	43.0	364	46.8	394	50.7	424	54.5
305	39.2	335	43.1	365	46.9	395	50.8	425	54.7
306	39.4	336	43.2	366	47.1	396	50.9	426	54.8
307	39.5	337	43.3	367	47.2	397	51.1	427	54.9
308	39.6	338	43.5	368	47.3	398	51.2	428	55.1
309	39.7	339	43.6	369	47.5	399	51.3	429	55.2

21° GRAVITY.

278	35.9	308	39.9	338	43.8	368	47.7	398	51.5
279	36.1	309	40.0	339	43.9	369	47.8	399	51.7
280	36.2	310	40.1	340	44.0	370	47.9	400	51.8
281	36.3	311	40.3	341	44.2	371	48.0	401	51.9
282	36.5	312	40.4	342	44.3	372	48.2	402	52.1
283	36.6	313	40.5	343	44.4	373	48.3	403	52.2
284	36.7	314	40.7	344	44.5	374	48.4	404	52.3
285	36.9	315	40.8	345	44.7	375	48.6	405	52.4
286	37.0	316	40.9	346	44.8	376	48.7	406	52.6
287	37.1	317	41.1	347	44.9	377	48.8	407	52.7
288	37.2	318	41.2	348	45.1	378	48.9	408	52.8
289	37.4	319	41.3	349	45.2	379	49.1	409	53.0
290	37.5	320	41.4	350	45.3	380	49.2	410	53.1
291	37.6	321	41.6	351	45.4	381	49.3	411	53.2
292	37.8	322	41.7	352	45.6	382	49.5	412	53.4
293	37.9	323	41.8	353	45.7	383	49.6	413	53.5
294	38.0	324	41.9	354	45.8	384	49.7	414	53.6
295	38.1	325	42.1	355	46.0	385	49.9	415	53.7
296	38.3	326	42.2	356	46.1	386	50.0	416	53.9
297	38.4	327	42.3	357	46.2	387	50.1	417	54.0
298	38.5	328	42.5	358	46.4	388	50.2	418	54.1
299	38.7	329	42.6	359	46.5	389	50.4	419	54.3
300	38.8	330	42.7	360	46.6	390	50.5	420	54.4
301	39.0	331	42.9	361	46.7	391	50.6	421	54.5
302	39.1	332	43.0	362	46.9	392	50.8	422	54.6
303	39.2	333	43.1	363	47.0	393	50.9	423	54.8
304	39.4	334	43.2	364	47.1	394	51.0	424	54.9
305	39.5	335	43.4	365	47.3	395	51.1	425	55.0
306	39.6	336	43.5	366	47.4	396	51.3	426	55.2
307	39.8	337	43.6	367	47.5	397	51.4	427	55.3

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

22° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
275	35.8	305	39.8	335	43.7	365	47.6	395	51.5
276	36.0	306	39.9	336	43.8	366	47.7	396	51.6
277	36.1	307	40.0	337	43.9	367	47.8	397	51.7
278	36.2	308	40.1	338	44.1	368	48.0	338	51.9
279	36.4	309	40.3	339	44.2	369	48.1	399	52.0
280	36.5	310	40.4	340	44.3	370	48.2	400	52.1
281	36.6	311	40.5	341	44.4	371	48.4	401	52.3
282	36.8	312	40.7	342	44.6	372	48.5	402	52.4
283	36.9	313	40.8	343	44.7	373	48.6	403	52.5
284	37.0	314	40.9	344	44.8	374	48.7	404	52.7
285	37.2	315	41.1	345	45.0	375	48.9	405	52.8
286	37.3	316	41.2	346	45.1	376	49.0	406	52.9
287	37.4	317	41.3	347	45.2	377	49.1	407	53.0
288	37.5	318	41.4	348	45.4	378	49.3	408	53.2
289	37.7	319	41.6	349	45.5	379	49.4	409	53.3
290	37.8	320	41.7	350	45.6	380	49.5	410	53.4
291	37.9	321	41.8	351	45.8	381	49.7	411	53.6
292	38.1	322	42.0	352	45.9	382	49.8	412	53.7
293	38.2	323	42.1	353	46.0	383	49.9	413	53.8
294	38.3	324	42.2	354	46.1	384	50.1	414	54.0
295	38.5	325	42.4	355	46.3	385	50.2	415	54.1
296	38.6	326	42.5	356	46.4	386	50.3	416	54.2
297	38.7	327	42.6	357	46.5	387	50.4	417	54.3
298	38.8	328	42.8	358	46.7	388	50.6	418	54.5
299	39.0	329	42.9	359	46.8	389	50.7	419	54.6
300	39.1	330	43.0	360	46.9	390	50.8	420	54.7
301	39.2	331	43.1	361	47.1	391	51.0	421	54.9
302	39.4	332	43.3	362	47.2	392	51.1	422	55.0
303	39.5	333	43.4	363	47.3	393	51.2	423	55.1
304	39.6	334	43.5	364	47.4	394	51.4	424	55.3

23° GRAVITY.

274	36.0	304	39.9	334	43.8	364	47.8	394	51.7
275	36.1	305	40.0	335	44.0	365	47.9	395	51.8
276	36.2	306	40.2	336	44.1	366	48.0	396	52.0
277	36.3	307	40.3	337	44.2	367	48.2	397	52.1
278	36.5	308	40.4	338	44.4	368	48.3	398	52.2
279	36.6	309	40.5	339	44.5	369	48.4	399	52.4
280	36.7	310	40.7	340	44.6	370	48.5	400	52.5
281	36.9	311	40.8	341	44.7	371	48.7	401	52.6
282	37.0	312	40.9	342	44.9	372	48.8	402	52.7
283	37.1	313	41.1	343	45.0	373	48.9	403	52.9
284	37.3	314	41.2	344	45.1	374	49.1	404	53.0
285	37.4	315	41.3	345	45.3	375	49.2	405	53.1
286	37.5	316	41.5	346	45.4	376	49.3	406	53.3
287	37.7	317	41.6	347	45.5	377	49.5	407	53.4
288	37.8	318	41.7	348	45.7	378	49.6	408	53.5
289	37.9	319	41.9	349	45.8	379	49.7	409	53.7
290	38.1	320	42.0	350	45.9	380	49.9	410	53.8
291	38.2	321	42.1	351	46.1	381	50.0	411	53.9
292	38.3	322	42.2	352	46.2	382	50.1	412	54.1
293	38.4	323	42.4	353	46.3	383	50.2	413	54.2
294	38.6	324	42.5	354	46.5	384	50.4	414	54.3
295	38.7	325	42.6	355	46.6	385	50.5	415	54.4
296	38.8	326	42.8	356	46.7	386	50.6	416	54.6
297	39.0	327	42.9	357	46.8	387	50.8	417	54.7
298	39.1	328	43.0	358	47.0	388	50.9	418	54.8
299	39.2	329	43.2	359	47.1	389	51.0	419	55.0
300	39.4	330	43.3	360	47.2	390	51.2	420	55.1
301	39.5	331	43.4	361	47.4	391	51.3	421	55.2
302	39.6	332	43.6	362	47.5	392	51.4	422	55.4
303	39.8	333	43.7	363	47.6	393	51.6	423	55.5

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

24° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
272	35.9	302	39.9	332	43.8	362	47.8	392	51.8
273	36.1	303	40.0	333	44.0	363	47.9	393	51.9
274	36.2	304	40.2	334	44.1	364	48.1	394	52.0
275	36.3	305	40.3	335	44.2	365	48.2	395	52.2
276	36.4	306	40.4	336	44.4	366	48.3	396	52.3
277	36.6	307	40.5	337	44.5	367	48.5	397	52.4
278	36.7	308	40.7	338	44.6	368	48.6	398	52.6
279	36.9	309	40.8	339	44.8	369	48.7	399	52.7
280	37.0	310	40.9	340	44.9	370	48.9	400	52.8
281	37.1	311	41.1	341	45.0	371	49.0	401	53.0
282	37.2	312	41.2	342	45.2	372	49.1	402	53.1
283	37.4	313	41.3	343	45.3	373	49.3	403	53.2
284	37.5	314	41.5	344	45.4	374	49.4	404	53.4
285	37.6	315	41.6	345	45.6	375	49.5	405	53.5
286	37.8	316	41.7	346	45.7	376	49.7	406	53.6
287	37.9	317	41.9	347	45.8	377	49.8	407	53.7
288	38.0	318	42.0	348	46.0	378	49.9	408	53.9
289	38.2	319	42.1	349	46.1	379	50.1	409	54.0
290	38.3	320	42.3	350	46.2	380	50.2	410	54.1
291	38.4	321	42.4	351	46.4	381	50.3	411	54.3
292	38.6	322	42.5	352	46.5	382	50.4	412	54.4
293	38.7	323	42.7	353	46.6	383	50.6	413	54.5
294	38.8	324	42.8	354	46.8	384	50.7	414	54.7
295	39.0	325	42.9	355	46.9	385	50.8	415	54.8
296	39.1	326	43.1	356	47.0	386	51.0	416	54.9
297	39.2	327	43.2	357	47.1	387	51.1	417	55.1
298	39.4	328	43.3	358	47.3	388	51.2	418	55.2
299	39.5	329	43.5	359	47.4	389	51.4	419	55.3
300	39.6	330	43.6	360	47.5	390	51.5	420	55.5
301	39.8	331	43.7	361	47.7	391	51.6	421	55.6

25° GRAVITY.

271	36.0	301	40.0	331	44.0	361	48.0	391	62.0
272	36.1	302	40.1	332	44.1	362	48.1	392	52.1
273	36.3	303	40.3	333	44.3	363	48.2	393	52.2
274	36.4	304	40.4	334	44.4	364	48.4	394	52.4
275	36.5	305	40.5	335	44.5	365	48.5	395	52.5
276	36.7	306	40.7	336	44.7	366	48.6	396	52.6
277	36.8	307	40.8	337	44.8	367	48.8	397	52.8
278	36.9	308	40.9	338	44.9	368	48.9	398	52.9
279	37.1	309	41.1	339	45.1	369	49.0	399	53.0
280	37.2	310	41.2	340	45.2	370	49.2	400	53.2
281	37.3	311	41.3	341	45.3	371	49.3	401	53.3
282	37.5	312	41.5	342	45.4	372	49.4	402	53.4
283	37.6	313	41.6	343	45.6	373	49.6	403	53.6
284	37.7	314	41.7	344	45.7	374	49.7	404	53.7
285	37.9	315	41.9	345	45.8	375	49.8	405	53.8
286	38.0	316	42.0	346	46.0	376	50.0	406	54.0
287	38.1	317	42.1	347	46.1	377	50.1	407	54.1
288	38.3	318	42.3	348	46.2	378	50.2	408	54.2
289	38.4	319	42.4	349	46.4	379	50.4	409	54.4
290	38.5	320	42.5	350	46.5	380	50.5	410	54.5
291	38.7	321	42.7	351	46.6	381	50.6	411	54.6
292	38.8	322	42.8	352	46.8	382	50.8	412	54.8
293	38.9	323	42.9	353	46.9	383	50.9	413	54.9
294	39.1	324	43.1	354	47.0	384	51.0	414	55.0
295	39.2	325	43.2	355	47.2	385	51.2	415	55.1
296	39.3	326	43.3	356	47.3	386	51.3	416	55.3
297	39.5	327	43.5	357	47.4	387	51.4	417	55.4
298	39.6	328	43.6	358	47.6	388	51.6	418	55.5
299	39.7	329	43.7	359	47.7	389	51.7	419	55.7
300	39.9	330	43.9	360	47.8	390	51.8	420	55.8

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

26° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
269	36.0	299	40.0	329	44.0	359	48.0	389	52.0
270	36.1	300	40.1	330	44.1	360	48.2	390	52.2
271	36.2	301	40.3	331	44.3	361	48.3	391	52.3
272	36.4	302	40.4	332	44.4	362	48.4	392	52.4
273	36.5	303	40.5	333	44.5	363	48.6	393	52.6
274	36.7	304	40.7	334	44.7	364	48.7	394	52.7
275	36.8	305	40.8	335	44.8	365	48.8	395	52.8
276	36.9	306	40.9	336	44.9	366	49.0	396	53.0
277	37.1	307	41.1	337	45.1	367	49.1	397	53.1
278	37.2	308	41.2	338	45.2	368	49.2	398	53.2
279	37.3	309	41.3	339	45.3	369	49.4	399	53.4
280	37.5	310	41.5	340	45.5	370	49.5	400	53.5
281	37.6	311	41.6	341	45.6	371	49.6	401	53.6
282	37.7	312	41.7	342	45.8	372	49.8	402	53.8
283	37.9	313	41.9	343	45.9	373	49.9	403	53.9
284	38.0	314	42.0	344	46.0	374	50.0	404	54.0
285	38.1	315	42.1	345	46.2	375	50.2	405	54.2
286	38.3	316	42.3	346	46.3	376	50.3	406	54.3
287	38.4	317	42.4	347	46.4	377	50.4	407	54.4
288	38.5	318	42.5	348	46.6	378	50.6	408	54.6
289	38.7	319	42.7	349	46.7	379	50.7	409	54.7
290	38.8	320	42.8	350	46.8	380	50.8	410	54.8
291	38.9	321	42.9	351	47.0	381	51.0	411	55.0
292	39.1	322	43.1	352	47.1	382	51.1	412	55.1
293	39.2	323	43.2	353	47.2	383	51.2	413	55.2
294	39.3	324	43.4	354	47.4	384	51.4	414	55.4
295	39.5	325	43.5	355	47.5	385	51.5	415	55.5
296	39.6	326	43.6	356	47.6	386	51.6	416	55.6
297	39.7	327	43.8	357	47.8	387	51.8	417	55.8
298	39.9	328	43.9	358	47.9	388	51.9	418	55.9

27° GRAVITY.

267	35.9	297	40.0	327	44.0	357	48.1	387	52.1
268	36.1	298	40.1	328	44.2	358	48.2	388	52.2
269	36.2	299	40.3	329	44.3	359	48.3	389	52.4
270	36.3	300	40.4	330	44.4	360	48.5	390	52.5
271	36.5	301	40.5	331	44.6	361	48.6	391	52.6
272	36.6	302	40.7	332	44.7	362	48.7	392	52.8
273	36.7	303	40.8	333	44.8	363	48.9	393	52.9
274	36.9	304	40.9	334	45.0	364	49.0	394	53.0
275	37.0	305	41.1	335	45.1	365	49.1	395	53.2
276	37.2	306	41.2	336	45.2	366	49.3	396	53.3
277	37.3	307	41.3	337	45.4	367	49.4	397	53.4
278	37.4	308	41.5	338	45.5	368	49.5	398	53.6
279	37.6	309	41.6	339	45.6	369	49.7	399	53.7
280	37.7	310	41.7	340	45.8	370	49.8	400	53.9
281	37.8	311	41.9	341	45.9	371	49.9	401	54.0
282	38.0	312	42.0	342	46.6	372	50.1	402	54.1
283	38.1	313	42.1	343	46.2	373	50.2	403	54.3
284	38.2	314	42.3	344	46.3	374	50.3	404	54.4
285	38.4	315	42.4	345	46.4	375	50.5	405	54.5
286	38.5	316	42.5	346	46.6	376	50.6	406	54.7
287	38.6	317	42.7	347	46.7	377	50.7	407	54.8
288	38.8	318	42.8	348	46.8	378	50.9	408	54.9
289	38.9	319	42.9	349	47.0	379	51.0	409	55.1
290	39.0	320	43.1	350	47.1	380	51.2	410	55.2
291	39.2	321	43.2	351	47.3	381	51.3	411	55.3
292	39.3	322	43.3	352	47.4	382	51.4	412	55.5
293	39.4	323	43.5	353	47.5	383	51.6	413	55.6
294	39.6	324	43.6	354	47.7	384	51.7	414	55.7
295	39.7	325	43.7	355	47.8	385	51.8	415	55.9
296	39.9	326	43.9	356	47.9	386	52.0	416	56.0

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

28° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
265	35.9	295	40.0	325	44.0	355	48.1	385	52.1
266	36.0	296	40.1	326	44.2	356	48.2	386	52.3
267	36.2	297	40.2	327	44.3	357	48.4	387	52.4
268	36.3	298	40.4	328	44.4	358	48.5	388	52.6
269	36.5	299	40.5	329	44.6	359	48.6	389	52.7
270	36.6	300	40.6	330	44.7	360	48.8	390	52.8
271	36.7	301	40.8	331	44.8	361	48.9	391	53.0
272	36.9	302	40.9	332	45.0	362	49.0	392	53.1
273	37.0	303	41.1	333	45.1	363	49.2	393	53.2
274	37.1	304	41.2	334	45.2	364	49.3	394	53.4
275	37.3	305	41.3	335	45.4	365	49.5	395	53.5
276	37.4	306	41.5	336	45.5	366	49.6	396	53.6
277	37.5	307	41.6	337	45.7	367	49.7	397	53.8
278	37.7	308	41.7	338	45.8	368	49.9	398	53.9
279	37.8	309	41.9	339	45.9	369	50.0	399	54.1
280	37.9	310	42.0	340	46.1	370	50.1	400	54.2
281	38.1	311	42.1	341	46.2	371	50.3	401	54.3
282	38.2	312	42.3	342	46.3	372	50.4	402	54.5
283	38.4	313	42.4	343	46.5	373	50.5	403	54.6
284	38.5	314	42.5	344	46.6	374	50.7	404	54.7
285	38.6	315	42.7	345	46.7	375	50.8	405	54.9
286	38.8	316	42.8	346	46.9	376	50.9	406	55.0
287	38.9	317	42.9	347	47.0	377	51.1	407	55.1
288	39.0	318	43.1	348	47.1	378	51.2	408	55.3
289	39.2	319	43.2	349	47.3	379	51.3	409	55.4
290	39.3	320	43.4	350	47.4	380	51.5	410	55.5
291	39.4	321	43.5	351	47.6	381	51.6	411	55.7
292	39.6	322	43.6	352	47.7	382	51.8	412	55.8
293	39.7	323	43.8	353	47.8	383	51.9	413	56.0
294	39.8	324	43.9	354	48.0	384	52.0	414	56.1

29° GRAVITY.

263	35.9	293	40.0	323	44.0	353	48.1	383	52.2
264	36.0	294	40.1	324	44.2	354	48.3	384	52.4
265	36.1	295	40.2	325	44.3	355	48.4	385	52.5
266	36.3	296	40.4	326	44.5	356	48.5	386	52.6
267	36.4	297	40.5	327	44.6	357	48.7	387	52.8
268	36.5	298	40.6	328	44.7	358	48.8	388	52.9
269	36.7	299	40.8	329	44.9	359	49.0	389	53.0
270	36.8	300	40.9	330	45.0	360	49.1	390	53.2
271	36.9	301	41.0	331	45.1	361	49.2	391	53.3
272	37.1	302	41.2	332	45.3	362	49.4	392	53.4
273	37.2	303	41.3	333	45.4	363	49.5	393	53.6
274	37.4	304	41.5	334	45.5	364	49.6	394	53.7
275	37.5	305	41.6	335	45.7	365	49.8	395	53.9
276	37.6	306	41.7	336	45.8	366	49.9	396	54.0
277	37.8	307	41.9	337	45.9	367	50.0	397	54.1
278	37.9	308	42.0	338	46.1	368	50.2	398	54.3
279	38.0	309	42.1	339	46.2	369	50.3	399	54.4
280	38.2	310	42.3	340	46.4	370	50.4	400	54.5
281	38.3	311	42.4	341	46.5	371	50.6	401	54.7
282	38.5	312	42.5	342	46.6	372	50.7	402	54.8
283	38.6	313	42.7	343	46.8	373	50.8	403	54.9
284	38.7	314	42.8	344	46.9	374	51.0	404	55.1
285	38.9	315	42.9	345	47.0	375	51.1	405	55.2
286	39.0	316	43.1	346	47.2	376	51.3	406	55.4
287	39.1	317	43.2	347	47.3	377	51.4	407	55.5
288	39.3	318	43.4	348	47.4	378	51.5	408	55.6
289	39.4	319	43.5	349	47.6	379	51.7	409	55.8
290	39.5	320	43.6	350	47.7	380	51.8	410	55.9
291	39.7	321	43.8	351	47.9	381	52.0	411	56.0
292	39.8	322	43.9	352	48.0	382	52.1	412	56.2

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

30° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
262	35.9	292	40.1	322	44.2	352	48.3	382	52.4
263	36.1	293	40.2	323	44.3	353	48.4	383	52.5
264	36.2	294	40.3	324	44.4	354	48.6	384	52.7
265	36.4	295	40.5	325	44.6	355	48.7	385	52.8
266	36.5	296	40.6	326	44.7	356	48.8	386	52.9
267	36.6	297	40.8	327	44.9	357	49.0	387	53.1
268	36.8	298	40.9	328	45.0	358	49.1	388	53.2
269	36.9	299	41.0	329	45.1	359	49.3	389	63.4
270	37.0	300	41.2	330	45.3	360	49.4	390	63.5
271	37.2	301	41.3	331	45.4	361	49.5	391	53.6
272	37.3	302	41.4	332	45.5	362	49.7	392	53.8
273	37.5	303	41.6	333	45.7	363	49.8	393	53.9
274	37.6	304	41.7	334	45.8	364	49.9	394	54.1
275	37.7	305	41.8	335	46.0	365	50.1	395	54.2
276	37.9	306	42.0	336	46.1	366	50.2	396	54.3
277	38.0	307	42.1	337	46.2	367	50.3	397	54.5
278	38.1	308	42.3	338	46.4	368	50.5	398	54.6
279	38.3	309	42.4	339	46.5	369	50.6	399	54.7
280	38.4	310	42.5	340	46.6	370	50.8	400	54.9
281	38.6	311	42.7	341	46.8	371	50.9	401	55.0
282	38.7	312	42.8	342	46.9	372	51.0	402	55.1
283	38.8	313	42.9	343	47.1	373	51.2	403	55.3
284	39.0	314	43.1	344	47.2	374	51.3	404	55.4
285	39.1	315	43.2	345	47.3	375	51.4	405	55.6
286	39.2	316	43.3	346	47.5	376	51.6	406	55.7
287	39.4	317	43.5	347	47.6	377	51.7	407	55.8
288	39.5	318	43.6	348	47.7	378	51.9	408	56.0
289	39.7	319	43.8	349	47.9	379	52.0	409	56.1
290	39.8	320	43.9	350	48.0	380	52.1	410	56.2
291	39.9	321	44.0	351	48.2	381	52.3	411	56.4

31° GRAVITY.

260	35.9	290	40.0	320	44.2	350	48.3	380	52.5
261	36.0	291	40.2	321	44.3	351	48.5	381	52.6
262	36.2	292	40.3	322	44.5	352	48.6	382	52.7
263	36.3	293	40.4	323	44.6	353	48.7	383	52.9
264	30.5	294	40.6	324	44.7	354	48.9	384	53.0
265	36.6	295	40.7	325	44.9	355	49.0	385	53.2
266	36.7	296	40.9	326	45.0	356	49.2	386	53.3
267	36.9	297	41.0	327	45.2	357	49.3	387	53.4
268	37.0	298	41.1	328	45.3	358	49.4	388	53.6
269	37.1	299	41.3	329	45.4	359	49.6	389	53.7
270	37.3	300	41.4	330	45.6	360	49.7	390	53.8
271	37.4	301	41.6	331	45.7	361	49.8	391	54.0
272	37.6	302	41.7	332	45.8	362	50.0	392	54.1
273	37.7	303	41.8	333	46.0	363	50.1	393	54.3
274	37.8	304	42.0	334	46.1	364	50.3	394	54.4
275	38.0	305	42.1	335	46.3	365	50.4	395	54.5
276	38.1	306	42.3	336	46.4	366	50.5	396	54.7
277	38.2	307	42.4	337	46.5	367	50.7	397	54.8
278	38.4	308	42.5	338	46.7	368	50.8	398	54.0
279	38.5	309	42.7	339	46.8	369	50.9	399	55.1
280	38.7	310	42.8	340	46.9	370	51.1	400	55.2
281	38.8	311	42.9	341	47.1	371	51.2	401	55.4
282	38.9	312	43.1	342	47.2	372	51.4	402	55.5
283	39.1	313	43.2	343	47.4	373	51.5	403	55.6
284	39.2	314	43.4	344	47.5	374	51.6	404	55.8
285	39.3	315	43.5	345	47.6	375	51.8	405	55.9
286	39.5	316	43.6	346	47.8	376	51.9	406	56.1
287	38.6	317	43.8	347	47.9	377	52.1	407	56.2
288	39.8	318	43.9	348	48.0	378	52.2	408	56.3
289	39.9	319	44.0	349	48.2	379	52.3	409	56.5

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

32° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
258	35.8	288	40.0	318	44.2	348	48.3	378	52.5
259	36.0	289	40.1	319	44.3	349	48.5	379	52.6
260	36.1	290	40.3	320	44.5	350	48.6	380	52.8
261	36.3	291	40.4	321	44.6	351	48.8	381	52.9
262	36.4	292	40.6	322	44.7	352	48.9	382	53.1
263	36.5	293	40.7	323	44.9	353	49.0	383	53.2
264	36.7	394	40.8	324	45.0	354	49.2	384	53.3
265	36.8	295	41.0	325	45.1	355	49.3	385	53.5
266	36.9	296	41.1	326	45.3	356	49.4	386	53.6
267	37.1	297	41.3	327	45.4	357	49.6	387	53.8
268	37.2	298	41.4	328	45.6	358	49.7	388	53.9
269	37.4	299	41.5	329	45.7	259	49.9	389	54.0
270	37.5	300	41.7	330	45.8	360	50.0	390	54.2
271	37.6	301	41.8	331	46.0	361	50.1	391	54.3
272	37.8	302	42.0	332	46.1	362	50.3	392	54.5
273	37.9	303	42.1	333	46.3	363	50.4	393	54.6
274	38.1	304	42.2	334	46.4	364	50.6	394	54.7
275	38.2	305	42.4	335	46.5	365	50.7	395	54.9
276	38.3	306	42.5	336	46.7	366	50.8	396	55.0
277	38.5	307	42.6	337	46.8	367	51.0	397	55.1
278	38.6	308	42.8	338	47.0	368	51.1	398	55.3
279	38.8	309	42.9	339	47.1	369	51.3	399	55.4
280	38.9	310	43.1	340	47.2	370	51.4	400	55.6
281	39.0	311	43.2	341	47.4	371	51.5	401	55.7
282	39.2	312	43.3	342	47.5	372	51.7	402	55.8
283	39.3	313	43.5	343	47.7	372	51.8	403	56.0
284	39.5	314	43.6	344	47.8	374	52.0	404	56.1
285	39.6	315	43.8	345	47.9	375	52.1	405	56.3
286	39.7	316	43.9	346	48.1	376	52.2	406	56.4
287	39.9	317	44.0	347	48.2	377	52.4	407	56.5

33° GRAVITY.

257	35.9	287	40.1	317	44.3	347	48.6	377	52.7
258	36.1	288	40.3	318	44.5	348	48.6	378	52.8
259	36.2	289	40.4	319	44.6	349	48.8	379	53.0
260	36.3	290	40.5	320	44.7	350	48.9	380	53.1
261	36.6	291	40.7	321	44.9	351	49.1	381	53.3
262	36.6	292	40.8	322	45.0	352	49.2	382	53.4
263	36.8	293	41.0	323	45.2	353	49.3	383	53.5
264	36.9	294	41.1	324	45.3	354	49.5	384	53.7
265	37.0	295	41.2	325	45.4	355	49.6	385	53.8
266	37.2	296	41.4	326	45.6	356	49.8	386	54.0
267	37.3	297	41.5	327	45.7	357	49.9	387	54.1
268	37.5	298	41.7	328	45.9	358	50.0	388	54.2
269	37.6	299	41.8	329	46.0	359	50.2	389	54 4
270	37.7	300	41.9	330	46.1	360	50.3	390	54.5
271	37.9	301	42.1	331	46.3	361	50.5	391	54.7
272	38.0	302	42.2	332	46.4	362	50.6	392	54.8
273	38.2	303	42.4	333	46.5	363	50.7	393	54.9
274	38.3	304	42.5	334	46.7	364	50.9	394	55.1
275	38.4	305	42.6	335	46.8	365	51.0	395	55.2
276	38.6	306	42.8	336	47.0	366	51.2	396	55.4
277	38.7	307	42.9	337	47.1	367	51.3	397	55.5
278	38.9	308	43.1	338	47.2	368	51.4	398	55.6
279	39.0	309	43.2	339	47.4	369	51.6	399	55.8
280	39.1	310	43.3	340	47.5	370	51.7	400	55.9
281	39.3	311	43.5	341	47.7	371	51.9	401	56.1
282	39.4	312	43.6	342	47.8	372	52.0	402	56.2
283	39.6	313	43.8	343	47.9	373	52.1	403	56.3
284	39.7	314	43.9	344	48.1	374	52.3	404	56.5
285	39.8	315	44.0	345	48.2	375	52.4	405	56.6
286	40.0	316	44.2	346	48.4	376	52.6	406	56.8

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

34° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
255	35.9	285	40.1	315	44.3	345	48.5	375	52.7
256	36.0	286	40.2	316	44.4	346	48.7	376	52.9
257	36.1	287	40.4	317	44.6	347	48.8	377	53.0
258	36.3	289	40.5	318	44.7	348	49.0	378	53.2
259	36.4	289	40.6	319	44.9	349	49.1	379	53.3
260	36.6	290	40.8	320	45.0	350	49.2	380	53.4
261	36.7	291	40.9	321	45.1	351	49.4	381	53.6
262	36.8	292	41.1	322	45.3	352	49.5	382	53.7
263	37.0	293	41.2	323	45.4	353	49.6	383	53.9
264	37.1	294	41.3	324	45.6	354	49.8	384	54.0
265	37.3	295	41.5	325	45.7	355	49.9	385	54.1
266	37.4	296	41.6	326	45.8	356	50.1	386	54.3
267	37.5	297	41.8	327	46.0	357	50.2	387	54.4
268	37.7	298	41.9	328	46.1	358	50.4	388	54.6
269	37.8	299	42.1	329	46.3	359	50.5	389	54.7
270	38.0	300	42.2	330	46.4	360	50.6	390	54.9
271	38.1	301	42.3	331	46.6	361	50.8	391	55.0
272	38.2	302	42.5	332	46.7	362	50.9	392	55.1
273	38.4	303	42.6	333	46.8	363	51.1	393	55.3
274	38.5	304	42.8	334	47.0	364	51.2	394	55.4
275	38.7	305	42.9	335	47.1	365	51.3	395	55.6
276	38.8	306	43.0	336	47.3	366	51.5	396	55.7
277	38.9	307	43.2	337	47.4	367	51.6	397	55.8
278	39.1	308	43.3	338	47.5	368	51.8	398	56.0
279	39.2	309	43.5	339	47.7	369	51.9	399	56.1
280	39.4	310	43.6	340	47.8	370	52.0	400	56.3
281	39.5	311	43.7	341	48.0	371	52.2	401	56.4
282	39.7	312	43.9	342	48.1	372	52.3	402	56.5
283	39.8	313	44.0	343	48.2	373	52.5	403	56.7
284	39.9	314	44.2	344	48.4	374	52.6	404	56.8

35° GRAVITY.

254	35.9	284	40.2	314	44.4	344	48.7	374	52.9
255	36.1	285	40.3	315	44.6	345	48.8	375	53.1
256	36.2	286	40.5	316	44.7	346	49.0	376	53.2
257	36.4	287	40.6	317	44.9	347	49.1	377	53.4
258	36.5	288	40.8	318	45.0	348	49.2	378	53.5
259	36.6	289	40.9	319	45.1	349	49.4	379	53.6
260	36.8	290	41.0	320	45.3	350	49.5	380	53.8
261	36.9	291	41.2	321	45.4	351	49.7	381	53.9
262	37.1	292	41.3	322	45.6	352	49.8	382	54.1
263	37.2	293	41.5	323	45.7	353	50.0	383	54.2
264	37.4	294	41.6	324	45.9	354	50.1	384	54.4
265	37.5	295	41.7	325	46.0	355	50.2	385	54.5
266	37.6	296	41.9	326	46.1	356	50.4	386	54.6
267	37.8	297	42.0	327	46.3	357	50.5	387	54.8
268	37.9	298	42.2	328	46.4	358	50.7	388	54.9
269	38.1	299	42.3	329	46.6	359	50.8	389	55.1
270	38.2	300	42.5	330	46.7	360	50.9	390	55.2
271	38.4	301	42.6	331	46.8	361	51.1	391	55.3
272	38.5	302	42.7	332	47.0	362	51.2	392	55.5
273	38.6	303	42.9	333	47.1	363	51.4	393	55.6
274	38.8	304	43.0	334	47.3	364	51.5	394	55.8
275	38.9	305	43.2	335	47.4	365	51.7	395	55.9
276	39.1	306	43.3	336	47.6	366	51.8	396	56.0
277	39.2	307	43.4	337	47.7	367	51.9	397	56.2
278	39.3	308	43.6	338	47.8	368	52.1	398	56.3
279	39.5	309	43.7	339	48.0	369	52.2	399	56.5
280	39.6	310	43.9	340	48.1	370	52.4	400	56.6
281	39.8	311	44.0	341	48.3	371	52.5	401	56.7
282	39.9	312	44.1	342	48.4	372	52.6	402	56.9
283	40.1	313	44.3	343	48.6	373	52.8	403	57.0

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

40° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
246	35.9	276	40.2	306	44.6	336	49.0	366	53.4
247	36.0	277	40.4	307	44.8	337	49.1	367	53.5
248	36.2	278	40.5	308	44.9	338	49.3	368	53.7
249	36.3	279	40.7	309	45.0	339	49.4	369	53.8
250	36.5	280	40.8	310	45.2	340	49.6	370	53.9
251	36.6	281	41.0	311	45.3	341	49.7	371	54.1
252	36.7	282	41.1	312	45.5	342	49.9	372	54.2
253	36.9	283	41.3	313	45.6	343	50.0	373	54.4
254	37.0	284	41.4	314	45.8	344	50.1	374	54.5
255	37.2	285	41.6	315	45.9	345	50.3	375	54.7
256	37.3	286	41.7	316	46.1	346	50.4	376	54.8
257	37.5	287	41.8	317	46.2	347	50.6	377	55.0
258	37.6	288	42.0	318	46.4	348	50.7	378	55.1
259	37.8	289	42.1	319	46.5	349	50.9	379	55.2
260	37.9	290	42.3	320	46.7	350	51.0	380	55.4
261	38.1	291	42.4	321	46.8	351	51.2	381	55.5
262	38.2	292	42.6	322	46.9	352	51.3	382	55.7
263	38.4	293	42.7	323	47.1	353	51.5	383	55.8
264	38.5	294	42.9	324	47.2	354	51.6	384	56.0
265	38.6	295	43.0	325	47.4	355	51.8	385	56.1
266	38.8	296	43.2	326	47.5	356	51.9	386	56.3
267	38.9	297	43.3	327	47.7	357	52.0	387	56.4
268	39.1	298	43.5	328	47.8	358	52.2	388	56.6
269	39.2	299	43.6	329	48.0	359	52.3	389	56.7
270	39.4	300	43.7	330	48.1	360	52.5	390	56.9
271	39.5	301	43.9	331	48.3	361	52.6	391	57.0
272	39.7	302	44.0	332	48.4	362	52.8	392	57.1
273	39.8	303	44.2	333	48.5	363	52.9	393	57.3
274	39.9	304	44.3	334	48.7	364	53.1	394	57.4
275	40.1	305	44.5	335	48.8	365	53.2	395	57.6

43° GRAVITY.

242	35.9	272	40.4	302	44.8	332	49.3	362	53.7
243	36.1	273	40.5	303	45.0	333	49.4	363	53.9
244	36.2	274	40.6	304	45.1	334	49.5	364	54.0
245	36.3	275	40.8	305	45.2	335	49.7	365	54.1
246	36.5	276	40.9	306	45.4	336	49.8	366	54.3
247	36.6	277	41.1	307	45.5	337	50.0	367	54.4
248	36.8	278	41.2	308	45.7	338	50.1	368	54.6
249	36.9	279	41.4	309	45.8	339	50.3	369	54.7
250	37.1	280	41.5	310	46.0	340	50.4	370	54.9
251	37.2	281	41.7	311	46.1	341	50.6	371	55.0
252	37.4	282	41.8	312	46.3	342	50.7	372	55.2
253	37.5	283	42.0	313	46.4	343	50.9	373	55.3
254	37.7	284	42.1	314	46.6	344	51.0	374	55.5
255	37.8	285	42.3	315	46.7	345	51.2	375	55.6
256	38.0	286	42.4	316	46.9	346	51.3	376	55.8
257	38.1	287	42.6	317	47.0	347	51.5	377	55.9
258	38.3	288	42.7	318	47.2	348	51.6	378	56.1
259	38.4	289	42.9	319	47.3	349	51.8	379	56.2
260	38.6	290	43.0	320	47.5	350	51.9	380	56.4
261	38.7	291	43.2	321	47.6	351	52.1	381	56.5
262	38.9	292	43.3	322	47.8	352	52.2	382	56.7
263	39.0	293	43.5	323	47.9	353	52.4	383	56.8
264	39.2	294	43.6	324	48.1	354	52.5	384	57.0
265	39.3	295	43.8	325	48.2	355	52.7	385	57.1
266	39.5	296	43.9	326	48.4	356	52.8	386	57.3
267	39.6	297	44.1	327	48.5	357	53.0	387	57.4
268	39.8	298	44.2	328	48.7	358	53.1	388	57.6
269	39.9	299	44.4	329	48.8	359	53.3	389	57.7
270	40.1	300	44.5	330	49.0	360	53.4	390	57.9
271	40.2	301	44.7	331	49.1	361	53.6	391	58.0

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

44° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
240	35.8	270	40.2	300	44.7	330	49.2	360	53.7
241	35.9	271	40.4	301	44.9	331	49.3	361	53.8
242	36.1	272	40.5	302	45.0	332	49.5	362	54.0
243	36.2	273	40.7	303	45.2	333	49.6	363	54.1
244	36.4	274	40.8	304	45.3	334	49.8	364	54.3
245	36.5	275	41.0	305	45.5	335	49.9	365	54.4
246	36.7	276	41.1	306	45.6	336	50.1	366	54.6
247	36.8	277	41.3	307	45.8	337	50.2	367	54.7
248	37.0	278	41.4	308	45.9	338	50.4	368	54.9
249	37.1	279	41.6	309	46.1	339	50.5	369	55.0
250	37.3	280	41.7	310	46.2	340	50.7	370	55.2
251	37.4	281	41.9	311	46.4	341	50.8	371	55.3
252	37.6	282	42.0	312	46.5	342	51.0	372	55.5
253	37.7	283	42.2	313	46.7	343	51.1	373	55.6
254	37.9	284	42.3	314	46.8	344	51.3	374	55.8
255	38.0	285	42.5	315	47.0	345	51.4	375	55.9
256	38.2	286	42.6	316	47.1	346	51.6	376	56.0
257	38.3	287	42.7	317	47.3	347	51.7	377	56.2
258	38.5	288	42.9	318	47.4	348	51.9	378	56.3
259	38.6	289	43.1	319	47.6	349	52.0	379	56.5
260	38.8	290	43.2	320	47.7	350	52.2	380	56.6
261	38.9	291	43.4	321	47.9	351	52.3	381	56.8
262	39.1	292	43.5	322	48.0	352	52.5	382	56.9
263	39.2	293	43.7	323	48.2	353	52.6	383	57.1
264	39.4	294	43.8	324	48.3	354	52.8	384	57.2
265	39.5	295	44.0	325	48.5	355	52.9	385	57.4
266	39.6	296	44.1	326	48.6	356	53.1	386	57.5
267	39.8	297	44.3	327	48.7	357	53.2	387	57.7
268	39.9	298	44.4	328	48.9	358	53.4	388	57.8
269	40.1	299	44.6	329	49.0	359	53.5	389	58.0

45° GRAVITY.

240	36.0	270	40.5	300	45.0	330	49.5	360	54.0
241	36.2	271	40.7	301	45.2	331	49.7	361	54.2
242	36.3	272	40.8	302	45.3	332	49.8	362	54.3
243	36.5	273	41.0	303	45.5	333	50.0	363	54.5
244	36.6	274	41.1	304	45.6	334	50.1	364	54.6
245	36.8	275	41.3	305	45.8	335	50.3	365	54.8
246	36.9	276	41.4	306	45.9	336	50.4	366	54.9
247	37.1	277	41.6	307	46.1	337	50.6	367	55.1
248	37.2	278	41.7	308	46.2	338	50.7	368	55.2
249	37.4	279	41.9	309	46.4	339	50.9	369	55.4
250	37.5	280	42.0	310	46.5	340	51.0	370	55.5
251	37.7	281	42.2	311	46.7	341	51.2	371	55.7
252	37.8	282	42.3	312	46.8	342	51.3	372	55.8
253	38.0	283	42.5	313	47.0	343	51.5	373	56.0
254	38.1	234	42.6	314	47.1	344	51.6	374	56.1
255	38.3	285	42.8	315	47.3	345	51.8	375	56.3
256	38.4	286	42.9	316	47.4	346	51.9	376	56.4
257	38.6	287	43.1	317	47.6	347	52.1	377	56.6
258	38.7	288	43.2	318	47.7	348	52.2	378	56.7
259	38.9	289	43.4	319	47.9	349	52.4	379	56.9
260	39.0	290	43.5	320	48.0	350	52.5	380	57.0
261	39.2	291	43.7	321	48.2	351	52.7	381	57.2
262	39.3	292	43.8	322	48.3	352	52.8	382	57.3
263	39.5	293	44.0	323	48.5	353	53.0	383	57.5
264	39.6	294	44.1	324	48.6	354	53.1	384	57.6
265	39.8	295	44.3	325	48.8	355	53.3	385	57.8
266	39.9	296	44.4	326	48.9	356	53.4	386	57.9
267	40.1	297	44.6	327	49.1	357	53.6	387	58.1
268	40.2	298	44.7	328	49.2	358	63.7	388	58.2
269	40.4	299	44.9	329	49.4	359	53.9	389	58.4

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

46° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
238	35.9	268	40.4	298	45.0	328	49.5	358	54.0
239	36.1	269	40.6	299	45.1	329	49.7	359	54.2
240	36.2	270	40.7	300	45.3	330	49.8	360	54.3
241	36.4	271	40.9	301	45.4	331	50.0	361	54.5
242	36.5	272	41.0	302	45.6	332	50.1	362	54.6
243	36.7	273	41.2	303	45.7	333	50.3	363	54.8
244	36.8	274	41.3	304	45.9	334	50.4	364	54.9
245	37.0	275	41.5	305	46.0	335	50.6	365	55.1
246	37.1	276	41.7	306	46.2	336	50.7	366	55.2
247	37.3	277	41.8	307	46.3	337	50.9	367	55.4
248	37.4	278	42.0	308	46.5	338	51.0	368	55.5
249	37.6	279	42.1	369	46.6	339	51.2	369	55.7
250	37.7	280	42.3	310	46.8	340	51.3	370	55.8
251	37.9	281	42.4	311	46.9	341	51.5	371	56.0
252	38.0	282	42.6	312	47.1	342	51.6	372	56.1
253	38.2	283	42.7	313	47.2	343	51.8	373	56.3
254	38.3	284	42.9	314	47.4	344	51.9	374	56.4
255	38.5	285	43.0	315	47.5	345	52.1	375	56.6
256	38.6	286	43.2	316	47.7	346	52.2	376	56.7
257	38.8	287	43.3	317	47.8	347	52.4	377	56.9
258	38.9	288	43.5	318	48.0	348	52.5	378	57.0
259	39.1	289	43.6	319	48.1	349	52.7	379	57.2
260	39.2	290	43.8	320	48.3	350	52.8	380	57.3
261	39.4	291	43.9	321	48.4	351	53.0	381	57.5
262	39.5	292	44.1	322	48.6	352	53.1	382	57.6
263	39.7	293	44.2	323	48.7	353	53.3	383	57.8
264	39.8	294	44.4	324	48.9	354	53.4	384	57.9
265	40.0	295	44.5	325	49.1	355	53.6	385	58.1
266	40.1	296	44.7	326	49.2	356	53.7	386	58.3
267	40.3	297	44.8	327	49.4	357	53.9	387	58.4

47° GRAVITY.

236	35.8	266	40.4	296	44.9	326	49.5	356	54.0
237	36.0	267	40.5	297	45.1	327	49.6	357	54.1
238	36.1	268	40.7	298	45.2	328	49.8	358	54.3
239	36.3	269	40.8	299	45.4	329	49.9	359	54.5
240	36.4	270	41.0	300	45.5	330	50.1	360	54.6
241	36.6	271	41.1	301	45.7	331	50.2	361	54.8
242	36.7	272	41.3	302	45.8	332	50.4	362	54.9
243	36.9	273	41.4	303	46.0	333	50.5	363	55.1
244	37.0	274	41.6	304	46.1	334	50.7	364	55.2
245	37.2	275	41.7	305	46.3	335	50.8	365	55.4
246	37.3	276	41.9	306	46.4	336	51.0	366	55.6
247	37.5	277	42.0	307	46.6	337	51.1	367	55.7
248	37.6	278	42.2	308	46.7	338	51.3	368	55.8
249	37.8	279	42.4	309	46.9	339	51.5	369	56.0
250	38.0	280	42.5	310	47.1	340	51.6	370	56.2
251	38.1	281	42.7	311	47.2	341	51.8	371	56.3
252	38.3	282	42.8	312	47.4	342	51.9	372	56.5
253	38.4	283	43.0	313	47.5	343	52.1	373	56.6
254	38.6	284	43.1	314	47.7	344	52.2	374	56.8
255	38.7	285	43.3	315	47.8	345	52.4	375	56.9
256	38.9	286	43.4	316	48.0	346	52.5	376	57.1
257	39.0	287	43.6	317	48.1	347	52.7	377	57.2
258	39.2	288	43.7	318	48.3	348	52.8	378	57.4
259	39.3	289	43.9	319	48.4	349	53.0	379	57.5
260	39.5	290	44.0	320	48.6	350	53.1	380	57.7
261	39.6	291	44.2	321	48.7	351	53.3	381	57.8
262	39.8	292	44.3	322	48.9	352	53.4	382	58.0
263	39.9	293	44.5	323	49.0	353	53.5	383	58.1
264	40.1	294	44.6	324	49.2	354	53.7	384	58.3
265	40.2	295	44.8	325	49.3	355	53.9	385	58.4

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

50° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
234	36.1	264	40.8	294	45.4	324	50.0	354	54.6
235	36.3	265	40.9	295	45.5	325	50.2	355	54.8
236	36.4	266	41.1	296	45.7	326	50.3	356	55.0
237	36.6	267	41.2	297	45.8	327	50.5	357	55.1
238	36.7	268	41.4	298	46.0	328	50.6	358	55.3
239	36.9	269	41.5	299	46.2	329	50.8	359	55.4
240	37.0	270	41.7	300	46.3	330	50.9	360	55.6
241	37.2	271	41.8	301	46.5	331	51.1	361	55.7
242	37.4	272	42.0	302	46.6	332	51.2	362	55.9
243	37.5	273	42.1	303	46.8	333	51.4	363	56.0
244	37.7	274	42.3	304	46.9	334	51.6	364	56.2
245	37.8	275	42.4	305	47.1	335	51.7	365	56.3
246	38.0	276	42.6	306	47.2	336	51.9	366	56.5
247	38.1	277	42.8	307	47.4	337	52.0	367	56.6
248	38.3	278	42.9	308	47.5	338	52.2	368	56.8
249	38.4	279	43.1	309	47.7	339	52.3	369	57.0
250	38.6	280	43.2	310	47.8	340	52.5	370	57.1
251	38.7	281	43.4	311	48.0	341	52.6	371	57.3
252	38.9	282	43.5	312	48.2	342	52.8	372	57.4
253	39.1	283	43.7	313	48.3	343	52.9	373	57.6
254	39.2	284	43.8	314	48.5	344	53.1	374	57.7
255	39.4	285	44.0	315	48.6	345	53.2	375	57.9
256	39.5	286	44.2	316	48.8	340	53.4	376	58.0
257	39.7	287	44.3	317	48.9	347	53.6	377	58.2
258	39.8	288	44.5	318	49.1	348	53.7	378	58.3
259	40.0	289	44.6	319	49.2	349	53.9	379	58.5
260	40.1	290	44.8	320	49.4	350	54.0	380	58.7
261	40.3	291	44.9	321	49.5	351	54.2	381	58.8
262	40.4	292	45.1	322	49.7	352	54.3	382	59.0
263	40.6	293	45.2	323	49.9	353	54.5	383	59.1

60° GRAVITY.

220	35.8	250	40.7	280	45.6	310	50.5	340	55.4
221	36.0	251	40.9	281	45.8	311	50.7	341	55.6
222	36.1	252	41.1	282	45.9	312	50.8	342	55.7
223	36.3	253	41.2	283	46.1	313	51.0	343	55.9
224	36.5	254	41.4	284	46.3	314	51.2	344	56.0
225	36.6	255	41.6	285	46.4	315	51.3	345	56.2
226	36.8	256	41.7	286	46.6	316	51.5	346	56.4
227	37.0	257	41.9	287	46.8	317	51.6	347	56.5
228	37.1	258	42.0	288	46.9	318	51.8	348	56.7
229	37.3	259	42.2	289	47.1	319	52.0	349	56.9
230	37.5	260	42.4	290	47.2	320	52.1	350	57.0
231	37.6	261	42.5	291	47.4	321	52.3	351	57.2
232	37.8	262	42.7	292	47.6	322	52.4	352	57.3
233	38.0	263	42.8	293	47.7	323	52.6	353	57.5
234	38.1	264	43.0	294	47.9	324	52.8	354	57.7
235	38.3	265	43.2	295	48.1	325	52.9	355	57.8
236	38.5	266	43.3	296	48.2	326	53.1	356	58.0
237	38.6	267	43.5	297	48.4	327	53.3	357	58.2
238	38.8	268	43.7	298	48.5	328	53.4	358	58.3
239	38.9	269	43.8	299	48.7	329	53.6	359	58.5
240	39.1	270	44.0	300	48.9	330	53.8	360	58.6
241	39.3	271	44.1	301	49.0	331	53.9	361	58.8
242	39.4	272	44.3	302	49.2	332	54.1	362	59.0
243	39.6	273	44.5	303	49.4	333	54.3	363	59.1
244	39.8	274	44.6	304	49.5	334	54.4	364	59.3
245	39.9	275	44.8	305	49.7	335	54.6	365	59.5
246	40.1	276	45.0	306	49.9	336	54.7	366	59.6
247	40.2	277	45.1	307	50.0	337	54.9	367	59.8
248	40.4	278	45.3	308	50.2	338	55.1	368	59.9
249	40.6	279	45.5	309	50.3	339	55.2	369	60.1

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

63° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
217	35.9	247	40.9	277	45.8	307	50.8	337	55.8
218	36.1	248	41.0	278	46.0	308	51.0	338	55.9
219	36.2	249	41.2	279	46.2	309	51.1	339	56.1
220	36.4	250	41.4	280	46.3	310	51.3	340	56.3
221	36.6	251	41.5	281	46.5	311	51.5	341	56.4
222	36.7	252	41.7	282	46.7	312	51.6	342	56.6
223	36.9	253	41.9	283	46.8	313	51.8	343	56.8
224	37.1	254	42.0	284	47.0	314	52.0	344	56.9
225	37.2	255	42.2	285	47.2	315	52.1	345	57.1
226	37.4	256	42.4	286	47.3	316	52.3	346	67.3
227	37.6	257	42.5	287	47.5	317	52.5	347	57.4
228	37.7	258	42.7	288	47.7	318	52.6	348	57.6
229	37.9	259	42.9	289	47.8	319	52.8	349	57.8
230	38.1	260	43.0	290	48.0	320	53.0	350	57.9
231	38.2	261	43.2	291	48.2	321	53.1	351	58.1
232	38.4	262	43.4	292	48.3	322	53.3	352	58.3
233	38.6	263	43.5	293	48.5	323	53.5	353	58.4
234	38.7	264	43.7	294	48.7	324	53.6	354	58.6
235	88.9	265	43.9	295	48.8	325	53.8	355	58.8
236	39.1	266	44.0	296	49.0	326	54.0	356	58.9
237	39.2	267	44.2	297	49.2	327	54.1	357	59.1
238	39.4	268	44.4	298	49.3	328	54.3	358	59.2
239	39.6	269	44.5	299	49.5	329	54.5	359	59.4
240	39.7	270	44.7	300	49.7	330	54.6	360	59.6
241	39.9	271	44.9	301	49.8	331	54.8	361	59.8
242	40.1	272	45.0	302	50.0	332	54.9	362	59.9
243	40.2	273	45.2	303	50.2	333	55.1	363	60.1
244	40.4	274	45.3	304	50.3	334	55.3	364	60.2
245	40.6	275	45.5	305	50.5	335	55.4	365	60.4
246	40.7	276	45.7	306	50.7	336	55.6	366	60.6

65° GRAVITY.

214	35.8	244	40.8	274	45.8	304	50.8	334	55.9
215	36.0	245	41.0	275	46.0	305	51.0	335	56.0
216	36.1	246	41.1	276	46.1	306	51.2	336	56.2
217	36.3	247	41.3	277	46.3	307	51.3	337	56.4
218	36.5	248	41.5	278	46.5	308	51.5	338	56.5
219	36.6	249	41.6	279	46.6	309	51.7	339	56.7
220	36.8	250	41.8	280	46.8	310	51.8	340	56.9
221	37.0	251	42.0	281	47.0	311	52.0	341	57.0
222	37.1	252	42.1	282	47.2	312	52.2	342	57.2
223	37.3	253	42.3	283	47.3	313	52.3	343	57.4
224	37.5	254	42.5	284	47.5	314	52.5	344	57.5
225	37.6	255	42.6	285	47.7	315	52.7	345	57.7
226	37.8	256	42.8	286	47.8	316	52.8	346	57.9
227	38.0	257	43.0	287	48.0	317	53.0	347	58.0
228	38.1	258	43.1	288	48.2	318	53.2	348	58.2
229	38.3	259	43.3	289	48.3	319	53.3	349	58.4
230	38.5	260	43.5	290	48.5	320	53.5	350	58.5
231	38.6	261	43.6	291	48.7	321	53.7	351	58.7
232	38.8	262	43.8	292	48.8	322	53.8	352	58.9
233	39.0	263	44.0	293	49.0	323	54.0	353	59.0
234	39.1	264	44.1	294	49.2	324	54.2	354	59.2
235	39.3	265	44.3	295	49.3	325	54.3	355	59.4
236	39.5	266	44.5	296	49.5	326	54.5	356	59.5
237	39.6	267	44.6	297	49.7	327	54.7	357	59.7
238	39.8	268	44.8	298	49.8	328	54.8	358	59.9
239	40.0	269	45.0	299	50.0	329	55.0	359	60.0
240	40.1	270	45.1	300	50.2	330	55.2	360	60.2
241	40.3	271	45.3	301	50.3	331	55.4	361	60.4
242	40.5	272	45.5	302	50.5	332	55.5	362	00.5
243	40.6	273	45.6	303	50.7	333	55.7	363	60.7

TABLE OF COMPARATIVE WEIGHTS AND MEASURES OF OIL—Continued.

70° GRAVITY.

Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.	Pounds.	Gallons.
210	36.0	240	41.2	270	46.3	300	51.4	330	56.6
211	36.2	241	41.3	271	46.5	301	51.6	331	56.8
212	36.4	242	41.5	272	46.6	302	51.8	332	56.9
213	36.5	243	41.7	273	46.8	303	52.0	333	57.1
214	36.7	244	41.9	274	47.0	304	52.1	334	57.3
215	36.9	245	42.0	275	47.2	305	52.3	335	57.4
216	37.1	246	42.2	276	47.3	306	52.5	336	57.6
217	37.2	247	42.4	277	47.5	307	52.6	337	57.8
218	37.4	248	42.5	278	47.7	308	52.8	338	58.0
219	37.6	249	42.7	279	47.8	309	53.0	339	58.1
220	37.7	250	42.9	280	48.0	310	53.2	340	58.3
221	37.9	251	43.0	281	48.2	311	53.3	341	58.5
222	38.1	252	43.2	282	48.4	312	53.5	342	58.6
223	38.2	253	43.4	283	48.5	313	53.7	343	58.8
224	38.4	254	43.6	284	48.7	314	53.9	344	59.0
225	38.6	255	43.7	285	48.9	315	54.0	345	59.2
226	38.8	256	43.9	286	49.1	316	54.2	346	59.3
227	38.9	257	44.1	287	49.2	317	54.4	347	59.5
228	39.1	258	44.2	288	49.4	318	54.5	348	59.7
229	39.3	259	44.4	289	49.6	319	54.7	349	59.8
230	39.4	260	44.6	290	49.7	320	54.9	350	60.0
231	39.6	261	44.8	291	49.9	321	55.0	351	60.2
232	39.8	262	44.9	292	50.1	322	55.2	352	60.4
233	40.0	263	45.1	293	50.2	323	55.4	353	60.5
234	40.1	264	45.3	294	50.4	324	55.6	354	60.7
235	40.3	265	45.5	295	50.6	325	55.7	355	60.9
236	40.5	266	45.6	296	50.8	326	55.9	356	61.0
237	40.6	267	45.8	297	50.9	327	56.1	357	61.2
238	40.8	268	46.0	298	51.1	328	56.2	358	61.4
239	41.0	269	46.1	299	51.3	329	56.4	359	61.6

85° GRAVITY.

195	36.0	225	41.5	255	47.0	285	52.5	315	58.1
196	36.1	226	41.7	256	47.2	286	52.7	316	58.3
197	36.3	227	41.9	257	47.4	287	52.9	317	58.4
198	36.5	228	42.0	258	47.6	288	53.1	318	58.6
199	36.7	229	42.2	259	47.8	289	53.3	319	58.8
200	36.9	230	42.4	260	47.9	290	53.5	320	59.0
201	37.1	231	42.6	261	48.1	291	53.6	321	59.2
202	37.2	232	42.8	262	48.3	292	53.8	322	59.4
203	37.4	233	43.0	263	48.5	293	54.0	323	59.6
204	37.6	234	43.1	264	48.7	294	54.2	324	59.7
205	37.8	235	43.3	265	48.9	295	54.4	325	59.9
206	38.0	236	43.5	266	49.0	296	54.6	326	60.1
207	38.2	237	43.7	267	49.2	297	54.8	327	60.3
208	38.4	238	43.9	268	49.4	298	54.9	328	60.5
209	38.5	239	44.1	269	49.6	299	55.1	329	60.7
210	38.7	240	44.2	270	49.8	300	55.3	330	60.8
211	38.9	241	44.4	271	60.0	301	55.5	331	61.0
212	39.1	242	44.6	272	50.1	302	55.7	332	61.2
213	39.3	243	44.8	273	50.3	303	55.9	333	61.4
214	39.5	244	45.0	274	50.5	304	56.1	334	61.6
215	39.6	245	45.2	275	50.7	305	56.2	335	61.8
216	39.8	246	45.4	276	50.9	306	56.4	336	62.0
217	40.0	247	45.5	277	51.1	307	56.6	337	62.1
218	40.2	248	45.7	278	51.3	308	56.8	338	62.3
219	40.4	249	45.9	279	51.4	309	57.0	339	62.5
220	40.6	250	46.1	280	51.6	310	67.2	340	62.7
221	40.7	251	46.3	281	51.8	311	57.3	341	62.9
222	40.9	252	46.5	282	52.0	312	57.5	342	63.1
223	41.1	253	46.6	283	52.2	313	57.7	343	63.2
224	41.3	254	46.8	284	52.4	314	57.9	344	63.4

TABLE OF THE SPECIFIC GRAVITY CORRESPONDING TO EACH DEGREE OF BAUMÉ'S HYDROMETER; ALSO, THE NUMBER OF POUNDS CONTAINED IN ONE UNITED STATES GALLON AT 60° F.

Baumé.	Specific gravity.	In one gallon.	Baumé.	Specific gravity.	In one gallon.
Deg.	*Deg.*	*Pounds.*	*Deg.*	*Deg.*	*Pounds.*
10	1.0000	8.33	43	0.8092	6.74
11	0.9929	8.27	44	0.8045	6.70
12	0.9859	8.21	45	0.8000	6.66
13	0.9790	8.16	46	0.7954	6.63
14	0.9722	8.10	47	0.7909	6.59
15	0.9655	8.04	48	0.7865	6.55
16	0.9589	7.99	49	0.7821	6.52
17	0.9523	7.93	50	0.7777	6.48
18	0.9459	7.88	51	0.7734	6.44
19	0.9395	7.83	52	0.7692	6.41
20	0.9333	7.78	53	0.7650	6.37
21	0.9271	7.72	54	0.7608	6.34
22	0.9210	7.67	55	0.7567	6.30
23	0.9150	7.62	56	0.7526	6.27
24	0.9090	7.57	57	0.7486	6.24
25	0.9032	7.53	58	0.7446	6.20
26	0.8974	7.48	59	0.7407	6.17
27	0.8917	7.43	60	0.7368	6.14
28	0.8860	7.38	61	0.7329	6.11
29	0.8805	7.34	62	0.7290	6.07
30	0.8750	7.29	63	0.7253	6.04
31	0.8695	7.24	64	0.7216	6.01
32	0.8641	7.20	65	0.7179	5.98
33	0.8588	7.15	66	0.7142	5.95
34	0.8536	7.11	67	0.7106	5.92
35	0.8484	7.07	68	0.7070	5.89
36	0.8433	7.03	69	0.7035	5.86
37	0.8383	6.98	70	0.7000	5.83
38	0.8333	6.94	75	0.6829	5.69
39	0.8284	6.90	80	0.6666	5.55
40	0.8235	6.86	85	0.6511	5.42
41	0.8187	6.82	90	0.6363	5.30
42	0.8139	6.78	95	0.6222	5.18

MEMORANDA.

One United States gallon of pure water = 231 cubic inches, contains 58,318 grains (or 3779.031 grams) = 8.331 pounds avoirdupois.
One imperial gallon of pure water = 277.276 cubic inches, contains 70,000 grains (or 4536.029 grams) = 10 pounds avoirdupois.
One cubic foot of pure water at 60° F. contains 1,000 ounces = 62.5 pounds avoirdupois.
To reduce imperial gallons to United States gallons, divide by 1.2.
To reduce United States gallons to imperial gallons, multiply by 1.2.
To reduce United States gallons to cubic feet, divide by 7.5.
To reduce cubic feet to United States gallons, multiply by 7.5.
To find the number of pounds avoirdupois in one cubic foot of any substance, multiply its specific gravity by 62.5.
To find the degree Baumé corresponding to any specific gravity:

$$\frac{140}{\text{sp. gr.}} - 130 = \text{B.}^\circ$$

To find the specific gravity corresponding to any degree Baumé:

$$\frac{140}{130 + \text{B.}^\circ} = \text{sp. gr.}$$

CHAPTER X.—PRODUCTION OF PETROLEUM IN THE UNITED STATES DURING THE CENSUS YEAR.

SECTION I.—THE CONDITIONS OF THE PROBLEM.

The localities which furnished the petroleum which entered the commerce of the United States during the census year were the region in northwestern Pennsylvania north and east of Pittsburgh; Mecca, in Trumbull county, Grafton, in Lorain county, and Washington county, Ohio; Pleasants, Wood, and Ritchie counties, West Virginia; Greene county, in southwestern Pennsylvania, and Glasgow, in Barren county, Kentucky.

The actual production of petroleum in the United States cannot be accurately given for any period of time; but an approximate estimate has been made up from all available sources of information, which is believed to be as nearly correct as can be made. The reports of the pipe-lines are believed to be correct; but they do not necessarily represent the production of oil. The statistics of production are usually made up of the total amount of oil run into the pipe-lines, an estimated amount handled by private lines and tank-cars, and "dump oil" handled in barrels, to be modified by adding or subtracting the amount of oil added to or subtracted from the stock in private and well tanks during the year.

The receipts of the incorporated pipe-lines have been reported in accordance with the requirements of a law of the state of Pennsylvania, and are easily accessible. I have received estimates of the oil handled by private lines and "dump oil", verified in some instances from independent sources, and, on the whole, I believe from well-informed and reliable parties.

The estimation of the amount of oil held in tanks at wells is at all times a problem of great difficulty. This difficulty is due to the fact that the business of producing oil is conducted in such a manner that the owners of the wells themselves do not know how much oil is in their tanks; and further, that they do not, in the aggregate, care to have the production of their wells known. Again, if the owners were anxious to have a census of the oil in tanks taken, it would have to be done simultaneously, as the amount in the tanks is constantly changing; and such concerted action as would be necessary would be beset with practical difficulties if it were unanimously agreed upon. Mr. J. C. Welch is in constant communication with a number of those producers who conduct their business in the most systematic manner, and really know from actual measurement how much oil runs into their tanks from day to day. From this exact information, and much other scarcely less reliable in its character, he makes up his daily and monthly reports, which are much the most reliable of any furnished in reference to this subject. I shall therefore quote from his reports in reference to this matter. In his report for August, 1879, he writes:

There is no accumulation of stocks at wells anywhere except in the Bradford district. In the Bradford district, as is well known, the stocks at wells are very large, generally and probably rightly estimated in the vicinity of 1,500,000 barrels. By my table, given above, of comparative stocks at wells of the same owners July 1 and August 1, I find on the Bradford stocks my returns show an increase of a little over 3 per cent. Taking this increase on, say, 1,400,000 barrels, and it would make about 45,000 barrels of July production as having gone into stocks at wells. This would be about 1,500 barrels per day, and, added to July Bradford pipe-runs, would make my estimate of the production of that district saved in July a daily average of 39,556 barrels. In districts other than Bradford I think the pipe-runs of July substantially represent the production. In the light of these facts, and bringing forward my estimate of June, I estimate the production out of the ground, with the exception of what was lost in the Bradford district in July (of which no intelligent estimate can be made), as follows:

	July.	June.
	Barrels.	*Barrels.*
Butler & Armstrong	6,569	7,000
Clarion	5,034	5,100
Bullion	1,086	1,100
O. C. & A. R	3,679	3,900
Bradford	39,556	41,600
	55,924	58,700

In his September report he says:

My returns of the stocks at wells of the same owners in the Bradford district August 1 and September 1 show great uniformity.

In his October report he writes:

The Bradford stocks at wells October 1, compared with September 1, show a decline of 7 per cent. Taking this percentage from the presumed stocks at wells in the Bradford district September 1, 1,500,000 barrels, and it makes a decrease in September of 105,000, or 3,500 barrels a day going into pipe-runs.

In November his returns from the owners of the wells showed a gain of over 5 per cent., giving 1,470,000 barrels as the stock November 1. Owing to the loss during that month, the reported stocks December 1 were 1,395,000 barrels, the same as on October 1. Referring to his reports from well owners for December, in that for January, 1880, he says:

This shows a decline in the Bradford stocks I received of 17 per cent., and substantially no change in the stocks in Butler and Clarion. Assuming a stock at the Bradford wells, December 1, of 1,400,000 barrels, which in the general estimate is not far from being right, a decline of 17 per cent. would reduce them during December 238,000 barrels.

In his February report he says:

The decline in the Bradford district on the above stocks in January was 6 per cent., against a decline in December of the stocks I received of 17 per cent.

His returns show a gain in February of 7 per cent., in March of 13 per cent., and in April of 14½ per cent. In his May report he states:

I have returns of 121,993 barrels of oil at 882 wells, May 1, making an average per well of 138 barrels. Taking the Bradford wells, May 1, at 6,600, it would make a total stock at those wells, May 1, of 910,800. * * * Drilling wells finished in May have been very considerable in number, and will show a high average of production, as the new territory now being operated upon between Bordell City and the Gray and Van Vleck wells has proved exceptionally rich.

In his report for June, which brings up his statistics to June 1, 1880, and closes the census year, he says:

I have received returns of 988 Bradford wells, June 1, with stocks at them, exclusive of wells that had their well stocks burned in May. These 988 wells had stocks, June 1, of 167,694 barrels, an average of 171 barrels. Taking 7,000 wells as the number in the Bradford district, June 1, and with this average the total Bradford well stocks, June 1, were 1,197,000. The large amount of oil lost in the Bradford district makes estimates on the production there an uncertain thing. The amount lost now is estimated as high as 10,000 and 12,000 barrels daily.

Mr. Welch estimated the average number of barrels per well for April as 138, and for May as 171; an increase in average well stocks during May of nearly 24 per cent. per well, and in total well stocks of over 31 per cent. In his report for August, 1880, he says:

I have received returns from 1,443 Bradford wells, August 1, showing stock at them of 270,821 barrels. The average per well is 187.6. Of these 1,443 wells, 1,078 belong to companies that have 30 wells or more, with an average per well of 187¼ barrels; the other 365 wells, from companies owning less than 30 wells, show an average per well of 188½ barrels. This, I think, shows clearly that my average of 187.6 for the entire number of wells is not vitiated on account of the returns being mostly from the larger companies.

I think this statement is good evidence of the general accuracy of Mr. Welch's conclusions, as the 1,443 wells were about one-fifth of the whole number at that time in the Bradford district.

In an editorial article, August 1, 1879, the Oil City *Derrick* remarks:

There is a large extent of territory in the Bradford field, but it has now 4,700 producing well.

In an article the following day the same paper remarks:

The *Derrick* is generally able to back up its assertions with figures, and we have prepared a table of all wells completed in the Bradford region since drilling began in 1875, with their production each month. These figures have been carefully compiled from the monthly oil reports, and are as accurate as can possibly be obtained without visiting personally every well in the region. We believe the table below does not vary from the actual producing wells 100.

I have completed this table from the files of the *Derrick* to September 1, 1880, and have added a column showing the average initial daily production per well for the productive wells drilled each month.

TABLE SHOWING THE NUMBER OF PRODUCTIVE WELLS DRILLED EACH MONTH, AND THEIR AVERAGE INITIAL DAILY PRODUCTION FOR EACH MONTH, FROM JULY 1, 1875, TO SEPTEMBER 1, 1880, IN THE BRADFORD DISTRICT.

Month.	Productive wells drilled.	Initial daily production.	Average.
1875.	*Number.*	*Barrels.*	*Barrels.*
July	6	174	29.00
August	2	50	25.00
September	3	94	31.33
October	8	160	20.00
November	3	44	14.67
December	1	25	25.00
Total	23	547	23.78
1876.			
January	11	155	14.09
February	11	252	22.91
March	14	508	36.29
April	17	286	16.82
May	25	392	15.68
June	34	544	16.00
July	31	507	16.35
August	45	652	14.49
September	29	412	14.21
October	52	550	10.58
November	46	450	9.78
December	42	390	9.29
Total	357	5,098	14.28
1877.			
January	53	490	9.24
February	37	349	9.43
March	61	631	10.34
April	42	510	12.14
May	54	514	9.52
June	52	515	9.90
July	33	516	15.64
August	48	506	10.54
September	84	1,158	13.79
October	153	2,091	13.66
November	114	1,368	12.00
December	143	2,502	17.50
Total	874	11,150	12.76

Month.	Productive wells drilled.	Initial daily production.	Average.
1878.	*Number.*	*Barrels.*	*Barrels.*
January	105	1,537	14.64
February	96	1,508	15.71
March	110	1,758	15.98
April	220	3,597	16.35
May	346	5,650	16.30
June	205	3,264	15.92
July	151	2,437	16.14
August	142	2,632	18.54
September	122	1,938	15.89
October	186	2,572	13.83
November	211	2,724	12.91
December	127	2,575	20.28
Total	2,021	32,192	15.93
1879.			
January	110	2,017	18.33
February	107	2,525	23.60
March	202	4,705	23.29
April	233	5,805	24.91
May	355	8,559	24.11
June	308	7,902	25.66
July	269	7,291	27.10
August	206	5,939	28.83
September	160	4,639	28.99
October	167	4,837	28.96
November	148	4,065	27.47
December	188	5,657	30.09
Total	2,453	63,941	26.07
1880.			
January	216	5,999	27.77
February	256	7,542	29.46
March	335	8,185	24.43
April	418	10,531	25.19
May	409	11,554	28.25
June	302	8,959	29.67
July	311	7,839	25.21
August	325	8,587	26.42
Total eight months	2,572	69,196	26.90
Total census year	3,080	84,141	27.32

GENERAL SUMMARY.

Years.	Productive wells drilled.	Initial daily production.	Average per well.
	Number.	*Barrels.*	*Barrels.*
1875, six months	23	547	23.78
1876, twelve months	357	5,098	14.28
1877, twelve months	874	11,150	12.76
1878, twelve months	2,021	32,192	15.93
1879, twelve months	2,453	63,941	26.07
1880, eight months	2,572	69,196	26.90
Total	8,300	182.124	21.94
At beginning of the census year	4,282	72,598	16.95
At end of the census year	7,362	156,739	21.29

An examination of this table shows that the 357 wells drilled in 1876 started off with a production of an average of only 11.48 barrels per day. At that time the Butler-Clarion district was at the height of its prosperity, with an occasional well of great value, leaving but little inducement for labor in the northern field. The 874 wells drilled the following year averaged a little better, but only 12.76 barrels per day. The 2,021 new wells of 1878 started off at a daily average of 15.93 barrels. In 1879 only 432 more wells were drilled, but their average initial daily production was 26.07 barrels, an increase of 63 per cent. The 4,282 wells that had been drilled in the four years preceding the beginning of the census year started off with a production of 72,598 barrels; the 3,080 wells drilled during the census year started off with a production of 84,141 barrels. Allowing the production of all the wells drilled previous to the census year to have been, June 1, 1879, 50 per cent. of their original flow, which is perhaps allowable when we consider that more than half were not twelve months' old, the production must have been increased during the census year 232 per cent. It is true that during this and the previous year the production of other fields had been declining, but the increased production in the Bradford district was beyond all precedent, and was due, first, to an increased number of wells, and, second, to a greatly increased average initial daily production, that average having risen from 19.41 barrels during the twelve months preceding the census year to 27.32 barrels during that year, an increase of 41.78 per cent.

Commenting on the monthly report of "oil operations" for May, 1879, the Oil City *Derrick*, in its issue of May 31, 1879, the day before the beginning of the census year, says:

As regards production and consumption, the supply and demand, we cannot discover anything in common between this and preceding years. Not one element of the outlook at the present time has a true counterpart in any preceding period. In 1874, when the market declined to about 40 cents, the outlook was bright as compared with the present. The daily production at that time was between 25,000 and 30,000 barrels. It is now not less than 50,000 or 52,000 barrels. The stock held in the oil regions then did not exceed 3,000,000 barrels. It is now not less than 7,000,000 barrels, and constantly augmenting. The decline at that time was attributable to the increased production caused by the striking of the large fourth-sand wells on the Butler county cross-belt. The territory where those wells were found was limited to a small area, and the gushers declined rapidly. Now the territory known to be prolific is almost boundless. * * * Developments in the Cole Creek district are being pushed with a persistence that bodes no good for the future price of the product. The producers are paying extravagant prices for the privilege of drilling.

On this day oil opened and closed at 73¾ cents per barrel.

June 28 the *Derrick's* special report on the petroleum market says:

We are informed by parties who know what they are talking about that the stock at the wells in the Bradford district at the present time is not less than 1,000,000 barrels.

August 29 the report for that date says:

The condition of tankage in the northern region has not improved, notwithstanding the enormous shipments during this month being full and running over. The matter is further complicated by the necessity the lines are under of emptying two 25,000-barrel tanks, which have sprung a leak. The status of the wells may be judged of from the fact that the first fifteen days of this month 60,000 barrels of wooden tankage was erected in the Bradford region, all of which is presumably full.

September 1 petroleum opened at Oil City at 65⅝ cents. The editor of the *Derrick* congratulated the trade that the monthly report for August showed fewer wells finished and but little addition to the daily production, and indulged the hope of improved prices. The report of petroleum markets for that date says:

If the well reports should show a decline, men will anxiously jump in and buy, to find ultimately that there is a sufficiency of petroleum to spare for all. *There only needs an advance of a few cents to set the walking-beam wagging and producers by the ears again, scrambling after more territory.*

The sagacity of this remark is exemplified in a remarkable manner in the history of the few months following. In the issue of September 12 the *Derrick* again warns its patrons of the dire effects of overproduction, and implores them to stop drilling, giving figures to show that the production was continually on the increase and stocks accumulating. Again, on the 20th, this paper refers to the quarrel then going on between the owners of tanks and the pipe-lines, and says:

It is easy to trace back all these troubles to overproduction. The owners of large tanks soon fill the capacity, and then seek means to have it emptied that it can be again filled from their flowing wells. Even if they put up new tanks, it is but a short time before they are filled. We hear reports of 25,000-barrel tanks being built in many of the districts; yet how slight is all this new capacity when 2,000,000 barrels and over are backed up at the wells. Still the production goes on increasing. Our specials every morning give a long list of new wells. Consider the millions of stock on hand; the markets abroad nearly glutted with refined; storage capacity in the East nearly or quite filled; every well of the thousands in the Bradford district flowing daily into tanks already full or overflowing; pumping-wells forced to shut down or pump on the ground; then look at the new rigs going up and new wells daily coming in; the market hanging dead and lifeless at a ruinous figure; and ask yourself what must be the result of all this? Every week the production is greater than the week before; there is no use denying these facts, nor shirking the results they will bring.

Again, on the 23d, the editor remarks:

The runs on Saturday (20th) and Sunday (21st) were the largest ever known in the history of the trade. They amounted to over 132,000 barrels.

In the face of this enormous production the price of oil advanced, and on the 30th of September closed at 79$\frac{3}{8}$ cents. The next day, in consequence of the decrease of rigs and completed wells in the Bradford district, it advanced to 82$\frac{1}{2}$ cents. The development of oil territory continued to decrease until December, and the price advanced, with occasional fluctuations, until on December 3 it touched 128$\frac{1}{2}$. The result of this movement was a general advance along the entire line of production and a gradual reduction of prices, culminating in the spring of 1880 in such an outflow of oil as rendered all attempts to transport it futile. The pipe-lines were taxed beyond their capacity; storage tanks and well tanks were all full, and the oil flowed out upon the ground; but the drilling went on, and the average production kept pace with the unparalleled number of wells.

The following statement gives the number of wells finished, the average number of barrels per day, and the average price of oil during the census year, divided into quarters:

	Number of wells.	Average number of barrels per day.	Average price per barrel.
First quarter	783	26.99	$0 70
Second quarter	475	28.51	85
Third quarter	660	29.09	1 10
Fourth quarter	1,162	26.05	83

The advance in price beyond $1 in December stimulated production to an extent hitherto unparalleled, and produced, near the close of the year, a reaction in prices that touched 72$\frac{1}{2}$ cents on the 5th of May. Thus the year opened and closed with oil at nearly the same price.

As indicated in the foregoing pages, an estimate of the amount of third-sand oil produced during the census year embraces the following items:

1. Pipe-line runs.
2. Fluctuations in well stocks.
3. Oil wasted.
4. Oil burned in tanks outside of pipe-lines.
5. Oil marketed outside the pipe-lines, otherwise known as "dump oil".

SECTION 2.—WELL STOCKS.

Mr. Welch's monthly reports of the percentage of gain or loss in well stocks in the Bradford district, and his estimates of the actual stocks per well on May 1 and June 1, 1880, being based upon a sufficient number of reliable returns of individual wells, and carefully made, I think may be taken as substantially correct. They afford the means of revising his estimates of the gross Bradford well stocks for the earlier months of the census year, which' like most published estimates for that period, are excessive. Taking his estimate of the average Bradford stocks on May 1, 1880, 138 barrels per well, and the total number of productive wells which had then been drilled, 6,953, we derive 959,514 barrels as the total Bradford well stocks at that date. In the same manner, applying his average per well on June 1, 1880, 171 barrels, to the total number of productive wells that had been drilled at that date, 7,362, we reach 1,258,902 barrels as the Bradford well stocks at the close of the census year. It is true that some of these wells were doing little or nothing, but the 988 wells upon which the average of 171 barrels per well were based included all classes of wells, and I regard the average as substantially correct.

The monthly fluctuations from July 1, 1879, to May 1, 1880, were reported by Mr. Welch as follows: In July a gain of 3 per cent.; in August no change; in September a loss of 7 per cent.; in October a gain of 5$\frac{3}{8}$ per cent.; in November a loss equal to the gain in October, so that stocks stood December 1 precisely as they stood October 1; in December a loss of 17 per cent.; in January a loss of 6 per cent.; in February a gain of 7 per cent.; in March a gain of 13 per cent.; in April a gain of 14$\frac{1}{2}$ per cent.

This is a net increase for the ten months from July 1, 1879, to May 1, 1880, of 3$\frac{465}{1000}$ per cent. But the stocks at the later date, as we have found, were 959,514; consequently the stocks July 1, 1879, were 927,379, instead of

1,400,000, which Mr. Welch gave as the general estimate of the actual well stocks at that date, and which he himself adopted. Accepting, therefore, Mr. Welch's rates of the monthly fluctuations, and his conclusions as to the stocks of May and June, 1880, as correct, and taking the increase for June, 1879, as $14\frac{1}{5}$ per cent., which is my judgment of the change for that month, we derive the following tabular statement of the Bradford well stocks for each month of the census year:

Month.	Whole number of productive wells drilled prior to the 1st of each month.	Total stocks at wells on the 1st of each month.	Number of barrels per well.	Percentage of increase or decrease of well stocks during each month.		Month.	Whole number of productive wells drilled prior to the 1st of each month.	Total stocks at wells on the 1st of each month.	Number of barrels per well.	Percentage of increase or decrease of well stocks during each month.	
				Increase.	Decrease.					Increase.	Decrease.
1879.		*Barrels.*		*Per cent.*	*Per cent.*	1880.		*Barrels.*		*Per cent.*	*Per cent.*
June	4,282	812,067	189.65	$14\frac{1}{5}$	....	January	5,728	737,319	128.72	....	6
July	4,590	927,379	202.04	3	....	February	5,944	693,080	116.60	7	....
August	4,859	955,200	196.58	....	....	March	6,200	741,596	119.61	13	....
September	5,065	955,200	188.59	....	7	April	6,535	838,003	128.23	$14\frac{1}{2}$	....
October	5,225	888,336	170.02	$5\frac{3}{8}$	....	May	6,953	959,514	138.00	$31\frac{1}{5}$	....
November	5,392	936,084	173.61	....	$5\frac{1}{10}$	June	7,362	1,258,902	171.00	....	....
December	5,540	888,336	160.35	....	17						

An inspection of this table will show that the well stocks at the close of the year were 446,835 barrels more than at the beginning.

Section 3.—OIL THAT WAS WASTED AND BURNED.

Of the oil that ran to waste no estimate approaching accuracy can be made. Mr. Welch says, in his report for August, 1879:

It is well known a large amount of oil went to waste in July on account of inability to take care of it. Early in the month there may have been 5,000 or 6,000 barrels per day lost in this way, and considerable loss continued most of the time during the month.

In his report for September he says:

I may say that there was scarcely any oil lost in the district in August, while in July there was a large amount, and this month there is some being lost, although probably no great amount.

In his report for June, 1880, he says:

The large amount of oil being lost in the Bradford district makes estimates on the production there an uncertain thing. The amount lost now is being estimated as high as 10,000 and 12,000 barrels daily.

On comparing these statements with the table given above, it will be seen that the losses that were reported from the unavoidable waste of oil in July, August, and September, 1879, and in May, 1880, corresponded in the first three months with those periods when the average stocks at wells were nearly 200 barrels each, and in the last instance with a sudden increase of those stocks by 31 per cent., which raised that average in one month from 138 to 171 barrels per well.

Returns from four large corporations owning 296 wells distributed in the Bradford district give a total loss from oil wasted of 13,620 barrels, an average of 46 barrels per well. These losses occurred in July, August, and September, 1879, and in May, 1880. There were nearly 5,000 wells in August, 1879, and nearly 7,000 in May, 1880. Assuming that this loss of 46 barrels per well occurred upon 6,000 wells, a total loss occurred of 276,000 barrels. I have placed this loss at 275,000 barrels, and believe this a conservative estimate, for the reason that this average is based on returns made by gentlemen who took great care to make them correct, and also because this loss occurred on the property of corporations using ample capital, with every means at their disposal to take care of their oil, if it were possible. The estimate made is under rather than over the amount actually lost.

On the 6th, 9th, and 12th of May, 1880, three very destructive fires occurred in the Bradford district. The report of operations in the issue of the Oil City *Derrick* for June 1 of that year says:

In addition to the numerous isolated rigs burned in various parts of the field previous to and since May 6, the conflagration on that day, which destroyed Rew City, also burned 54 rigs at that point, and fires in other points in the field on that day destroyed 101 rig along Foster Brook, 19 in Tram Hollow, 6 in Tuna valley, and 2 on the East branch, making a total loss on that day of 182 rigs, beside a large amount of tankage and a considerable amount of oil. But three days intervened between the fires of the 6th and the disastrous conflagration which destroyed the village of Rixford, together with 54 rigs, 3 iron tanks, and about 75,000 barrels of oil. After another interval of three days the last and greatest of the series of fires swept through Tram Hollow, totally destroying the hamlets of Otto City, Middaughville, and Oil Center, and burning 300 rigs, a 25,000-barrel tank, and a large number of smaller tanks, with nearly 100,000 barrels of oil.

This gives a total of 536 rigs destroyed in these three fires, which, together with the isolated rigs burned during the month, have led to an estimated total of 600 rigs lost by fire in May, 1880. A fair estimate of stocks at these wells would be 150 barrels per well, amounting in the aggregate to 90,000 barrels of oil burned. The

25,000-barrel tank belonged to the United Lines. Deducting this 115,000 barrels from the 175,000, there remains 60,000 barrels of oil in small tanks burned. An editorial in the *Derrick* for May 13 concerning these fires remarks:

The oil region has never suffered so severely from fire within so short a time as the last week. Beginning with the conflagration which swept away Rew City last Thursday, the flames have crept over Rixford, portions of Summit, Red Rock, Foster Brook, and Four Mile, and are now raging in the vicinity of Duke Center. The disasters caused by these fires are the natural result of peculiar circumstances. For several weeks only a limited quantity of rain has fallen, and the ground is dry and parched, while in the woods which stretch in an unbroken line from one end of the Bradford field to the other the leaves and dried branches are like tinder. Scattered through this forest stand the rigs of the oil-wells, the ground about them saturated with oil and the boilers throwing up sparks day and night. Railroads also traverse some sections of it, and every one who has seen the burned patches of grass or wood each summer by the side of the track know how prolific a source of fire the locomotive is. Add to all these favorable materials for incipient conflagrations a high wind blowing almost a gale, as it has most of the time this spring, and the producers may feel that they have been lucky in escaping so well heretofore. Beside, the operator is careless, and sets his rigs and tanks in the midst of the forest, without clearing up the brush or leaves, or making any effort to escape the consequences if a fire breaks out in his vicinity. The lower oil country escaped such widespread disaster because the land was cleared of its forest. In Butler and Clarion counties more oil was produced in cultivated fields than in woods, while in Bradford there is more wood than cleared land; hence the chances of fire are greatly increased.

In the lower country there was no accumulation of stocks at wells; none wasted nor burned. The pipe-line runs therefore represent the production of that region.

I therefore estimate the production of third-sand oil out of the ground during the census year as in section 4.

SECTION 4.—ESTIMATE OF THE PRODUCTION OF THIRD-SAND OIL DURING THE CENSUS YEAR.

	Barrels.
1. Pipe-line receipts	22,628,286
2. Gain in well stocks	*a* 446,855
3. Oil run to waste	275,000
4. Oil burned outside of well stocks and pipe-lines	60,000
5. "Dump oil" and oil run in private lines	578,670
Total	23,988,791

This oil was produced in—

	Barrels.
Northwestern Pennsylvania	23,835,982
Greene county, Pennsylvania	3,118
West Virginia and Washington county, Ohio	138,325
Glasgow, Kentucky	5,376
Total	23,988,791

The second-sand oil is produced near Franklin, Pennsylvania, and embraces also the B, C, D, and E grades of West Virginia oils. Of this oil there was produced in—

	Barrels.
West Virginia	68,392.88
Near Franklin, Pennsylvania	105,600.00
Grafton, Ohio	2,773.00
Total	176,765.88

Four-fifths of the first-sand oil comes from the first oil-sand of the Venango group near Franklin, Pennsylvania. The oils of this class were produced in—

	Barrels.
Franklin, Pennsylvania	86,857.00
West Virginia	12,536.00
Grafton, Ohio	1,386.00
Mecca, Ohio	900.00
Erie, Pennsylvania	25.00
Total	101,704.00

The specific gravity of this class of oils is 29.5° B. and lower. A few barrels of oil of this grade were produced on the Cumberland river, in Kentucky, but the actual figures could not be obtained. Probably the amount did not exceed 50 barrels.

The production at Smith's Ferry and Slippery Rock creek, Beaver county, Pennsylvania, has been placed by competent persons at 86,803 barrels. The following is a summary of these amounts:

	Barrels.
First-sand oil	101,704
Second-sand oil	176,766
Third-sand oil	23,988,791
Beaver county, Pennsylvania	86,803
Total	24,354,064

a By an inadvertence Professor Peckham, in preparing an abstract of this report for the Compendium, placed the gains in the Bradford well stocks at 327,852 barrels, instead of 446,855 barrels. In consequence, all the numbers into which these stocks enter were understated by 118,983 barrels.

The following is a summary of the total production of the different localities:

	Barrels.
Northwestern Pennsylvania	24,034,429
West Virginia and Washington county, Ohio	219,254
Beaver county, Pennsylvania	86,803
Glasgow, Kentucky	5,376
Grafton, Lorain county, Ohio	4,159
Greene county, Pennsylvania	3,118
Mecca, Trumbull county, Ohio	900
Erie, Pennsylvania	25
Total	24.354,064

I have been unable to visit California recently, and have not received any returns from that locality. A few thousands of barrels were produced there during the census year. A spring in Crook county, Wyoming, yielded 26 barrels of heavy lubricating oil, and others at the petroleum locality at Beaver Creek yielded 428 barrels. This production, while locally valuable, selling in some instances for $1 50 per gallon, is of little importance when considered in relation to the production of the entire country.

SECTION 5.—THE ACCUMULATION OF STOCKS.

It is evident from the preceding pages that for some time antecedent to and during the census year the production of petroleum, and especially of third-sand oil, had been in excess of any demand for it, and consequently there had been a gradual accumulation of stocks in excess of the amount required in handling the oil. This process of accumulation did not take place proportionally in all the districts producing petroleum, but took place mainly in the Bradford district of northwestern Pennsylvania.

In the Grafton and Mecca districts, Ohio, and at the Glasgow, Kentucky, district the stock of oil in tanks at wells would not probably exceed 150 barrels. The amount remained about constant during the year, as it represents only the stock necessary to the handling of the oil. The constant demand for the entire production of the Smith's Ferry district, including Slippery Rock creek, prevents any accumulation of stocks, and in consequence the well stocks are always low. These stocks, together with that in the hands of the Smith's Ferry Transportation Company, have been estimated by competent persons at 3,200 barrels on June 1, 1879. On the 31st of May, 1880, the same stocks were estimated at 3,000 barrels. In West Virginia and Washington county, Ohio, the well and tank stocks, together with the stocks held by the West Virginia Transportation Company on June 1, 1879, were 79,606 barrels, and the corresponding stocks on the 31st of May, 1880, were estimated at 50,848 barrels. In Greene county, Pennsylvania, the stocks were practically nothing.

In the heavy oil district near Franklin, Pennsylvania, there was an accumulation of this quality of oil, the stock at the beginning of the census year, allowing an estimated well stock of 3,000 barrels, being 19,898 barrels, and at the end 27,106 barrels.

In northwestern Pennsylvania, exclusive of the Franklin district, the net stocks in the custody of the pipe-lines June 1, 1879, and May 31, 1880, are represented in the following table:

	June 1, 1879.	May 31, 1880.
United Pipe Lines	$5.864,850	$9,851,885
Tide-Water Pipe Company	378,312	1,009,063
Tidioute and Titusville	189,767	270,718
Pennsylvania Transportation Company	9,855	3,271
Church run	1,751	
Octave	11,642	14,558
Cherry Tree	4,602	
Tidioute and Warren	11,198	15,129
Fox Farm	29,954	19,631
Charley and Shaeffer run	23,211	26,024
Emlenton	13,215	15,022
Total	6,538,357	11,225,301

To this must be added, for stocks outside the pipe-lines in the old territory above and below Oil City, as estimated by Mr. J. C. Welch, the following:

	Barrels.
June 1, 1879	293,474
May 31, 1880	382,318
Stock in iron tankage unattached to pipe-lines not otherwise given	150,000
	532,318

Mr. Welch's returns give an average of well stocks in the region outside the Bradford district of 32 barrels per well, an amount that remained practically constant throughout the year. The number of wells in this so-called "lower country" to which this average would apply is much more difficult to estimate than that of the Bradford district. During the year previous to the beginning of the census year the decline of production in the Butler and Clarion districts had been rapid, and producers had been turning their attention to the Bradford district. As the census year advanced, the decreased production of the lower country became more pronounced, and the transfer of property to the Bradford district became almost equal to an hegira. Train after train of cars, loaded with all kinds of material used about an oil-well, even to old derricks in a few instances, went up the Allegheny Valley and Oil Creek roads to Bradford. No careful record of the wells drilled in the lower country was ever kept, hence the number producing at the beginning of the census year can never be known, nor can the number be known that ceased to produce and were pulled out during that year. Different estimates place the number pulled out at equal to double or treble the number drilled, but such divergent estimates show the worthlessness of all of them. Mr. Stowell puts the number of wells in the different districts of Pennsylvania, outside of Franklin, Bradford, and Beaver, at 6,693, but upon what basis this estimate rests I do not know. The following table from Stowell's *Petroleum Reporter* will give some idea of the value of this estimate as compared with the well-known changes taking place in the localities named:

NUMBER OF WELLS IN THE PENNSYLVANIA OIL-FIELDS, BY DISTRICTS, ON THE DATES GIVEN.

Name of district.	1879.									1880.					
	Jan. 31.	May 31.	June 30.	July 31.	Aug. 31.	Sept. 30.	Oct. 31.	Nov. 30.	Dec. 31.	Jan. 31.	Feb. 28.	Mar. 31.	Apr. 30.	May 31.	Dec. 31.
Butler, Parker, Clarion	4,560	4,350	4,300	4,260	4,200	4,200	4,200	4,175	4,075	4,000	4,000	4,000	4,050	4,050	3,713
Scrubgrass	270	270	270	260	260	270	270	270	270	272	272	272	272	272	272
Reno	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Oil City	360	355	355	350	350	350	350	350	350	350	350	345	345	345	345
Rouseville	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Rynd Farm	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Columbia	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Petroleum Centre	45	43	43	43	40	40	40	40	40	40	40	40	40	40	40
Shamburg	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
Titusville	750	700	680	680	660	650	650	650	650	635	635	635	635	635	625
Pithole	75	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Fagundus	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Tidioute	115	115	115	115	115	115	115	115	115	115	115	115	115	115	115
Warren	100	100	100	100	100	100	100	100	100	100	100	105	105	105	130
Total	6,965	6,693	6,623	6,568	6,485	6,485	6,485	6,460	6,360	6,272	6,272	6,272	6,322	6,322	6,000
Losses	....	287	70	55	83	....	....	25	....	88	....	....	....	....	320
Gains	....	....	....	....	....	....	....	....	....	....	....	....	50	....	....
Wells completed	....	110	26	23	45	16	45	59	73	56	33	38	34	32	211
Total losses	....	397	96	78	128	16	45	84	73	144	33	38	....	32	531
Total gains	....	....	....	....	....	....	....	....	....	....	....	....	84	....	....
Franklin	357	352	350	350	350	350	350	350	350	350	350	350	350	350	350
Wells completed	....	27	4	5	15	8	5	3	4	2	2	2	2	2	13
Losses	....	32	4	5	15	8	5	3	4	2	2	2	2	2	13

These figures show a total loss in the districts producing third-sand oil, due to wells abandoned, of 851 wells during the whole census year. The number of producing wells at the beginning of the census year was 6,693. During the year 480 wells were completed, which, added to the number producing at the beginning of the year, equals 7,173 wells. The number reported producing at the end of the year was 6,322; difference, 851. These wells were in most cases plugged with pine plugs or filled with sand.

I use these figures, not because I believe them to be correct, but because they are the only approximation to the truth now available; they vary in their subdivisions from any others published, and are not fully consistent with themselves. The *Petroleum World* gives the names of the parties who completed wells in the lower country as follows:

	Wells.	Production.	Dry.
	Number.	*Barrels.*	*Number.*
In Clarion county	61	564	16
In Butler and Armstrong counties	51	335	19
In Venango, Forest, and Warren counties	44	244	10
In Jefferson county	1	0	1
Near Byrom Center	171	2,089	30
Near Emlenton	7	27	3
Total	335	3,259	79

In the Franklin district, January 31, 1879, there were reported by Mr. Stowell 357 wells, which were reduced to 352 on May 31, 1879, the day before the census year commenced, and to 350 by June 30, continuing at that number until December 31, 1880, a period of eighteen months, during which period he reports 63 wells as having been completed. In the *Reporter* for January, 1880, he quotes a local correspondent of the *Franklin Spectator* as stating that "during the past year there were 123 wells drilled and 16 wells cleaned out and retubed. * * * The number of wells pumping January 1, 1879, was about 400, and taking the number of dry wells, 22, and the number abandoned during the year from the number pumping January 1, 1879, and the number drilled and cleaned out, it will leave the pumping wells, January 1, 1880, 475. Taking these figures, the average number of wells pumping for the year 1879 would be about 450".

Mr. Stowell reports only 80 wells of the 122 completed during 1879, and a total of 350 producing December 31, 1879, against 475 as given by the correspondent whom he quotes. Furthermore, it is highly improbable that in the old and nearly exhausted territory in the neighborhood of Rouseville and Rynd farm there should be for twenty-three months, from January 31, 1879, to December 31, 1880, 400 producing wells, and at the same time 90 at Shamburg, 150 at Fagundus, and 115 in the neighborhood of Tidioute. However, while calling attention to these manifest discrepancies, I repeat that this table furnishes the nearest approximation to the facts that is available. I shall therefore apply Mr. Welch's average of 32 barrels to 6,300 wells, and estimate the well stocks of the lower country at 201,600 barrels.

Summarized, the stocks of crude oil in the producing regions June 1, 1879, may be stated as follows:

ACCUMULATED STOCKS, JUNE 1, 1879.

	Barrels.
Pipe-line stocks, third sand	6,538,357
Well stocks, Bradford district	812,067
Well stocks, lower country	201,600
Iron-tankage stocks, outside of pipe-lines	293,474
Franklin stocks, heavy oil	19,898
Smith's Ferry	3,200
West Virginia and southern Ohio	79,606
Grafton and Mecca, Ohio, and Glasgow, Kentucky	150
	7 948,352

ACCUMULATED STOCKS, MAY 31, 1880.

	Barrels.
Pipe-line stocks, third sand	11,225,291
Well stocks, Bradford district	1,258,902
Well stocks, lower country	201,600
Iron tankage stocks, outside of pipe-lines	532,318
Franklin stocks, heavy oil	27,106
Smith's Ferry	3,000
West Virginia and southern Ohio	50,848
Grafton and Mecca, Ohio, and Glasgow, Kentucky	150
	13,299,215

From these summaries it will be seen that the total accumulated stocks in the whole country at the end of the census year was 13,299,215 barrels, and that the accumulation of stocks during the census year was 5,350,863 barrels. The stocks decreased during that year in the West Virginia and southern Ohio district 28,758 barrels; Smith's Ferry district, 200 barrels. They increased during the year in the Bradford district and lower country 5,372,613 barrels; Franklin heavy oil district, 7,208 barrels.

SECTION 6.—STATISTICS OF CAPITAL AND LABOR EMPLOYED IN THE PRODUCTION OF PETROLEUM DURING THE CENSUS YEAR.

The amount of capital that has been or that is invested in the production of petroleum is a problem involved in the deepest obscurity. Capital has often been ventured in this business legitimately without return, the investment proving a total loss. From such total loss to a return of enormous value the gradation has been by infinite steps. The actual cost of the wells which have been drilled since Drake's first well (1859) could be estimated with tolerable certainty, as the price per foot for drilling has been a well-known though fluctuating factor in investment from year to year; but what any given oil-well has cost, and upon what sum a dividend of profit or loss should be declared, is often scarcely known to the owners themselves. There are large corporations that have invested money systematically for years with uniform success; but any general estimate for the whole oil region based on the operations of such concerns would be very erroneous, for the business of such corporations has been managed with prudence and sagacity upon territory that has already been proved, and usually without great speculative risks. Producing oil has not been uniformly successful in individual enterprises, although, when taken as a whole, it may have been in a general way. The capital invested in producing oil involves as a constant and well-known factor the cost of drilling and equipping wells, and also, as a fluctuating factor, the cost of the land privilege for drilling. This varies from nothing (when the original owner of the land drills his own well or offsets its cost for an equal share with those who drill it) to a bonus of from $100 to $500 an acre, in addition to a royalty of from one-sixteenth to one-fourth of the product. In other cases the fee to the land is purchased outright for large sums before the wells are drilled. Such purchases, made where land is proved, have often been very profitable business enterprises, while on the other hand they have as often proved worthless. A certain tract of land in the Oil Creek region was purchased by A., B. & Co. for $13,000 and sold to C. for $113,500 within three months. Three months later A., B. & Co. could have bought back the land for less than $10,000, it having in the mean time been proved of little value for oil. Transactions involving the loss of large sums have been so often repeated that those familiar with the oil regions frequently declare that, vast as the wealth may be which the product of petroleum represents, the losses have been fully equal to the gains. The vast number of wells that have produced nothing, the still larger number whose production has never covered the cost of drilling, together with the millions that have been wasted through fraud and reckless speculative risks, involve the loss of a vast sum which can never be accurately estimated. The area of the Bradford field was pretty clearly outlined by the end of the census year, and there were those who were declaring with added emphasis that each month had witnessed the culmination of its production, but it has continued to pour out from 50,000 to 80,000 barrels of oil a day for the last two years. If the fee to the 68,000 acres of the Bradford field was to be sold to-morrow, the estimated value, as given by different producers, would vary by so many millions of dollars as to make such estimates worthless for statistical purposes. The fact is, the present value of the land franchise of the oil-producing region is an unknown quantity, and must be so until it ceases to have value; then its past value at any given time can be estimated. The men of conservative temperament and those of sanguine temperament differ as widely as the poles are sundered in their estimates of the value of oil property. I shall not, therefore, attempt any estimate of the value of the land franchise of the oil-producing country, but shall confine my estimates to the number of wells drilled, cost of rigs, including engines, cost of casing and tubing, total cost of wells and rigs drilled during the census year, and the number of men employed in drilling wells and in producing oil during the census year.

These estimates will be made for the upper or Bradford district, the lower country, the Franklin district, and the Beaver district, Pennsylvania; the Grafton district and the Mecca district, Ohio; the West Virginia district and Washington county, Ohio; and the Glasgow, Kentucky, district.

During the census year there were 3,080 wells completed in the Bradford district, but at the close of the year there were 58 more rigs building and wells drilling than at the beginning. In the last month in the year 536 rigs were burned, about one-half of which were rebuilt immediately, and the rebuilding of the remainder was, on an average, half completed at the close of the census year, making the rebuilding equal to 75 per cent. of the whole number burned, or 402 rigs. It is fair to assume that the 47 rigs building at the end of the year in excess of those building at the beginning were one-half completed, and that the 11 wells drilling at the end of the year in excess of those drilling at the beginning were, with rigs completed, one-half drilled. This estimate would thus place the rigs built during the census year:

Rigs for wells completed	3,080
Rigs rebuilt	402
50 per cent. of rigs building at the close in excess of those building at the beginning of the year	23
Rigs to wells drilling at the close of the year in excess of those drilling at the beginning	11
Total	3,516

Each of these rigs required in building forty days of labor, making, for all, an aggregate of 140,640 days, or, estimating 300 working days to the year, equal to the continued labor through the year of 468 men, of whom 75 per cent., or 351 men, were skilled workmen and 117 ordinary laborers. Rigs cost during the census year from $325 to $400 each, according to the cost of placing the material where it was to be used, or an average of $362.50. This would give a total investment in rigs during the year of $1,274,550, of which $316,440 represents the cost of labor, estimated at the rate of $2 50 per day for skilled workmen and $1 50 per day for ordinary laborers. Returns of the cost of rigs built in the Bradford district during the census year from three large corporations are as follows: No. 1 built 25 rigs for $10,000; average cost, $400 each. No. 2 built 50 rigs for $17,500; average cost, $350 each. No. 3 built 29 rigs for $12,500; average cost, $431 each. Average cost of 104 rigs, $384 62 each.

Each of the 3,516 rigs built during the census year required for its construction 17,000 feet of lumber, of which 9,000 feet were sawed and 8,000 feet were hewn. This amount represents an aggregate consumption of 59,772,000 feet of lumber, of which probably 30 per cent. was hard wood.

It is almost impossible to estimate, with any approximation to accuracy, the capital invested in engines and boilers. There are engines in the oil regions fifteen years old, and some of them are to be found in the Bradford district, moved up there from the lower country. I have conversed with a number of oil producers on this subject, and find their opinions quite divergent. An estimate based on these opinions and my own observations would lead me to think that at least 90 per cent. of the wells in the Bradford region are supplied with engines and 60 per cent. with boilers, and an average valuation for these engines would not exceed $100 and $200 each for the boilers. I have been informed that at least one-half the wells drilled in the Bradford district during the census year were supplied with engines and boilers from wells abandoned in the lower country, for which I make no estimate. For the other half, it is fair to assume that a large proportion, if not all, of the engines and boilers were new or nearly new. While the above estimate of valuations of boilers may be fair as applied to the whole field, it is too low by one-half for the engines and boilers purchased for new wells. I place the value, in round numbers, of—

Engines (50 per cent. of 90 per cent.) of (3,080 + 11) at $200	$278,200
Boilers (50 per cent. of 60 per cent.) of (3,080 + 11) at $400	370,800
	649,000

This would give an average valuation of $210 per well for all the boilers and engines purchased for the 3,091 wells drilled during the census year. That this valuation is not too high is further proved by returns which I have received from two large corporations with ample capital, both largely interested in the lower country and in the Bradford district. No. 1 drilled 29 wells; the boilers and engines cost $13,000. No. 2 drilled 45 wells; the boilers and engines cost $15,360. The average cost for No. 1 is $448; that for No. 2, $341. I have no doubt that a large percentage of the wells were drilled with poorer machinery than would be used by either of these parties.

The rig, boiler, and engine belong to the owner of the well; but the contractor who drills the well owns the drillers' tools and provides fuel for the engine and coal for the blacksmith. It is estimated that 2 per cent. of the wells use gas, which, practically costing nothing, reduces the number supplied with fuel to 3,024. Experienced producers estimate the consumption of fuel at an average of 100 cords of wood per well, amounting in the aggregate to 302,400 cords, and costing for cutting, at 90 cents per cord, $272,160. It is estimated that 500 men are employed in cutting wood in the Bradford district. The wood usually stands upon the land upon which the well is located, and, except for the cost of cutting, is considered of little or no value.

Each well requires for drilling two drillers and two tool-dressers, who are men skilled in the work which they perform. The tool-dressers are not blacksmiths, but men who are expert in the art of dressing tools. Each well also requires two teams, with teamsters, for hauling wood and material. From returns received from 104 wells drilled in the Bradford district in the census year, 25 drillers drilled the wells and 18 dressers dressed the tools. These wells were drilled more economically, as regards the amount of labor, than the average, as they were drilled by corporations employing very skillful men at maximum wages, from which I judge that a fair estimate would give a year's labor of a skilled workman to every two wells drilled, or, in round numbers, for the 3,086 wells drilled in the census year, a year's labor of 1,500 men, at an average rate of $3 per day. Estimating 300 working days to the year, the amount earned by them would equal $1,350,000. As many more laborers are employed, at an average compensation of $45 per month, earning an amount equal to $810,000. The outfit for drilling a well is worth $900, and is damaged an average of 25 per cent. by use in drilling one well, representing an investment of $694,350 during the census year. These sums show the cost to the contractor. The average contract price for drilling deep (2,000 feet) wells was 55 cents per foot. At this rate the 3,086 wells would represent an investment by the well-owner of $3,394,600. Such estimates are hardly worth the name of statistics, but are, I believe, as close an approximation to accuracy as can now be made.

Each well requires from 30 to 100 feet of 8-inch drive-pipe, which is driven to the bed-rock, and on an average 300 feet of casing, 5⅝ inches in diameter, and 2,000 feet of 2-inch pipe, through which the oil flows.

At an average of 50 feet of drive-pipe for each well, there were required during the census year for the 3,086 wells drilled 154,300 feet of 8-inch drive-pipe, 925,800 feet of 5⅝-inch casing, and 6,172,000 feet of 2-inch pipe.

It is extremely difficult to estimate the actual cost of this pipe, as the different manufacturers made bids for large contracts, and a proportion, impossible to ascertain accurately, was old pipe. One large corporation paid an average of $310 50 each for casing 29 wells; another an average of $210 each for 45 wells. In one case it is to be presumed a larger amount of old casing was used than in the other, but just what this difference of one-third signifies with reference to the whole number of wells it is impossible to ascertain. Prudent men, with ample capital, would sell old casing and use new, while men of limited means would purchase and use the old; but to what extent this was done it is now impossible to determine with accuracy. It is probable, however, that $210 per well is nearer an average price for casing for the entire Bradford district than $310 50. Returns from the same firms give an average expenditure of $343 per well for tubing 74 wells. These were firms using ample capital, and the average is no doubt too high for the whole field, $300 per well being without doubt an ample average cost at which to estimate tubing. Assuming that all of the drive-pipe was new and cost $3 per foot, the total cost would be as follows:

Drive-pipe	$462,900
Casing	648,060
Tubing	925,800
Total	2,036,750

The cost of torpedoes is subject to caprice. There are those who do not use them at all; some use small ones, others use very large ones. One firm torpedoed 25 wells at an aggregate cost of $9,982, average cost, $400; a second firm 29 wells for $3,000, average cost, $103; another firm 45 wells for $9,360, at an average cost of $208.

These firms and corporations are all managed by judicious, conservative men, of large experience, while a large proportion of the wells are drilled by men who operate recklessly and rely upon torpedoes to produce large and quick results. I regard $300 per well as a low estimate for torpedoes, amounting in the aggregate to $925,800.

These estimates foot up as follows:

Cost of 3,516 rigs	$1,274,550
Engines and boilers for 3,091 wells	649,000
Drilling 3,086 wells	3,394,600
Piping 3,086 wells	2,036,760
Torpedoing 3,086 wells	925,800
Total	8,280,710

Returns from eight of the largest firms and corporations doing business in the oil regions, having more than 20,000 acres under development and operating over 600 wells during the census year, give an average of five acres to one well, and assign to the land a value of $300 per acre for oil purposes. Upon this basis they estimate a general average cost of the land at $1,500 per well, and of the well itself from $2,500 to $3,000. At $2,500 each, the cost of the 3,080 wells completed during the census year would be $7,700,000; at $3,000 each the same wells would cost $9,240,000. My estimate of $8,280,710 is therefore a fair average estimate, as based upon that of the owners, of about 10 per cent. of the wells that had been drilled in the Bradford district at the beginning of the census year.

The approximate value of labor employed in building rigs was $316,440; in cutting wood, $272,160; in drilling wells, $2,160,000; total, $2,748,600. To this sum must be added the value of labor employed in operating and repairing wells already drilled, a service which requires the labor of a large number of men.

Returns from the owners of 590 wells show that they employ 275 men in pumping and gauging, and 34 men as overseers; a total of 309 men. Apply this average to the 4,000 wells in the Bradford district at the beginning of the census year, and it gives, in round numbers, 2,000 men, earning $45 per month, or an aggregate of $1,080,000, which makes up a total labor account for the Bradford field of $3,828,600.

The number of wells drilled in the lower country during the census year was 335. Their average depth has been placed at 1,400 feet, and the rigs and tools are the same as those used in the Bradford district, at the same average cost; but their lessened depth reduces the cost of both drilling and tubing. Three hundred and thirty-five rigs, at the average price of $362 50, would cost $121,437 50, and would require for their construction 5,695,000 feet of lumber, 3,015,000 of which would be sawed soft lumber and 2,680,000 hewn lumber. These wells would require for drilling 33,500 cords of wood, the cutting of which would cost $30,150.

I estimate the cost of engines and boilers in this district as averaging $300 per well, which, for 335 wells, would give a valuation of $100,500. Estimating the average of 50 feet of drive-pipe per well at $3 per foot, casing at $210 and tubing at $200 per well for an average depth of 1,400 feet, the cost of casing and tubing the 335 wells drilled in the lower country would be as follows:

Drive-pipe, 8-inch, 16,750 feet	$50,250
Casing, 5⅝-inch, 100,500 feet	70,350
Tubing, 2-inch, 469,000 feet	67,000

The drilling of 1,400-foot wells was worth during the census year 60 cents per foot, and at that rate the drilling of the 335 wells in the lower country cost $281,400.

Summarized, these estimates foot up as follows:

335 rigs, at $362 50 each	$121,437
Engines and boilers for 335 wells, at an average cost per well of $300	100,500
335 wells, drilled 1,400 feet each, at 60 cents per foot	281,400
Drive-pipe	50,250
Casing	70,350
Tubing	67,000
Total	690,937

The general estimate given by producers of large experience that 1,400-foot wells cost about $2,000 each confirms these detailed estimates; and at this rate the 335 wells would cost $670,000.

The employment of labor in the lower country is divided between drilling wells and caring for those already drilled. Unlike the wells in the Bradford district, nearly all of which were flowing during the census year, those of the lower country were all pumping-wells. The labor required in building 335 rigs, estimating 30 days of skilled labor at $2 50 and 10 days of ordinary labor at $1 50 per day, amounts to the labor of 33 carpenters, $25,125; 11 laborers, $5,025.

In drilling the wells there were required 175 skilled workmen at $3 per day, and as many more laborers at $45 per month, which would amount in a year as follows: 175 skilled workmen, at $3 per day, 300 days, $157,500; 175 laborers, $45 per month, $94,500.

The investment in drillers' tools, on an average of five wells to a set, amounts to $60,300.

The employment of labor in the lower country in the care of wells is proportionally greater, for reasons already stated.

Three corporations, owning 112 wells, all in the lower country, employed 74 men to care for them, four-fifths of whom were engaged in pumping and gauging. As these wells belonged to corporations having a thoroughly organized business, it is to be presumed that a minimum number of men are employed. Using these numbers as the basis of an average, the 6,000 wells that were cared for in the lower country during the census year required the services of 3,960 men; but I think it is fair to assume that 4,500 men were employed, at an average rate of compensation of $50 per month, which would make the aggregate sum paid in wages $2,700,000. The approximate value of labor employed in the lower country is, therefore—

In rig-building	$30,150
In cutting wood	30,150
In drilling wells	252,000
In caring for wells	2,700,000
Total	3,012,300

In estimating the investment in drilling wells and the value of labor employed in the Franklin district entirely different conditions must be considered. The wells are not more than 100 feet deep, and cost, on an average, only about $400 each. As a portion of the productive territory is owned by farmers, who in some instances drill the wells themselves and pump them at intervals as other work may slacken, it will be readily perceived that a much larger number of persons are interested in the production of oil, and find partial occupation in it, than would be necessary to carry on the business if constantly employed. In the most productive portion of the field the wells are constantly pumped six days in the week on the sucker-rod plan, from 12 to 40 wells being by this method pumped by one engine. There were 475 productive wells January 1, 1880, and I shall assume that 450 was the average for the census year, of which 400 were pumped constantly. The rigs used here are only about 30 feet in height.

Drilling in this district was comparatively active during the census year, an average of about 10 wells per month having been completed, with an average daily production of about 2 barrels each. The drilling of these wells could not have employed constantly more than 50 men, including the rig-builders, and their care, allowing 5 men to 20 wells, would employ 120 men. Summarized, the items appear as follows:

Cost of 120 wells	$48,000
Labor of 50 men, at $50 per month	30,000
Labor of 120 men, at $50 per month	72,000

In the Beaver district it is estimated there were 200 wells, 15 wells being drilled during the year. These wells are about 600 feet deep, and cost about $700 each. The rigs used are low and comparatively inexpensive, and the pumping is done with sucker-rods. Probably 75 men, at $50 per month, is a maximum estimate for the labor employed in this district. Summarized the items appear as follows:

Cost of 15 wells, at $700 each	$10,500
Labor of 75 men for one year, at $50 per month	45,000

At Belden and at Grafton, Lorain county, Ohio, 72 paying and twice as many more unproductive wells have been drilled, generally from 60 to 250 feet in depth, the deepest yielding the lightest oil, of which about 20 were producing during the census year. Wells cost here from $30 to $40 each, exclusive of the rig and machinery, which are moved about as required. The oil industry here gives employment to about 10 men, and their labor, at $50 per month, for one year, amounts to $6,000.

In the Mecca district the cost of operating for oil is reduced to a minimum. The wells are from 40 to 70 feet deep. A rig costs only $20, and is moved about as required. A rig was hired, and three wells were put down at a total expense of $100.

Probably 20 wells, at an estimated cost of $40 each, were drilled during the census year. It is estimated that 15 men are fully employed here in producing oil. Very few wells are pumped by machinery, a wooden conductor being carried down to the rock; and after the well is drilled and the production has run down everything is removed but this conductor. The well is then pumped at intervals with a sand pump. There are several hundred wells that are pumped in this manner, but the exact number would be very difficult to ascertain. Summarized, the items appear as follows: Cost of 20 wells, at $40, $800; labor of 15 men, at $50 per month, one year, $9,000.

The West Virginia and Washington county (Ohio) oil district is the most peculiar in the country. It has produced oil for a long time, and yields a great variety. The number of wells in this region is about 600. Some of them, yielding heavy and valuable oil, have been pumped since 1865 and 1866; others, yielding lighter oils, have been abandoned, and others still that had been abandoned have been cleaned out and pumping has been resumed. A few wells are being drilled there every year. In the absence of records, it has been estimated that the number of pumping wells has remained about the same for several years, the new ones about equaling those abandoned. I could not ascertain that more than 120 wells were drilled in the district during the census year, the depths varying from 150 to 1,500 feet, as the well penetrates the different horizons at which oil is found. Very few wells, however, have been put down to the 1,500-foot level, and perhaps an equally small number have proved remunerative at the 150- to 200-foot level. The average depth is about 750 feet, and the average cost is estimated at $1,000. Both skilled and ordinary labor is cheaper in this section than in northwestern Pennsylvania, skilled labor being reported here to be worth during the census year from $2 to $2 50 per day, against $2 50 to $3 50 in Pennsylvania, and ordinary labor from $1 to $1 50, against $1 75 to $2 in Pennsylvania. A large number of wells are pumped here by one engine, but instead of a sucker-rod connection the pump rod is attached to a wheel, over which passes an endless wire rope. The uneven surface of the country, as well as the greater depth of the wells, renders this method of transmitting power necessary; but while it is more expensive, it is more reliable.

From returns received I estimate the average cost of the 120 rigs built during the census year at $250 each, requiring twenty-four days of skilled and eight days of ordinary labor and 12,000 feet of lumber in their construction. Coal is used as fuel in this section, the wells often passing through the veins. I estimate very few, if any, new engines and boilers in use for drilling these wells. This section has produced oil since 1861, and some of the machinery used is very old. In drilling the machinery is attached to a gang of wells by an endless rope, and is run without any increase in the expense account. Wooden conductors are used. I estimate an average expense of $125 as ample to cover the cost of casing, and an average of 500 feet for each would include all of the tubing required. The cost per foot for drilling would not vary much from 60 cents per foot. Summarized, these estimates appear as follows:

120 rigs, at $250 each	$30,000
120 wells drilled	54,000
Casing, $125 each	15,000
Tubing	9,000
	108,000

The labor employed for the year is estimated as follows:

In rig-building, 10 men, earning	$7,200
In rig-building, 3 men, earning	960
In drilling wells, 25 men, earning	15,000
In caring for wells, 250 men, earning	150,000
	173,160

On Boyd's creek, near Glasgow, Kentucky, there were five wells in operation during the census year, furnishing employment to seven men, including teamsters, at an average compensation of $35 per month, the wages amounting to $2,940.

The following table represents in a tabulated form the statistics of this section:

STATISTICS OF THE INVESTMENT OF CAPITAL AND THE EMPLOYMENT OF LABOR IN THE PRODUCTION OF PETROLEUM DURING THE YEAR ENDING MAY 31, 1880.

Name of district.	No. of wells drilled.	No. of dry holes.	No. of rigs built.	Cost of rigs.	Cost of engines and boilers.	Cost of drive-pipe.	Cost of casing.	Cost of tubing.	Cost of torpedoes.	Cost of drilling.	Total cost of wells.	Estimated number of skilled workmen.	Average rate of wages.
Bradford, Pennsylvania	3,080	53	3,516	$1,274,550	$649,000	$462,900	$648,060	$925,800	$925,800	$3,394,600	$8,280,710	1,851	$2 50—4 00
Lower country, Pennsylvania	335	79	335	121,437	100,500	50,250	70,350	67,000		281,400	690,937	208	2 50—4 00
Franklin, Pennsylvania	120	15	120								48,000	15	2 50—4 00
Beaver county, Pennsylvania	15		15								10,500	12	2 50—4 00
Grafton, Ohio													
Mecca, Ohio	20										800		
West Virginia and southern Ohio	120		120	30,000			15,000	9,000		54,000	120,000	25	2 00—2 50

Name of district.	Estimated number of ordinary laborers.	Average rate of wages.	Estimated number of wood-choppers.	Rate paid per cord.	Total number of men employed.	Total amount of wages paid.	Estimated number of men employed in drilling wells.	Estimated number of men employed in caring for wells.	Estimated amount of feet of lumber used in rigs.	Estimated amount of cords of fuel used in drilling wells.	Total production in barrels.
Bradford, Pennsylvania	3,617	$1 50—2 00	500	$0 90	5,968	$3,828,600	3,000	2,000	59,772,000	302,400	} 23,828,589
Lower country, Pennsylvania	4,686	1 50—2 00	50		4,944	3,012,300	350	4,500	5,695,000	33,500	}
Franklin, Pennsylvania	155	1 50—2 00			170	102,000	50	120	600,000		86,857
Beaver county, Pennsylvania	63	1 50—2 00			75	45,000	10	60	225,000		86,803
Grafton, Ohio					10	6,000		10			4,159
Mecca, Ohio					15	9,000		15			900
West Virginia and southern Ohio	263	1 00—1 50			288	173,160	25	250	1,440,000		219,254
Glasgow, Kentucky					7	2,940					5,370
Greene county, Pennsylvania											3,118
Erie, Pennsylvania											25

Cost of raising oil: Flowing wells in the Bradford district, 6 to 8 cents per barrel; pumping wells in the lower country, 60 to 80 cents; pumping wells in Franklin district, $3 per barrel.

To this may be added the following table, showing the estimated number of wells at the beginning and the end of the census year in the United States east of the Mississippi river:

Name of district.	Estimated number of producing wells June 1, 1879.	Estimated number of producing wells May 31, 1880.	Number completed during census year.	Dry holes.
Bradford, Pennsylvania	4,282	7,362	3,080	53
Lower country, Pennsylvania	6,693	6,322	335	79
Franklin, Pennsylvania	400	500	120	15
Beaver county, Pennsylvania	200	200	15	?
Grafton, Ohio	20	20	?	?
Mecca, Ohio	?	?	20	?
West Virginia and southern Ohio	500	600	120	?
Glasgow, Kentucky	5	5	....	....
Total	12,100	15,009	3,690	147

SECTION 7.—GENERAL STATISTICS RELATING TO THE PRODUCTION OF THIRD-SAND PETROLEUM.

In illustration of this section I have been so fortunate as to secure the accompanying diagrams, prepared by Mr. Charles A. Ashburner, of Philadelphia, especially for this work, from the statistical tables of Stowell's *Petroleum Reporter*. No. I is a graphic representation of the total production by years of the different districts, by which the date of discovery, expansion, and contraction of the production of the different districts is noted; No. II shows the comparative volume of the total production of the different districts. No. III shows the comparative expansion and contraction of the total yearly production, with the total value in greenbacks and gold, from 1859 to 1880, inclusive. On pages 149, 150, and 151 are statistical tables from another source, which vary only slightly from the preceding in the aggregate, and present the matter in detail. On page 150 is a statistical statement, made by the United Pipe Lines, that offers its own explanation. On page 151 is a table giving some comparative miscellaneous pipe-line statistics that are included in the census year, taken from the *Titusville Herald* of April 11, 1881, except the averages for the census year. The following estimate of stocks in the oil region on the dates named is given for what it is worth, as the authority is unknown:

	Barrels.		Barrels.
February, 1868	534,000	February, 1874	1,248,919
February, 1869	264,000	February, 1875	4,250,000
February, 1870	340,751	February, 1876	3,585,143
February, 1871	537,000	February, 1877	2,604,128
February, 1872	623,048	February, 1878	3,555,342
February, 1873	1,085,435	February, 1879	5,385,523

STATEMENT SHOWING THE YEARLY PRODUCTION, AVERAGE YEARLY PRICE, AND VALUE, IN CURRENCY, OF ALL OIL PRODUCED FROM 1860 TO DECEMBER 31, 1880, BOTH INCLUSIVE.

Year.	Number of barrels.	Average price per barrel.	Amount.
Total	156,888,331	....	$334,871,063 84
1860	500,000	$9 60	4,800,000 00
1861	2,113,609	49	1,035,668 41
1862	3,056,690	1 05	3,209,524 50
1863	2,611,309	3 15	8,225,623 35
1864	2,116,109	9 87½	20,896,576 37
1865	2,497,700	6 59	16,459,843 00
1866	3,597,700	3 74	13,455,398 00
1867	3,347,300	2 41	8,066,993 00
1868	3,646,117	3 62½	13,217,174 12
1869	4,215,000	5 63	23,730,450 00
1870	5,260,745	3 89¾	20,503,753 63
1871	5,205,341	4 34	22,591,179 94
1872	5,890,248	3 64	21,440,502 72
1873	9,890,964	1 83	18,100,464 12
1874	10,809,852	1 17	12,647,526 84
1875	8,787,506	1 35	11,863,133 10
1876	8,968,906	2 56¼	22,982,821 62
1877	13,135,771	2 42	31,788,565 82
1878	15,163,462	1 19	18,044,519 78
1879	20,041,581	85⅞	17,210,707 68
1880	26,032,421	94½	24,600,637 84

Average price per barrel for 21 years, $2 13+.

CHART
No. 1.
Showing the annual production of **Petroleum** *and Development of the individual districts in the* OIL REGION *of Pennsylvania and Southern New York*

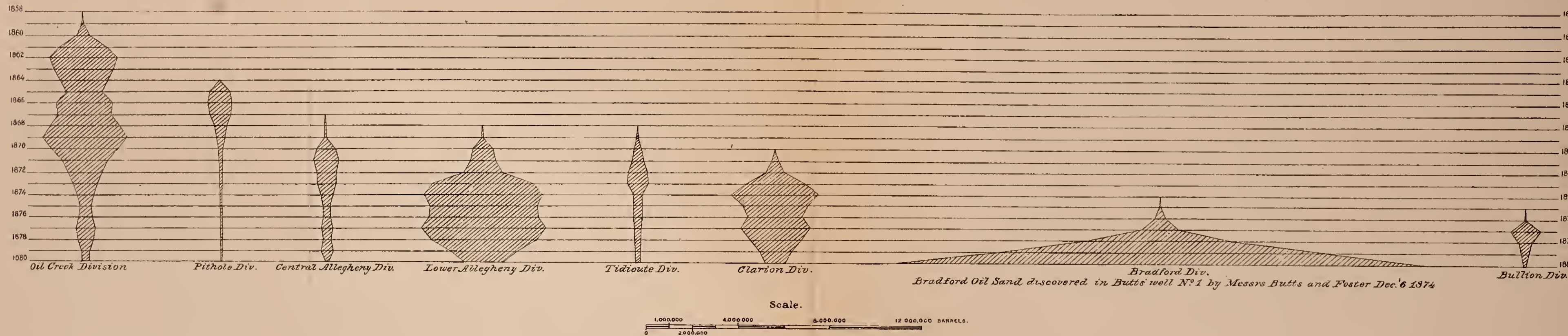
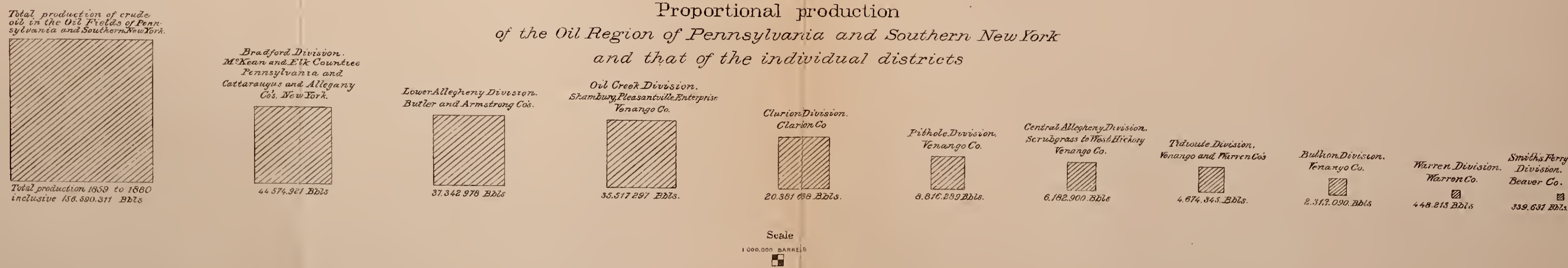


CHART
No. 2.
Proportional production
of the Oil Region of Pennsylvania and Southern New York and that of the individual districts



Compiled by
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Assistant, Second Geological Survey of Pennsylvania

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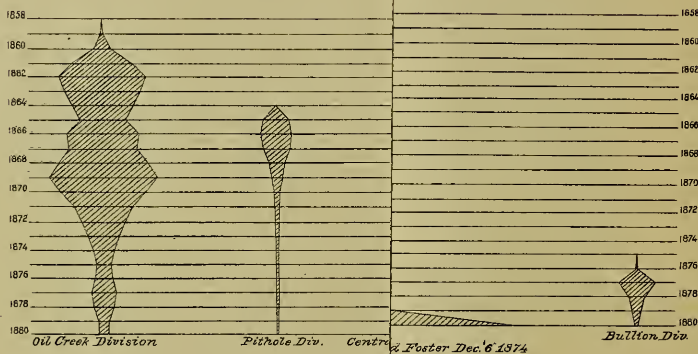
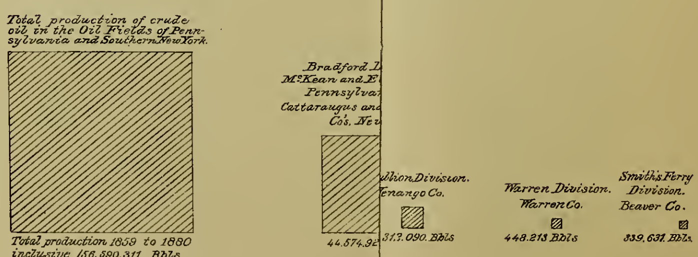




Harry King Del.

STATEMENT OF THE NUMBER OF BARRELS OF OIL PRODUCED FROM AUGUST 26, 1859, TO DECEMBER 31, 1880, BY YEARS AND BY COUNTIES, IN THE OIL REGIONS OF PENNSYLVANIA AND SOUTHERN NEW YORK.

Years.	Number of barrels.	State and county.
Total	156, 153, 807	
1859	1, 000	Venango county, Pennsylvania.
1860	500, 000	Venango, Forest, Crawford, and Warren, Pennsylvania.
1861	2, 113, 609	Do.
1862	2, 056, 690	Do.
1863	2, 611, 309	Do.
1864	2, 116, 109	Do.
1865	2, 497, 700	Venango, with Clarion and Armstrong.
1866	3, 597, 700	Venango, with Cattaraugus county, New York.
1867	3, 347, 300	Do.
1868	3, 715, 700	Do.
1869	4, 215, 100	Do.
1870	5, 659, 000	Venango, with Butler county, Pennsylvania.
1871	5, 202, 710	Do.
1872	5, 985, 635	Do.
1873	9, 882, 010	Venango, with McKean county, Pennsylvania.
1874	10, 920, 435	Do.
1875	8, 783, 470	Do.
1876	8, 952, 355	Do.
1877	13, 129, 780	Do.
1878	15, 159, 180	Do.
1879	19, 741, 755	Do.
1880	25, 960, 260	Do.

TOTAL PRODUCTION OF CRUDE PETROLEUM IN PENNSYLVANIA OIL-FIELDS FROM 1859 TO DECEMBER 31, 1880, BOTH INCLUSIVE, DIVIDED INTO PRODUCING DIVISIONS AND DISTRICTS.

Years.	Oil Creek division.	Pithole district.	Central Allegheny division.	Lower Allegheny division.	Tidioute district.	Clarion division.	Bradford division.	Bullion district.	Warren division.	Beaver division.	Yearly total of all districts.
	Barrels.	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*
Total	35, 517, 217	4, 816, 298	6, 482, 900	37, 342, 978	4, 674, 345	20, 381, 638	44, 574, 921	2, 312, 190	448, 213	339, 631	156, 890, 331
1859	2, 000										2, 000
1860	500, 000										500, 000
1861	2, 113, 609										2, 113, 609
1862	3, 056, 690										3, 056, 690
1863	2, 611, 309										2, 611, 309
1864	2, 116, 109										2, 116, 109
1865	1, 585, 200	912, 500									2, 497, 700
1866	2, 502, 700	1, 095, 000									3, 597, 700
1867	2, 393, 300	954, 000									3, 347, 300
1868	3, 072, 617	547, 500	26, 000								3, 646, 117
1869	3, 762, 500	365, 000	22, 000	45, 000	20, 500						4, 215, 000
1870	3, 039, 528	173, 585	813, 150	918, 644	315, 838						5, 260, 745
1871	2, 040, 263	182, 054	1, 083, 386	1, 091, 458	497, 887	310, 293					5, 205, 341
1872	1, 529, 685	145, 065	881, 140	1, 658, 080	847, 199	829, 079					5, 890, 248
1873	1, 094, 389	119, 864	851, 934	4, 402, 563	895, 983	2, 526, 231					9, 890, 964
1874	734, 247	55, 770	564, 978	5, 160, 265	373, 325	3, 921, 267					10, 809, 852
1875	504, 639	35, 130	343, 905	4, 712, 702	351, 407	2, 821, 214	18, 509				8, 787, 506
1876	611, 884	37, 450	333, 640	4, 755, 623	354, 284	2, 377, 700	382, 768	64, 220	51, 837		8, 968, 906
1877	834, 858	60, 380	474, 262	5, 431, 072	312, 700	3, 012, 120	1, 490, 481	1, 306, 442	151, 371	62, 085	13, 135, 771
1878	686, 948	60, 000	363, 710	4, 552, 815	308, 780	2, 276, 408	6, 208, 746	505, 265	108, 300	92, 490	15, 163, 462
1879	389, 400	36, 500	558, 652	2, 876, 787	227, 900	1, 438, 342	14, 096, 759	289, 591	45, 550	82, 100	20, 041, 581
1880	335, 342	36, 500	166, 143	1, 737, 969	168, 542	868, 984	22, 377, 658	146, 672	91, 655	102, 956	26, 032, 421

RECAPITULATION.

	Barrels.
Oil Creek division, including Shamburg, Pleasantville, and Enterprise	35, 517, 217
Pithole district, including Holderman, Morey, and Ball farms	4, 816, 298
Central Allegheny division, including Scrubgrass to West Hickory	6, 482, 900
Lower Allegheny division, including Butler and Armstrong counties	37, 342, 978
Tidioute district, including Economites, Henderson farm, etc	4, 674, 345
Clarion district, including Clarion county	20, 381, 638
Bradford district, including McKean and Elk counties; also Cattaraugus and Allegany counties, New York	44, 574, 921
Bullion district, including Venango county	2, 312, 190
Warren division, including Stoneham, Clarendon, etc	448, 213
Beaver division, including Smith's Ferry, etc	339, 631
Total production from all districts	156, 890, 331

STATEMENT, BY COUNTIES, OF THE NUMBER OF ACRES DEVELOPED IN THE OIL-FIELDS OF PENNSYLVANIA AND NEW YORK FROM AUGUST 26, 1859, TO DECEMBER 31, 1880.

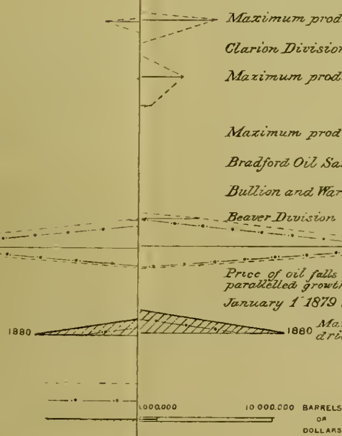
State and county.	Number of acres.
Total	156, 380
Venango county, Pennsylvania	32, 000
Crawford county, Pennsylvania	6, 400
Forest county, Pennsylvania	1, 920
Warren county, Pennsylvania	6, 720
Armstrong county, Pennsylvania	5, 120
Clarion county, Pennsylvania	19, 200
Butler county, Pennsylvania	27, 520
McKean county, Pennsylvania	50, 000
Cattarangue county, New York	7, 500

STATEMENT MADE BY THE UNITED PIPE-LINES FROM THE BEGINNING OF APRIL, 1877, TO JULY 9, 1881.

Month.	Gross stocks.	Sediment and surplus.	Net stocks.	Outstanding acceptances.	Credit balances.	Receipts from all sources.	Total deliveries.
	Barrels.	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*
1877.							
April	1, 895, 153. 71	77, 386. 70	1, 817, 767. 01	449, 640. 14	1, 368, 126. 87	200, 570. 81	125, 797. 90
May	1, 762, 602. 64	75, 364. 87	1, 687, 237. 77	683, 663. 71	1, 003, 574. 06	493, 200. 58	619, 612. 26
June	1, 569, 367. 68	81, 255. 42	1, 488, 112. 26	661, 786. 57	826, 325. 69	538, 906. 95	737, 609. 77
July	1, 482, 433. 51	81, 741. 50	1, 400, 692. 01	667, 166. 36	733, 525. 65	615, 145. 46	699, 476. 18
August	1, 489, 052. 53	81, 144. 63	1, 407, 907. 90	643, 281. 46	764, 626. 44	673, 403. 04	866, 144. 28
September	1, 339, 032. 27	67, 163. 68	1, 271, 868. 59	552, 676. 26	719, 192. 33	624, 225. 37	760, 745. 57
October	1, 434, 728. 78	46, 771. 99	1, 387, 956. 79	673, 850. 05	714, 106. 74	687, 094. 59	570, 092. 71
November	1, 691, 399. 52	39, 418. 00	1, 651, 981. 52	657, 591. 36	994, 390. 16	913, 644. 16	649, 242. 70
December	2, 830, 415. 36	68, 729. 63	2, 761, 685. 73	754, 338. 25	2, 007, 347. 48	1, 656, 150. 37	506, 322. 99
1878.							
January	3, 124, 641. 15	72, 453. 43	3, 052, 187. 72	864, 711. 41	2, 187, 476. 31	972, 681. 18	715, 149. 78
February	3, 439, 526. 98	82, 452. 66	3, 357, 074. 32	1, 404, 292. 13	1, 952, 782. 19	1, 030, 688. 44	720, 478. 14
March	3, 940, 000. 65	92, 963. 06	3, 847, 037. 59	1, 487, 439. 50	2, 359, 598. 09	1, 196, 251. 26	701, 681. 27
April	4, 335, 274. 84	133, 934. 76	4, 201, 340. 08	1, 615, 791. 19	2, 585, 548. 89	1, 137, 359. 40	778, 050. 53
May	4, 609, 681. 45	150, 117. 76	4, 459, 563. 69	2, 065, 333. 31	2, 394, 230. 38	1, 104, 352. 40	843, 081. 33
June	4, 719, 699. 25	181, 800. 03	4, 537, 899. 22	1, 950, 420. 81	2, 587, 478. 41	1, 092, 604. 02	1, 004, 474. 55
July	4, 885, 851. 72	229, 080. 78	4, 656, 770. 94	2, 078, 469. 56	2, 578, 301. 38	1, 258, 648. 45	1, 108, 074. 33
August	4, 571, 658. 59	217, 085. 19	4, 354, 573. 40	2, 064, 590. 76	2, 289, 982. 64	1, 195, 268. 67	1, 496, 009. 04
September	4, 410, 061. 84	225, 088. 86	4, 184, 972. 98	1, 705, 853. 95	2, 479, 119. 03	1, 182, 118. 57	1, 318, 265. 33
October	4, 072, 627. 43	234, 050. 89	3, 838, 576. 54	1, 517, 484. 27	2, 321, 092. 27	1, 271, 174. 73	1, 564, 984. 43
November	4, 083, 972. 42	216, 655. 30	3, 867, 317. 12	1, 784, 443. 35	2, 082, 873. 77	1, 159, 623. 71	1, 129, 047. 02
December	4, 098, 200. 92	201, 470. 30	3, 896, 730. 62	1, 741, 311. 07	2, 155, 419. 55	972, 338. 83	924, 035. 93
1879.							
January	4, 759, 031. 41	182, 707. 80	4, 576, 323. 61	2, 153, 763. 83	2, 422, 559. 78	1, 231, 237. 19	546, 271. 74
February	5, 157, 646. 15	171, 689. 80	4, 985, 956. 35	2, 346, 238. 22	2, 639, 718. 13	1, 055, 377. 95	633, 828. 71
March	5, 503, 768. 71	190, 797. 91	5, 312, 970. 80	2, 484, 881. 83	2, 828, 088. 97	1, 363, 512. 17	1, 029, 029. 70
April	5, 885, 675. 24	211, 957. 06	5, 673, 718. 18	2, 644, 301. 36	3, 029, 416. 82	1, 379, 349. 76	1, 015, 482. 04
May	6, 180, 843. 53	315, 992. 98	5, 864, 850. 55	2, 522, 486. 36	3, 342, 364. 19	1, 488, 514. 31	1, 228, 043. 27
June	6, 426, 802. 45	334, 457. 29	6, 092, 345. 16	2, 959, 921. 12	3, 132, 424. 04	1, 437, 250. 90	1, 204, 757. 54
July	6, 419, 699. 08	323, 295. 32	6, 096, 403. 76	3, 323, 575. 29	2, 772, 828. 47	1, 472, 651. 01	1, 465, 518. 05
August	6, 380, 606. 63	302, 345. 15	6, 078, 261. 48	3, 581, 224. 03	2. 497, 037. 45	1, 714, 620. 11	1, 728, 940. 81
September	6, 589, 859. 83	325, 363. 85	6, 264, 495. 98	3, 783, 480. 38	2, 481, 015. 60	1, 691, 863. 41	1, 455, 811. 45
October	6, 701, 209. 87	299, 393. 67	6, 401, 816. 20	3, 788, 155. 65	2, 613, 660. 55	1, 646, 725. 06	1, 502, 991. 20
November	6, 951, 133. 67	303, 641. 17	6, 647, 492. 50	3, 972, 300. 18	2, 675, 192. 32	1, 600, 961. 29	1, 328, 621. 19
December	7, 362, 409. 76	294, 571. 37	7, 067, 838. 39	4, 235, 459. 40	2, 832, 378. 99	1, 771, 781. 24	1, 331, 822. 12
1880.							
January	7, 735, 257. 38	295, 517. 60	7, 439, 739. 78	4, 436, 788. 55	3, 002, 951. 23	1, 832, 963. 04	1, 455, 194. 93
February	8, 187, 012. 49	322, 568. 93	7, 864, 443. 56	4, 602, 286. 49	3, 262, 157. 07	1, 607, 663. 89	1, 178, 111. 92
March	8, 621, 097. 49	351, 130. 35	8, 269, 967. 14	4, 811, 894. 33	3, 458, 072. 81	1, 815, 133. 31	1, 396, 037. 88
April	9, 662, 354. 59	388, 558. 16	9, 273, 796. 43	5, 846, 536. 60	3, 427, 259. 83	1, 739, 297. 37	723, 794. 73
May	10, 306, 078. 79	454, 193. 73	9, 851, 885. 06	6, 361, 320. 05	3, 490, 565. 01	1, 552, 240. 91	975, 061. 26
June	11, 266, 771. 77	477, 431. 69	10, 789, 340. 08	7, 397, 131. 89	3, 392, 208. 19	1, 781, 937. 29	848, 339. 08
July	12, 039, 010. 00	475, 446. 56	11, 563, 563. 44	8, 125, 241. 25	3, 438, 322. 19	1, 890, 161. 44	1, 095, 528. 25
August	12, 749, 623. 28	462, 987. 28	12, 286, 636. 00	8, 635, 394. 80	3, 651, 241. 20	1, 904, 452. 70	1, 177, 448. 42
September	13, 618, 726. 03	382, 398. 71	13, 236, 327. 32	9, 287, 193. 94	3, 949, 133. 38	2, 075, 105. 26	1, 115, 184. 71
October	14, 020, 877. 39	391, 331. 55	13, 629, 545. 84	9, 448, 615. 77	4, 180, 930. 07	1, 999, 457. 98	1, 498, 285. 06
November	14, 656, 891. 55	341, 262. 67	14, 315, 628. 88	10, 083, 824. 08	4, 231, 804. 80	1, 859, 991. 50	1, 064, 146. 39
December	15, 369, 758. 67	361, 184. 83	15, 008, 573. 84	10, 913, 283. 49	4, 095, 290. 35	1, 987, 283. 54	1, 207, 928. 35
1881.							
January	16, 291, 307. 87	360, 688. 98	15, 930, 618. 89	11, 672, 583. 61	4, 258, 035. 28	1, 876, 526. 50	931, 718. 71
February	17, 355, 485. 31	391, 616. 47	16, 963, 868. 84	12, 029, 594. 35	4, 934, 274. 49	1, 823, 713. 46	781, 747. 93
March	18, 488, 476. 94	432, 304. 19	18, 056, 172. 75	13, 099, 262. 44	4, 956, 910. 31	2, 222, 812. 39	1, 116, 695. 11
April	19, 560, 752. 23	517, 422. 38	19, 043, 329. 85	13, 846, 285. 20	5, 197, 044. 65	2, 182, 636. 96	1, 183, 779. 02
May	20, 591, 117. 33	640, 662. 03	19, 950, 455. 30	14, 608, 124. 70	5, 342, 330. 60	2, 278, 582. 78	1, 356, 688. 23
June	21, 397, 698. 53	756, 412. 85	20, 641, 285. 68	14, 738, 828. 77	5, 902, 456. 91	2, 318, 445. 18	1, 545, 448. 13

The above figures are in barrels of forty-two gallons each.

Year	Average yearly price	Total annual value of production in Greenbacks
1859	20.00	40.000.00
1860	9.60	4.800.000.00
1861	.49	1.035,668.41
1862	1.05	3.209.524.50
1863	3.15	8.225.623.35
1864	9.87½	20.896.576.37
1865	6.59	16.459.843.00
1866	3.74	13 455.398.00
1867	2.41	8.066.993.00
1868	3.62½	13.217.174.12
1869	5.63	23.730.450.00
1870	3.89¾	20.503.753.64
1871	4.34	22.591.179 94
1872	3.64	21.440.502.72
1873	1.63	18.100.464.12
1874	1.17	12.647.526.84
1875	1.35	12.133.133.10
1876	2.56¼	22.982.821.62
1877	2.42	31.788.323.82
1878	1.19	18.044.519.78
1879	.85⅝	16.953.151.38
1880	.94½	24.600.637.84
	TOTAL	$324.920.265.55



Notes.

Drake well, the pioneer well in Pennsylvania, "struck oil" August 28th 1859.

October to December 1861, average monthly price of crude oil .10 cts a barrel, minimum value.

January 1862, gold at a premium.

Oil field supposed to be defined, hence price of oil rises rapidly.

Pithole Division commenced to produce.

Gold at the maximum premium during 1865.

Maximum production of Pithole Division.

Central Allegheny Div commenced to produce.

Tidioute, Butler & Armstrong Divs commenced to produce.

Maximum production of Oil Creek Division.

Clarion Division commenced to produce.

Maximum production of Central Allegheny Div.

Maximum production of Tidioute Division.

Bradford Oil Sand discovered December 6th 1874.

Bullion and Warren Divisions commenced to produce.

Beaver Division commenced to produce.

Maximum total value of 31 788.323 dollars attained.

Price of oil falls rapidly in consequence of the unparalleled growth of the Bradford field.

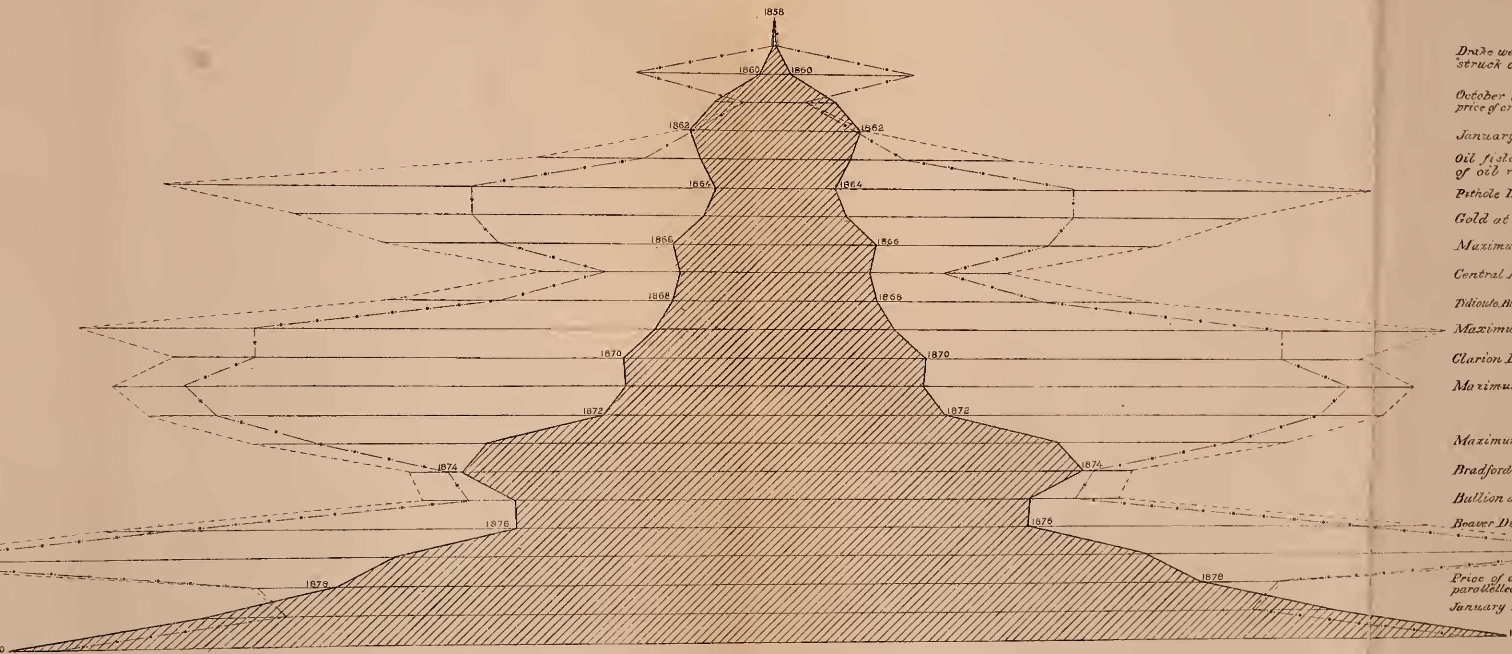
January 1st 1879 specie payments resumed in the U.S.

Maximum monthly average [495] of drilling wells attained.

Harry King Del.

CHART
No. 3.
Showing the annual production of Petroleum
IN THE OIL REGION
of Pennsylvania and Southern New York
Since its discovery, with the values of the production in Currency and in Gold.

Year	Average yearly price	Total annual value of production in Greenbacks
1859	20.00	40.000.00
1860	9.60	4.800.000.00
1861	.49	1.035.668.41
1862	1.05	3.209.524.50
1863	3.15	8.225.623.35
1864	9.87½	20.896.576.37
1865	6.59	16.459.843.00
1866	3.74	13.455.398.00
1867	2.41	8.066.993.00
1868	3.62½	13.217.174.12
1869	5.63	23.730.450.00
1870	3.89¾	20.503.753.64
1871	4.34	22.591.179.94
1872	3.64	21.440.502.72
1873	1.83	18.100.464.12
1874	1.17	12.647.526.84
1875	1.35	12.133.133.10
1876	2.56¼	22.982.821.62
1877	2.42	31.788.323.82
1878	1.19	18.044.519.78
1879	.85⅝	16.953.151.38
1880	.94½	24.600.637.84
TOTAL		$324.920.265.55



Notes.

Drake well, the pioneer well in Pennsylvania, "struck oil" August 28 1859.

October to December 1861, average monthly price of crude oil, 10 cts a barrel, minimum value.

January 1862, gold at a premium.

Oil field supposed to be defined, hence price of oil rises rapidly.

Pithole Division commenced to produce.

Gold at the maximum premium during 1865.

Maximum production of Pithole Division.

Central Allegheny Div commenced to produce.

Tidioute, Butler & Armstrong Divs commenced to produce.

Maximum production of Oil Creek Division.

Clarion Division commenced to produce.

Maximum production of Central Allegheny Div.

Maximum production of Tidioute Division.

Bradford Oil Sand discovered December 6 1874.

Bullion and Warren Divisions commenced to produce.

Beaver Division commenced to produce.

Maximum total value of 31 788.323 dollars attained.

Price of oil falls rapidly in consequence of the unparallelled growth of the Bradford field.

January 1 1879 specie payments resumed in the U.S.

Maximum monthly average [495] of drilling wells attained.

Legend.

Value of total production in Greenbacks.
Value of total production in Gold.
Total production of entire region.

Scale.

0 — 1,000,000 — 2,000,000 — 4,000,000 — 6,000,000 — 8,000,000 — 10,000,000 BARRELS OR DOLLARS

Notes.

The total annual value was obtained by multiplying the total production by the average yearly price.
The average yearly premium on gold was obtained by taking an average of the highest, lowest, opening and closing price of gold in currency for each month in each year.

Compiled by
Chas. A. Ashburner M.S.
Assistant, Second Geological Survey of Pennsylvania.

Harry King Del.

MISCELLANEOUS PIPE-LINE STATISTICS FOR 1879 AND 1880.

Month.	Daily average of charters.		Average daily runs by all lines.		Stocks in pipe-line tanks.		Tide-water.			
							Runs.		Shipments.	
	1879.	1880.	1879.	1880.	1879.	1880.	1879.	1880.	1879.	1880.
	Barrels.	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*
Average for the census year	32, 377	....	61, 837	....	8, 323, 681	....	203, 378	....	179, 409	....
January	14, 800	18, 303	45, 719	67, 330	5, 064, 693	8, 520, 696	65, 026	154, 034	216	118, 400
February	12, 200	20, 822	43, 105	62, 671	5, 541, 683	8, 930, 508	52, 182	125, 376	492	716, 057
March	27, 700	18, 954	48, 856	67, 024	5, 928, 628	9, 369, 240	55, 421	167, 564	37	741, 062
April	26, 000	18, 975	50, 754	67, 921	6, 332, 841	10, 545, 425	53, 477	199, 327	2, 585	34, 162
May	32, 800	18, 370	52, 963	59, 048	6, 565, 454	11, 230, 883	55, 489	905, 153	36, 728	88, 836
June	49, 000	36, 735	53, 908	69, 931	6, 849, 389	12, 281, 711	82, 035	230, 089	35, 575	94, 398
July	36, 000	35, 033	54, 061	71, 072	6, 938, 690	13, 150, 974	108, 020	210, 178	24, 588	94, 095
August	38, 600	30, 916	61, 886	71, 010	6, 998, 046	13, 945, 113	107, 402	196, 249	40, 680	85, 482
September	47, 300	33, 567	63, 504	67, 813	7, 328, 980	14, 713, 346	121, 303	169, 147	58, 054	97, 493
October	44, 700	18, 231	60, 694	70, 861	7, 402, 630	15, 114, 802	139, 883	185, 551	98, 889	129, 178
November	46, 300	21, 730	60, 278	65, 799	7, 675, 193	16, 756, 954	118, 092	162, 269	97, 366	121, 978
December	31, 300	21, 500	63, 722	57, 749	8, 094, 496	16, 616, 628	114, 352	173, 125	99, 243	110, 659

SECTION 8.—THE PRODUCTION OF THE PACIFIC COAST.

Concerning the petroleum production of the Pacific coast, I have to say that I have no official returns from any of the parties interested, no communication addressed to them having elicited any response whatever, and in consequence I have been forced to rely on such other sources of information as were available. My own experience in relation to the petroleum of that region led me to accept all reports published in the newspapers with great caution I addressed a letter of inquiry to the senior member of a firm long engaged in trade in refined oils upon the San Francisco market, and received the following reply, dated March 16, 1882:

The consumption of this coast of eastern oils is 4,500,000 gallons of refined. The product of all the refineries of this coast does not exceed 400,000 gallons refined. It is of inferior quality, low test, and is principally sold to the Chinese trade at about 16 cents per gallon in cans, or less, by 6 cents per gallon, than the cheapest eastern oils. In addition, about 400,000 gallons of crude oil is sold here for making gas and fuel. The production seems to be decreasing, the wells being, as a rule, short-lived. The above is, I consider, reliable, and is the best information I can get. My firm sell considerable oil, both high- and low-test eastern. We have no demand for California production.

Mr. J. C. Welch, in his report for February, 1880, says:

My California correspondent writes, February 2, as follows: "In reference to the Californian production, I would state that since my last letter there has nothing new been developed. It is very expensive and very difficult to drill wells in California, owing to the angle at which the rock stands, causing it to cave from the top to the bottom of the well. It requires four or five sizes of casing, telescoped from 12 inches to the smallest size that can be drilled through. In this way it requires about as much capital to case a well here as the entire expense of a well in Pennsylvania. The time required to drill is from three months to two years, it being very difficult to get the casing down, the rock caving at every point. However, these obstacles would all be overcome if there was a class of men like Pennsylvania producers in this country to drill wells, but, fortunately for the producing interests of the United States, the monopoly in California is in the producing interest instead of in the refining and transportation interest, as in Pennsylvania. A syndicate of millionaires, led by C. N. Felton (who was first in the development of the Bonanza mines of Nevada), have been busily engaged for the last two years in purchasing in fee all the lands that show any indications of being oil territory, which, as the tracts of land in which the oil district is located were originally divided by the old Spanish grants containing hundreds of thousands of acres, it has been a comparatively easy matter for them to do, and they seem inclined to keep their oil in the ground until such times as Pennsylvania shall have exhausted her supplies and the product here is needed for the world's demand. Although the same company have obtained all the necessary machinery, iron, and fixtures for the refinery (of which I wrote you recently), and have land secured in a favorable location, located on the bay and also connected with both systems of railroad, narrow and broad gauge, yet they have not actually commenced the erection of the works. It will require about ninety days from the time they break ground until the refinery can be completed.

As I suggested in my former letter to you, these parties at present do not intend to produce more oil than is required for the Pacific coast trade, and for the next two or three years the California territory need have no influence whatever on the general petroleum market unless some unexpected strike should be made that now seems unlikely, as there are only two or three wells being drilled.

I do not know exactly what percentage of refined oil is obtained from California crude; but should not, from my experience, place the production at above 1,000,000 gallons, or 2,500 barrels.

SECTION 9.—THE FOREIGN PRODUCTION OF PETROLEUM IN COMPETITION WITH THE UNITED STATES.

From various reports that have received my attention in reference to this subject I select the following as most entitled to confidence. The first which I offer, reviewing all of the European fields upon observations made during the census year, is from the February (1880) report of Mr. J. C. Welch. The second paper was prepared expressly for this report by William Brough, esq., of Franklin, Pennsylvania, a gentleman of large experience in the Pennsylvania oil regions, whose opinions are based upon a careful personal inspection of the Russian petroleum fields, they being really the only European fields likely to prove of more than local importance. Mr. Welch, in his report on Russia, says:

The various oil territories of the world have, during the past year, been receiving some attention, and the chance of their supplying oil to meet more or less of the world's needs is of course an important one to those whose interests are principally identified with that supply being drawn from western Pennsylvania. The Russian territory on the Caspian sea has received the most attention, and it has a prolific yield; the two things that have militated chiefly against its being a competitor of importance of the Pennsylvania petroleum are in the character of the oil, only yielding about 33 per cent. of illuminating oil, and in the difficulty of getting it to the markets of the world through inadequate means of transportation. The opinion prevails among some that a percentage of illuminating oil can be got from it as great as that obtained from American petroleum, requiring, however, some different process of refining. This plan is to be tested soon by the erection of a refinery in Russia, the owners having sufficient confidence in their process to erect a refinery of sufficient size to be a complete test as to whether the process will be a success or not.

Mr. L. Emery, jr., a well-known resident and producer of this region, has just returned from the Baku field, after having taken time to give it a critical examination. He estimates the production there during the past year to have been about 28,000 American barrels per day from 78 wells, showing the extraordinary average of 360 barrels. The depth of the wells is only about 500 feet. There were shipped from Baku last season about 1,230,000 gallons of refined oil. Oil is refined at Baku at 195 refineries, with a charging capacity of 28,000 American barrels. There are now in course of erection stills with a charging capacity of about 2,000 barrels, which will be ready for business with the opening of navigation in the spring. Some of these refineries are very small; others are owned by independent corporations with large capital. From Baku oil is sent east, south, and west by canals and wagons, and by the Volga river to Kisan, and thence by cars it reaches the principal markets of Russia.

Mr. Emery says it is estimated there are 25,000,000 poods (about 3,125,000 barrels) of crude oil in the vicinity of Baku held in excavations in the ground or lakes. Pipe-lines are being used from the wells to the refineries in the vicinity of Baku, a distance of 6 miles. Two 3-inch lines have recently been laid, one with pipes of American and one of English manufacture; and three more pipe-lines are in process of construction, one of 5 inches diameter, the other two of 3 inches diameter. A railroad also runs through the district. The price paid for pipeage is about 8 cents per American barrel, and oil is now a drug at 6 cents a barrel at the wells.

Petroleum is found more or less on both sides of the Caucasian mountains; and oil is produced within the city limits of Tiflis, a city which is rated by the latest census as having 70,591 inhabitants. A railroad is in operation from the Black sea to Tiflis, a distance of 180 miles, and is in process of construction from Tiflis to Baku. Eighteen miles of this is already built, its construction having commenced last summer. The contract calls for its completion within three years of its commencement, with a forfeiture for every day over that time that it is not completed The contractor, however, states his expectation of completing the road within eighteen months from the beginning. The Russian government is the chief mover in the construction of the road, and the road is being built by a government contractor of large means.

In this railroad, and in the possibility of a process of refining oil by which an increased percentage of illuminating oil can be eliminated, rests an apparent danger to the petroleum business of western Pennsylvania. With this railroad completed the Baku oil would be placed on tide-water navigation with a railroad haul of nearly 600 miles. The commerce of the Black sea is already very important, Odessa, located upon it, being one of the great grain markets of the world.

Very considerable attention is now being turned toward territory in Europe that presents some aspects of being oil-bearing. The country south of the Caucasian mountains, of which Tiflis is the center, while belonging to Russia, is in Asia. Immediately north of the Caucasian mountains is the Kouban river, emptying into the Black sea.

The following is from my New York daily report of March 12:

"I have recently come more fully in contact with people having knowledge of the oil-producing territory on the Caspian sea than I had at the time of writing my February monthly report, and I now find the statement I made in that report is of much too favorable a character in regard to Baku production and getting the Baku oil to market. The railroad I spoke of as being constructed between the Black and Caspian seas has been constructed for some time from the Black sea to Tiflis, and a short piece has been built, say 12 miles long, on the Baku end, in the vicinity of the oil-wells. It is intended to go to work on the road east of Tiflis soon, but operations have not yet commenced, or had not recently. This distance is between 300 and 400 miles, and there are some uncertainties concerning its construction which may keep it delayed for a long time. I am informed by merchants in this city, who have correspondents in that vicinity, that my information is at fault very considerably regarding the amount of production at Baku, and that it is very much less. Taking into consideration what I am recently informed, the matters at Baku are not of a nature, I judge, that require them at present to be taken into account as having a bearing upon the prices of American petroleum."

Dr. Tweddle, formerly of Pittsburgh and Franklin, representing a French company, is drilling two wells upon this river, and has a small refinery at Taman, a city located near the mouth of the Kouban. He has secured enormous tracts of territory from the Russian government. Five drillers and experienced well-men recently left Oil City to join Dr. Tweddle on the Kouban river. Mr. James R. Adams, of Oil City, experienced in oil matters, has been with Dr. Tweddle since last summer, having previously spent a year at Baku.

The following is Mr. Welch's report on Galicia and Germany:

Galicia, in Austria, has been producing some oil for a considerable time, and has now a production of about 500 barrels per day. This territory has been visited by Americans accustomed to drilling wells and refining oil, who had gone to inspect it, with a view of doing business there, and they came away unfavorably impressed with it as a place to locate in the oil business. Drilling is difficult and expensive there, the strata of the rocks not lying horizontally, but being at an angle that causes them to cave after being drilled through. Much or most of the oil is taken from near the surface from wells dug down, and the oil then bailed out. The oil is unreliable in gravity even at considerable depths, and the heavier grades are a drug, not being treated in such a way as to make a satisfactory lubricating oil. The Galician field is situated on the north side of the Carpathian mountains, and extends a distance of about 200 miles, with a width of about 10 miles. In Hungary, on the south side of the Carpathian mountains, there are the same indications of oil that there are on the north side. An English-American company has secured 29 square miles here, and are now taking steps to operate it.

There have been numerous cable reports published in the newspapers recently of oil discovered in Hanover, Germany. European petroleum circulars I have received since these reports were circulated make no mention of them, and I have as yet heard nothing from my European correspondents upon the subject, although I cabled Bremen about it, and it consequently appears to me that the European petroleum trade is not taking much notice of these reports.

Some petroleum has been found not far from Bremen for the past two hundred years. While I was in Bremen one year ago I took some notes of what gentlemen I met hoped would prove to be an oil district. It is located 128 English miles southeast of Bremen. They had three wells then down, of different depths, as follows: 181, 242, and 680 feet. Of the first two they were getting a small quantity of oil, one yielding 5 and the other 30 per cent. of illuminating oil. The other well they were then beginning to test. I am informed since that it only produces a barrel and a quarter per day, and that it is of heavy gravity. These wells are near the small city of Peine. Wells recently cabled about to the newspapers are near Heide, in the northwestern portion of Holstein.

The following is William Brough's description of the Russian oil-belt:

The Russian "oil belt" may be traced, at intervals more or less remote, from the island of Schily-Khany, near the eastern shore of the Caspian sea, westward over the promontory of Apscheron, and following the line of the Caucasian mountains into the valley of the river Kouban, which empties its waters through a lagoon into the Black sea; thence it may be traced in the same general direction across the Crimea and to the oil-fields of Galicia, in Austria. This belt is actively worked in the Crimea, in the valley of the Kouban, and on the promontory of Apscheron, near the city of Baku; it is only at the latter point, however, that the product is sufficiently large to induce the gathering of statistics. At all other points the petroleum produced, whether gathered from springs or obtained by well-boring, is entirely absorbed by local consumption.

The following table gives the shipments of petroleum and its products from Baku for the years named, in barrels of forty gallons each:

Year.	Refined.	Residuum.	Crude.
1876	392, 977	150, 021	22, 137
1877	561, 236	232, 782	17, 169
1878	750, 218	388, 042	24, 699
1879	828, 347	755, 088	38, 628
1880, to July 1	376, 730	427, 953	24, 470

As the average yield of refined petroleum from Apscheron crude is about one-third, we may estimate the total crude product of that field for the year 1879 at 2,500,000 barrels, or 6,850 barrels per day. This oil is all consumed in Russia, a very little manufactured for lubricating excepted. The residuum is used for fuel, and is consumed nearly altogether by the steam vessels on the Caspian sea and the Volga river.

As shown by the table, the product of the Apscheron field declined about 9 per cent. in the first half of the year 1880, and by the end of that year the decline was so serious that the price, which had ruled for two years with little variation at 24 cents per barrel, advanced in the autumn to between $1 and $2 per barrel; but in 1881 production was so increased that in August the price had fallen to 2 copecks per pood for oil at the wells, equal to 8 cents per barrel of 40 gallons.

The Apscheron oil-field as at present worked lies within a radius of 20 miles of the city of Baku, but nine-tenths of the total product has so far been obtained from the deposit at Balachany, which covers an area of from 2,000 to 3,000 acres. This deposit has proved very rich. The oil is found in a loose, open sand, at a depth varying from 120 to 450 feet, and is brought to the surface in balers having check-valves in the bottom similar to the sand-pump used in the Pennsylvanian oil regions, the large amount of loose sand which comes up with the oil preventing the use of the ordinary suction-valve pump used in American wells. The largest well ever found in the Balachany district had been producing for six years in 1879, and had yielded during that time an average of 1,200 barrels per day—a production much in excess of that of any Pennsylvanian well. The diameter of the wells is from 8 to 12 inches; the capacity of the balers from 20 to 40 gallons. There are about 400 wells in the entire Apscheron district, the largest outside of Balachany giving about 10 barrels per day, and the average yield of the whole number, including Balachany, being about 20 barrels per day.

Balachany is situated 12 miles north of Baku, and is connected with it by a railway. There are also two pipe-lines for the transportation of oil to the latter place, where the refineries are mainly situated, and which is the port of shipment. There is one other pipe-line from Balachany to Soorachany, 5 or 6 miles distant, and 10 miles northeast of Baku. At Soorachany a large refinery is located, in order to utilize as fuel the gas from gas-springs there; there, too, may still be seen an ancient temple of the fire-worshipers, where prayers are daily said to a jet of petroleum gas, whose flame is never permitted to expire.

The development of the Apschoron oil-field has constantly been restricted by want of transportation facilities, the only outlet for the production from Baku to the markets of Russia being by way of the Caspian sea and the Volga river. Beside this new business of petroleum, now thirteen years established, the general commerce of the Caspian has in the same time been steadily growing, and the number of sea-going vessels, though constantly increasing, is still quite inadequate to supply the demand for transportation. In 1878 there were 30 steamships plying this sea; and of these 12 were imperial, leaving 18 merchant ships, varying in size from 300 to 500 tons. Eleven more were added in 1879, making 29 merchant steamships in all. There are beside numerous sailing-vessels. The steamships are all of foreign build, mainly English, and having to pass through the canals connecting the Baltic with the Volga, their size is consequently limited thereby. Some of them have been floated through in two sections. As the depth of water in the delta of the Volga is ordinarily but 2 feet, it is only in the spring of the year, when the water is 9 feet deep there, that these vessels can enter the Caspian. The oil, both crude and refined, is conveyed by these vessels in bulk compartments, as well as in casks and barrels, steamers being used almost exclusively for refined and sailing-vessels for crude and for residuum. The voyage is made from Baku to "nine-foot" water, where the vessels anchor in open roads and deliver their cargoes to barges built expressly for the shallow waters of the delta. These barges convey the oil to Astrakhan, a distance of 330 miles.

At Tzaritzin the facilities for unloading the barges, for storing oil, or delivering it to the railroad are modern in character, and are really copied from the American methods. They consist of pipes, pumps, and large iron storage-tanks. The railroad also is equipped with iron tank-cars similar to the American. Farther up the Volga the railway again connects with the river at Saratov, at Syzran, and at Nijni-Novgorod, to all of which oil is shipped, the last named being the most northerly point of river shipment, and 1,400 miles from Astrakhan.

In January, 1880, the Russian government granted a concession for the building of a railroad between Baku and Tiflis, the capital of the Caucasus, which was already connected by rail with Poti, on the Black sea. When this road shall be completed, it will furnish an outlet for Baku oil to the markets of Europe, and will bring it into direct competition with American oil in those markets The work of building this road is, if measured by the Russian standard, progressing rapidly. In August, 1881, 120 versts (about 80 miles) between Baku and Adji-Kabul was finished and in running order, and it is expected that the whole road will be completed by August, 1882. Its oil-car equipment will have capacity to deliver at the Black sea 1,000,000 barrels per year. As the harbor of Poti is exposed and unsafe, the railway will be extended 60 miles farther south to Batoum, recently ceded by Turkey to Russia, and the best harbor on the Black sea. The whole length of the railway will be 660 miles. The freight rate is uniform on all the railroads of Russia, being prescribed by the imperial government, and in 1879 was for petroleum 1 copeck per pood for 45 versts, or 9¼ mills for carrying one ton of 2,000 pounds 1 mile. At this rate the cost of transferring a barrel of petroleum from Baku to Batoum will be 88 cents.

As the petroleum product of Apscheron has thus far been so steadily maintained above the carrying capacity of the vessels on the Caspian sea, we need not doubt that, with the opening of the Baku and Tiflis railroad, other deposits will be found along the line indicated. Indeed, the Russian oil man is fully alive to this conception, and is already prospecting along the whole line from Baku to Adji-Kabul, buying and selling, leasing and releasing, oil lands after the manner of his American prototype. But until this railroad is completed the Americans need not fear competition from that quarter. The high rates of freight on the Caspian, the delays and hazard attending the discharge of cargo in open sea at "Nine-foot", the double transfer, and the long voyage from "Nine-foot" to Tzaritzin, requiring the service of steam-tugs all the way, these, added to the fact that this only outlet is closed by ice from November until April, form a complete bar to such competition. Indeed, it is doubtful whether the Russian could now hold his place in his own market without the help of the duty imposed for his protection upon American petroleum. This duty is 9 cents per gallon, payable in gold.

The gravity of Baku oil ranges from 26° to 36° B., there being very little of the latter grade, and the gravity of oil taken from pipe-line tanks, where the product of different wells is mixed, is about 30° B. This mixed oil gives a yield of 33 per cent. illuminating oil, and the residuum is used for fuel. No other fuel is used by steamers on the Caspian sea. Many of the steamers on the Volga also use it. It is also the only fuel used by the locomotives on the railway now building and partly completed from the eastern shore of the Caspian sea into the Turkoman territory recently acquired by Russia.

The oil-fields of the Kouban valley and the peninsula of the Taman, on the Black sea, have been worked actively, with some intervals of comparative rest, since 1864. In that year a Russian nobleman, Count Novosiltzoff, leased 1,500,000 acres from the "Cossacks of the Kouban" and began operations on an extensive scale. He employed American workmen, and extended his well-drilling over a stretch of country 150 miles in length. He also built a large refinery at Taman, on the straits of Enikale, near the western end of his territory. It is difficult now to ascertain what success attended his operations. At one point, Kudokko, it is said he obtained a very large well, some Cossack estimates putting it at 10,000 barrels per day; but we may rest assured that this is a greatly exaggerated statement. It may be doubted whether the well produced at any time 1,000 barrels per day, or for any considerable time even a hundred, for Novosiltzoff failed to obtain oil enough from his wells to compensate him for his expenditures, notwithstanding that the price ruled very much higher then than now; and his enterprise finally failed, after sinking his original capital and involving him in an indebtedness of about 1,500,000 rubles. The Kudokko well is still producing; its yield in 1878 was about 23 barrels per day. The well was then four years old. It is pumped by steam-power, with a suction-valve pump. The oil is of good quality, olive-green in color, gravity 36° B., and yields when distilled 50 per cent. of illuminating oil. A small refinery on the estate works up the oil into lubricants and illuminants, and finds ready sale for the entire product in the Cossack community of the neighborhood. Twenty-eight other wells were drilled around this first well without increasing the total product; indeed, the Kudokko oil-field has been shrinking steadily since it was first opened, notwithstanding the occasional drilling of new wells, and its total product is now less than 20 barrels per day.

In 1879 a French company, under American management, leased all the Novosiltzoff land except the 25,000 acres which form the Kudokko estate, and began operations in a vigorous manner. This company is still at work; it has in its employ skilled, practical workmen from the oil regions of Pennsylvania, and it has made several large shipments of well machinery from America. It also recently purchased here pipe and pumps for a pipe-line from Ilsky, where its most productive wells are situated, to the port of Novorossisk, on the Black sea, 65 miles west of Ilsky. It is perhaps too soon to determine what success in finding oil will attend its operations; but the total yield of its wells is thus far about 80 barrels per day, and the greater part of this product is of inferior character, being a black bituminous oil. It may, however, be doubted whether any large deposit of petroleum will ever be formed within the limits of this field, taking Ilsky as its eastern boundary and including all the land westward which forms the peninsula of Taman, bounded on the north by the sea of Azov and the straits of Enikale and on the south by the Black sea. There has been a large amount of unsuccessful test-drilling done here in the last sixteen years, but no rock has yet been found which makes a suitable receptacle for petroleum. Wherever found, the oil is diffused through the whole strata of soil and near the surface, so that no mechanical ingenuity is required to reach it, but it can be obtained with the rudest well-boring implements. It is therefore reasonable to conclude that the country has been worked for oil from remote times.

The greatest depth at which oil has been found here is 400 feet, and deeper drilling has thus far given no promise of success. These remarks are equally applicable to the Crimean district, which is of the same character.

Although illuminating oils manufactured in Russia from the native crude product compare favorably with the American oils, the latter have nevertheless been yearly imported into Russia, though in diminishing quantity; but the fact that these imports still continue seems to need some explanation, in view of the heavy duty of 9 cents per gallon imposed on American oil. A comparison of the burning qualities of the two oils shows that the American gives a slightly whiter flame, and that it is less liable to smoke than the Russian. In odor and color they are equal. The Russian oil burns with undiminished flame until the oil in the lamp is exhausted, while the flame of the American sinks when the oil becomes low in the lamps. The fire-test of the Russian oil is quite as good as of the best American, and the tendency to smoke of the Russian is easily overcome by a proper adjustment of the lamp-chimney.

The Russians have lately introduced some new patterns of chimneys.

These remarks apply only to standard oils of both countries found in open market at St. Petersburg, rejecting special brands and inferior or defective lots.

The following table gives the imports of American refined petroleum into Russia for the years named, the figures being taken from Russian official records and transposed from "poods" into barrels of forty gallons each:

	Barrels.		Barrels.		Barrels.
1867	68,316	1872	203,901	1877	261,780
1868	111,424	1873	379,481	1878	251,227
1869	158,137	1874	310,981	1879	188,752
1870	198,386	1875	308,225	1880	143,154
1871	217,555	1876	277,671		

In conversation with Mr. Charles H. Trask, of the firm of William Ropes & Co., of 70 Wall street, New York, largely engaged in the Russian trade, he remarked that transportation from Baku to St. Petersburg was so expensive that a high gold duty, augmented by a depreciated currency, alone rendered the manufacture of Russian oils in St. Petersburg possible. Without this duty the oils could not compete with American, although the lubricating oils made from Russian crude do not chill and are superior to American lubricating oils. He said, further, that shipments of low-grade American oils to Russia had entirely ceased, but that high-test American oils were still sold there. As the tariff may be changed at any time, the business was somewhat uncertain both for those within and those outside Russia.

I have not been able to obtain any satisfactory statistics of the Canadian production. So far as I can learn, stocks had accumulated in Canada before 1879, but during that year and subsequently these stocks were drawn down, so that the production of refined during the census year was no indication of the production out of the ground. I have not therefore made any attempt to estimate the Canadian production, which is only of local importance, as partially supplying the Dominion markets.

PART II.

THE TECHNOLOGY OF PETROLEUM.

PART II.

Chapter I.—MIXTURES OF PETROLEUM.

Section 1.—FILTERED PETROLEUM.

Petroleum was prepared for use, particularly in medicine, by filtering, at a very early date in southern Ohio. Dr. Hildreth, as early as 1833, (*a*) mentions filtering petroleum through charcoal, by which much of its "empyreumatic smell is destroyed and the oil greatly improved in quality and appearance". Since that time petroleum has been filtered through gravel and through both wood and animal charcoal, in order to remove all sediment from it, and at the same time to remove in part both its color and its odor; but since the methods of refining by distillation have been discovered, it is chiefly the more dense oils that have been treated in this way. These dense natural oils are often injured by distillation in the properties which render them valuable for lubrication, and filtering appears to furnish the only means of removing, even in a partial manner, the color and the often quite disagreeable odor.

Section 2.—MIXTURES OF PETROLEUM.

The mixtures into which petroleum enters are chiefly used for lubrication. They consist of petroleum and heavy products of petroleum mixed mechanically with animal and vegetable oils, tallow, resin, and allied materials, of the same mixed with mineral substances, and also of the same mixed with chemical compounds. The first class of compounds is made in very great variety; in fact, there is scarcely a wholesale oil house in the country but has some formula of its own for compounding lubricating oils, into which petroleum or the products of petroleum enter as a constituent. Some of these are sold honestly as mixtures, while others are adulterations pure and simple. Some of these mixtures are prepared in the rudest manner, and are used only for the coarsest purposes; others are prepared with great care, the mixture being effected by heating and purified by straining or filtering the oil through various materials. The general purpose for which mixtures are prepared is to produce a lubricating material that will be quite as effective as animal or vegetable oils and at the same time be less expensive. A few mixtures are prepared and sold on their merits as preparations of a superior quality, while some dealers maintain that the larger the proportion of mineral oil the better.

The oils used in preparing these mixtures are sperm, whale, and lard oils to a considerable extent, especially for lubrication. Neat's-foot oil and castor oil are used in mixtures for dressing leather. Lard-oil mixtures have been used for oiling wool. In Germany a mixture is sold under the name of "Vulcan oil", which consists of a petroleum distillate of a specific gravity of from 0.870 to 0.890, treated with about 6 per cent. of sulphuric acid and well washed with water, and then mixed with 5 per cent. of rape oil. Another, called "opal" oil, consists of petroleum distillate of a specific gravity of from 0.850 to 0.870, similarly treated and washed, and mixed with 10 per cent. of rape oil.

The mixture of petroleum products with mineral substances have only been invented quite recently, and are principally the so-called plumbago oils manufactured in Rochester, New York. By a process which has been patented, reduced petroleum is apparently ground with graphite, as paints are ground in oil, resulting in a complete suspension of the graphite in the oil. It is claimed that these oils are very superior lubricators for railroad axles and steam cylinders, the latter becoming coated with a polished coat of graphite soft as silk. The Johnson Graphite Oil Company publishes a certificate showing that a car had made over 13,000 miles of mileage on one application. It has also been proposed to treat heavy reduced oils with powdered pyrophyllite. This mineral resembles talc, and when powdered is especially soft and greasy to the touch.

The most striking example of chemical preparations of petroleum is perhaps found in the justly celebrated Galena oils, manufactured at Franklin, Pennsylvania. These oils consist of a lead soap dissolved in petroleum. A lead soap is prepared after the ordinary manner by boiling oxide of lead with a saponifiable oil, and the whole is dissolved in the natural heavy oil of the Franklin district. The oils thus prepared have great tenacity and endurance as lubricators, particularly for car-axles, for which purpose they are principally used.

Mixtures of natural oils and tallow, natural oils and residuum, reduced petroleum, residuum from acid-restoring works, containing sulphur, pine tar, etc., are used on car-axles and for other heavy lubrication.

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a A. J. S. (1), xxiv, 63.

CHAPTER II.—PARTIAL DISTILLATION.

SECTION 1.—SUNNED OILS.

The thickening by evaporation of oils spilled upon the Allegheny river and its tributaries, by which an ordinary third-sand oil would become converted into a dense oil fit for lubrication, led to experiments upon the lighter first- and second-sand oils around Franklin that were too light for lubricators and too dense for profitable manufacture into illuminating oils. These experiments were first undertaken by Mr. William H. Brige, of Franklin, and consisted in an attempt to imitate the conditions observed on the river as nearly as possible. Mr. Brige first exposed the oil spread on the surface of water in a small pan 3 feet square. This pan was placed in the sun, and the light oils were allowed to evaporate until the desired consistence was reached. The method was found to be entirely successful. The plan, since adopted on a larger scale, is as follows: A wooden tank is provided, sunk in the ground nearly its entire depth, 60 to 70 feet long, 20 to 30 feet wide, and 1 foot deep. A flat steam coil is laid upon the bottom, and water is run in from 8 to 10 inches deep, upon which a layer of oil about an inch thick is placed. The water is heated by the coil to about 110° F., and the oil becomes very limpid. Every description of dirt, particularly minute particles of grit, that was held in suspension in the viscid oil is left free to fall to the bottom of the tank, and the specific gravity of the oil is reduced in a few days from 32° to 29° B. The oil loses by this treatment about 12 per cent. of its volume, and is increased in value from $5 to $12 per barrel.

SECTION 2.—REDUCED OILS.

Throughout the entire region the observation has been made repeatedly that oil left in open tanks evaporates and decreases in specific gravity Baumé. Mr. George Allen, of Franklin, acting on such observations, patented a novel method of partially evaporating petroleum which produces a very superior quality of oil. He suspends sheets of loosely woven cloth vertically above troughs in a heated chamber and by a perforated pipe distributes the oil upon the upper border of the curtain in thin streams. The oil is thus distributed over a large surface in the heated atmosphere, and the thin film is rapidly evaporated, the light portion passing into the atmosphere, and the heavy portion dripping from the lower border of the curtain into the troughs, from which it passes into a receptacle. This method of treatment furnishes a bright green, odorless oil, entirely free from sediment of any kind, such impurities remaining attached to the curtain. These methods of partial evaporation are particularly valuable, as they preserve all the qualities of the natural oil, without any danger from the effects of overheating.

Many thousands of barrels are reduced every year by partial evaporation in stills, either by direct application of heat or by the use of steam, the evaporation for this purpose being always so carefully conducted as to avoid overheating and "cracking" or any approach to destructive distillation. The different grades of naphtha are usually run off, and then a sufficient amount of distillate is removed to reduce the portion remaining in the still to the required specific gravity. The amount of reduction depends upon the purpose for which the oil is intended, not only with regard to its density, but also with regard to the velocity and temperature at which the machinery is to be run. For use on large journals and those revolving at moderate speed the oil is reduced to a specific gravity of from 29° to 32½° B., but for use on small journals moving with great velocity, and also in the interior of cylinders, where the temperature is very high, a still greater reduction is found necessary, and the oil is made more dense. At the same time it is made less volatile, having a specific gravity of from 26° to 29° B.

A large proportion of the lighter grade oils of West Virginia and Ohio and the entire production of the Smith's Ferry district are treated in this manner. The latter oil is very peculiar, having the color of pale sherry, without its transparency, and when freshly pumped has a specific gravity of 50° B., with a much less pronounced and less disagreeable odor than any other petroleum produced in commercial quantities in the United States. When reduced with the aid of steam the distillate of suitable specific gravity for burning oil requires little or no treatment with acid or alkali, and the reduced oil from the still preserves its amber color and freedom from offensive odor, furnishing a lubricator of very superior quality and attractive appearance.

Reduced oils are often filtered through animal charcoal, and are thereby greatly improved in color and odor.

CHAPTER III.—GENERAL TECHNOLOGY OF PETROLEUM BY DISTILLATION.

SECTION 1.—INTRODUCTION.

Oils were first obtained for commercial purposes by distilling shales and coal early in the present century, but they had been thus produced in small quantities for experiment more than a century before. Gesner, in *Coal, Petroleum, and Other Distilled Oils*, 1861, page 8, says:

As early as 1694 Eele, Hancock, and Portlock made "pitch, tar, and oyle out of a kind of stone", and obtained patents therefor. * * * In 1781 the earl of Dundonald obtained oils from coals by submitting them to dry distillation in coke ovens. * * * Laurent, Reichenbach and others distilled the tars obtained from bituminous schists. These tars were purified in some degree by Selligne, and the oils subsequently obtained an extensive sale in Europe for burning in lamps and for lubricating machinery. * * * Patents were granted in England in 1847 to Charles Mansfield for "an improvement in the manufacture and purification of spirituous substances and oils applicable to the purposes of artificial light", etc. Mr. Mansfield's operations appear to have been chiefly directed to the coal tar of gas works, from which he obtained benzole. He was perhaps the first to introduce the benzole or atmospheric light, which is described at length in his specifications.

From a letter received from the eminent English geologist, E. W. Binney, I extract the following statement concerning the origin of the paraffine oil industry of Scotland:

In 1847 Mr. James Young came to me to ask for information as to petroleum, he having agreed to work some at Riddings, near Alfreton. I gave him all the information I possessed. In 1848 I went over with him to Down Holland Moss (*a*) and showed him the petroleum peat there and brought away samples for him. In the same year I went to Riddings and descended Mr. Oakes' coal-pit and examined the petroleum as it came from the roof of the coal-seam. I then distinctly told him that the oil could be made from highly bituminous coal, distilled at a low heat in a something similar way as the peat and gas-coal yielded it. In 1850 Mr. Young and I became aware of the discovery of a highly bituminous coal at Boghead, in Scotland. We met at the British association, in Edinburgh, at the end of July. I went over to Bathgate, descended the pit where it was wrought, brought a sample of it, and showed it to Messrs. Young and Meldrum, who said they thought it would not make oil. I said that if they could not make oil from it I could. In a day afterward they asked me to join them in a patent to work the invention. Mr. Young was to take out the patent in his name, and Mr. Meldrum and I were to join him in owning and working it. I accordingly bought land, found money, and purchased 10,000 tons of Boghead coal. These works were carried on under the style or firm of E. W. Binney & Co. for fifteen years. I drew the specification of the Young's patent and invented the name paraffine oil, which term was quite new. In 1856 I took out an American patent in Mr. Young's name for the invention, and several parties took licenses in the United States to work it there, paying 2 pence per gallon royalty to us, they fetching Boghead coal from Scotland at a cost of £4 or £5 per ton when delivered. Breckenridge and some other American coals were also used, I believe. As some of these parties refused to pay their royalties, we went to law with them in the states, and their lawyers, having heard that our patent had been the subject of a trial in the court of Queen's Bench, wrote to England for the history of Young's patent, which was reported in the *Journal of Gas Lighting*, in a trial at law, Young *vs.* Hydrocarbon Gas Company, June, 1854. In this trial Mr. Young gave in evidence that he obtained paraffine oil from petroleum before he resorted to coal to obtain it. That would be about 1860; and our American patent never yielded us another cent of royalty. Oil lamps for burning it having been invented in Europe, all was ready for the start of your vast petroleum trade. We always dreaded your native oil coming on us, but we did pretty well before it rushed out, and our patent expired in 1864.

There was no lack of information in this country respecting the properties of petroleum prior to 1860.

Professor Silliman, sr., in 1833, wrote:

I have frequently distilled it in a glass retort, and the naphtha which collects in the receiver is of a light straw color and much lighter and more inflammable than petroleum. On the first distillation a little water rests in the receiver at the bottom of the naphtha, from which it is easily decanted, and a second distillation prepares it perfectly for preserving potassium and sodium, the object which has led me to distill it. (*b*)

In a communication made to the Bradford *Era* of July 4, 1881, some one signing himself "Old Salt Well" gives the following story of the first attempt to refine petroleum in northwestern Pennsylvania. Speaking of the salt-wells near Tarentum, Armstrong county, Pennsylvania, which, with the springs on Oil creek, at that time produced all of the petroleum of that region, he says:

To my certain knowledge they only produced from three to five barrels per day, and I recollect distinctly there was but one well that produced oil only. The wells were pumped, the oil mingling with the salt water. The wells were owned by a gentleman named Kier. When the wells first yielded oil it was placed in four-ounce vials and hawked about the country at 25 cents per bottle as Seneca or rock oil for medicinal purposes. In the year 1854 a small refinery was built at the corner of Grant street and Seventh avenue, Pittsburgh, the point of the old canal outlet into the Monongahela river and the same locality of the present railroad tunnel. It was there the first carbon oil was refined for illuminating purposes. The still did not have a capacity exceeding five barrels. It occupied a one-story building, in size about 12 by 24 feet. In the spring of 1855 I purchased a gallon of the oil, had it placed in a stone jug, and took it home for the purpose of illumination. The kind of lamp in which the oil was used was the same as what was then employed for a substance called burning fluid. The lamp had from one to five small tubes, and was made of britannia or pewter. To trim the lamps cotton-wick was drawn into the tubes, perfectly tight, and the wick was cut down closely until it ceased smoking, and then the lamp was nearly as perfect as any lamp of the period. Each one of those tubes produced a light equal to about two tallow candles. In the year 1876 or 1877 the still that was employed in this immense refinery was displayed at the exposition in Allegheny city, and was labeled as the first still ever used to refine petroleum. In its day it supplied the world's demand for that kind of an illumination. The matter of where the first oil was produced I believe is not the question. Any of the old salt manufacturers about Tarentum can corroborate

a On the coast north of the Mersey. *b* A. J. S. (1), xxiii, 101.

what is here stated, and perhaps furnish many interesting details not contained in this brief article. These wells were located 18 miles from Pittsburgh, near the path of the old Pennsylvania canal. Colonel Drake was not the first man to produce petroleum, but he was certainly the first person who drilled a well for the express purpose of finding oil. The questions of when and by whom the first oil was produced and refined can readily be established by indisputable proof.

The Mr. Kier mentioned above was Mr. Samuel M. Kier, before mentioned in this report (see page 10), who, with his friend Mr. McKuen, carried on the enterprise as described. This statement is corroborated by a large amount of evidence from independent sources. It was not a lack of knowledge, but a lack of petroleum, that prevented its use by American manufacturers before 1860. Drake sold his oil to McKuen for 75 cents a gallon.

The editor of the *American Journal of Science and Arts* in 1861 reviewed Gesner's *Coal, Petroleum, and other Distilled Oils*, and says:

The author recognizes the intimate relation of the manufacture of coal oils with the production in such increasing abundance of petroleum, destined to become a powerful competitor of the artificial product for economic use. It is instructive in this connection to recall the fact that the natural product (petroleum), which has been well known from the earliest records of human history, should have remained comparatively useless and almost neglected until the modern art of coal-oil distillation has shown its industrial value. *It is quite possible that the future historian of the industrial arts may look back on the coal-oil distillation as only an episode in the history of the development of the use of petroleum.* (*a*)

In 1862 Isaiah Warren and his father, being in the lard-oil and candle trade in Wheeling, West Virginia, commenced the distillation of West Virginia petroleum in three 15-barrel stills, and Mr. Warren, sr., was apprehensive that they would glut the market, the price of refined oil then ruling at from 85 cents to $1 15 per gallon.

SECTION 2.—EARLY METHODS.

The stills in general use at this time were made in three parts, bolted or riveted together, and consisted of a cylindrical cast-iron body, to which was attached a boiler-plate bottom and a cast-iron dome and goose-neck. They held about 25 barrels, were heated from the bottom and bricked up upon the sides, and were sometimes protected from the direct action of the fire by fire-brick. These stills were charged with crude oil, the charge run off, the still cooled, and the coke cut out, often with a cold-chisel. When four-fifths of the oil had been run off the remainder was, when cold, as thick as pitch; at this point some refiners introduced steam, which mechanically expanded and carried over the last volatile portions of the charge, leaving a compact coke, while others distilled to coke without steam. The use of steam at a high pressure in the distillation of Rangoon petroleum and coal had been patented in England in 1857 by Mr. Bancroft, of Liverpool; and Mr. Wilson, a manufacturer of stearic acid, in 1860 used superheated steam in the distillation of natural petroleums. (*b*) Steam under moderate pressure was also frequently used throughout the entire distillation, both above the charge and injected through it. In the latter case it becomes superheated as the boiling point of the oils rises above that of water; it was, however, considered preferable with the dense paraffine oils to superheat the steam before it entered the oil. Sometimes, after the charge in the retort was partly run off, it was the practice to allow a stream of fresh oil to enter the still about as fast as the vapors were condensed. In this way about twice the ordinary charge could be distilled and the residue of the whole run down to coke. The light naphthas were first taken off and were used for fuel or were allowed to run to waste, there being at that time little or no sale for these products. The distillate was then run to illuminating oil until the specific gravity reached 36° B. = 0.843, and the remaining charge run down till the distillate became of a greenish color. The illuminating oil was then placed in an iron- or lead-lined tank and agitated for one or two hours with oil of vitriol washed, then with water, and afterward treated in the same manner with caustic soda solution of a specific gravity of 1.400 and again washed with water. Some refiners considered this successive treatment with acid and alkali sufficient; others subjected the treated oil to a second distillation, sometimes over solid caustic soda; but this distillation had to be conducted with great care. Some of the earliest and most successful refiners of petroleum on the Atlantic coast were formerly manufacturers of whale and sperm oil, and, having been accustomed to expose their animal oils to sunlight under glass roofs in shallow tanks, they adopted with uniform success the same method of treatment for the mineral oils. Both the color and the odor are improved by this exposure. The heavier naphthas and heavy oils were subjected to redistillation, either alone or with more crude petroleum, and all of the distillate of a proper specific gravity for illuminating oil was carefully separated. The remaining heavy distillate was treated with acid and alkali and sold as "paraffine oil". It was of a dark color and rank odor, and found its way into use very slowly, not only on account of its real inferiority, but on account of violent prejudice against it.

SECTION 3.—DESTRUCTIVE DISTILLATION.

The general method of manipulation just given was in very general use until about 1865, when the method of cracking or destructive distillation of the heavier oils was generally adopted. A great variety of chemical reagents were used in treating the oils. Solid caustic soda was used in the stills. The oils were washed with nitric acid; bichromate of potash was added to the sulphuric acid, and the combined action of sulphuric and chromic acids

a A. J. S., 1861.

b J. F. I., lxix, 338, 1860; Cosmos, Mar., 1860.

was thus secured: and chloride of lime or bleaching powder in the proportion of 3 ounces to one gallon of oil has been used with hydrochloric acid, the oil finally being treated with lime water. Whatever reagents are used in treatment, it has been found necessary to bring the oil to a uniform temperature above 60° F. In the old form of agitator, when the mixture was effected by machinery, the injection of steam during agitation has been found beneficial both for bringing the oil to the required temperature and to facilitate the washing and settling of the acid and alkaline solutions. (*a*)

In December, 1865, James Young, jr., of Limefield, took out a patent in England for an improvement in treating hydrocarbon oils that was noticed as follows in the *Chemical News* for August 31, 1866:

> This looks like a very valuable invention. The patentee submits the heavier hydrocarbon oils to distillation under pressure, and finds that thereby the heavier oils originally operated upon are converted into oils of lower specific gravity, possessing a higher commercial value. The process may be carried on in ordinary steam boilers (not tubular), which should be proved to 100 pounds; but it is not found necessary to operate much beyond a pressure of 20 pounds to the inch. The means of regulating the escape of the vapor, and of condensing it, can be easily imagined. The operation may be carried on with the crude products of the original distillation, or the lighter oils may first be separated by an ordinary rectification, and only the heavy oils submitted to this treatment. (*b*)

At about the time that this invention was patented in England the same results were obtained in the United States by an entirely different method of manipulation. This method consisted in a slow and repeated distillation, which produced destructive distillation of the medium and heavy oils, converting them into oils of a density suitable for illumination with a production of gaseous products and deposition of carbon. In order to accomplish this result the brick casing was removed from the stills, and after that portion of the distillate suitable for illumination had been separated the fires were slackened and the vapors of the heavy oils as they rose into the dome of the still were allowed to condense and drip back upon the hot oil below, which had meanwhile been heated to a temperature above the boiling point of the oil dripping upon it. This practically superheats the vapors of the oils and produces decomposition. The effect of distillation under pressure is precisely the same: the oils are distilled at a temperature above their normal boiling points. By this method of distillation the petroleum can be converted into naphtha, illuminating oil, and coke, with a certain amount of gas either escaping into the atmosphere or being burned as it escapes. The illuminating oil may be collected in one receptacle and be made of uniform grade, or that portion of the petroleum suitable for purposes of illumination can be separated from that produced by destructive distillation, thus furnishing two grades of illuminating oil which are quite different in composition and quality, the light oils in the crude petroleum being superior to those produced by the decomposition of the heavier portions of the oil. This method of distillation had been successfully pursued in treating the distillates from coal before the introduction of petroleum, but it was not generally applied to the treatment of petroleum, especially in very large stills, until about the time here indicated. Its successful introduction and general adoption was, however, the result of an accumulated experience, not only in the distillation, but quite as much in the subsequent treatment of the oil with acids and alkalies, especial regard being had to the temperature while undergoing treatment. The result of the adoption of this method of manipulating the oil by one distillation was the gradual separation of petroleum refiners, in a general way, into two classes: a small number who continued to manufacture a variety of products from petroleum, and a large number who manufactured principally illuminating oils. While the division thus made is correct in a general sense, it must not be understood as applying strictly to all the parties engaged in manufacturing petroleum. There are those who reduce petroleum and sell their light distillates; others who reduce petroleum and treat their own distillates; others who produce nothing but enormous quantities of crude naphthas, illuminating oils, and residuum, selling their crude naphtha to parties who redistill and fractionate the naphtha into several products—their illuminating oils to the general trade, and their residuum to manufacturers of lubricating oils; others who refine and fractionate crude naphtha; others who manufacture lubricating oils, using both crude petroleum and residuum for the purpose; others who manufacture in one establishment nearly everything that can be made from petroleum; and still others who have special processes by which peculiar products are obtained. It is unnecessary to describe in detail all of these different methods of conducting the business of manufacturing petroleum; it is sufficient for my purpose to describe carefully what may be termed two typical establishments, and then to describe a number of processes that are used for special purposes.

Section 4.—DESCRIPTION OF THE APPARATUS USED IN MANUFACTURING PETROLEUM.

Before describing the process above mentioned, it will be necessary to describe in detail the apparatus which is in general use in such establishments.

Location.—The largest petroleum refineries in the country are at tide-water at Hunter's Point and Newtown creek, Long Island; Bayonne, New Jersey; Point Breeze, below Philadelphia, and at Thurlow, below Chester, on the Delaware; and near Baltimore, Maryland. At Bayonne, New Jersey, the Standard and Ocean refineries have piers 1,000 feet in length, with sufficient water to float the largest ships and facilities for loading from 6,000 to 7,000 barrels of refined oil daily. In western Pennsylvania and Ohio the refineries are usually located upon the side of a hill, the storage-tanks for crude oil being placed highest and the oil distributed by gravity so far as is possible.

a See *Chemical News*, vi, 230. *b* C. N., xiv, 108.

BUILDINGS.—The buildings of refineries are in the greatest variety possible. In the older establishments, particularly in the Atlantic cities, the works are carefully inclosed with substantial buildings of brick and iron, while the other extreme is to be observed in newer establishments, either just going into operation or being rebuilt after destructive fires, when scarcely anything about the place except boilers, engine, and pumps is covered, the receiving-tanks being underground and the stills without any covering at all. The works of the Downer Kerosene Oil Company, at South Boston, have always been very carefully inclosed in valuable brick buildings, and no serious loss has occurred there for many years. Some of the immense refineries at and around Hunter's Point, Long Island, are also fully inclosed; but the works of the Tide-Water Pipe Company at Thurlow, Pennsylvania, on the Delaware, only recently constructed, and said to be one of the most complete establishments of the kind, are almost as completely exposed to the elements as those of the smallest and rudest concerns in the oil regions. The boilers are placed in one building, the pumps in another, the office in another, all of which are of brick; but the stills and condensers are without any covering whatever. The distillate tanks are all underground; the agitating tank is isolated and uncovered; and the sunning and spraying tanks are in buildings made of rough boards, and are of little value. The works of the Acme Oil Company, at Titusville, Pennsylvania, built to replace those burned during the census year, appear to be built on a hillside from which fire has removed even the soil, and to be without a building or a covering of any description.

TANKAGE.—The oil is received at the refineries either from pipe-lines or from the tank-cars of transportation companies, and in either case it is pumped into vast storage-tanks holding from 10,000 to 36,000 barrels each. The tank-cars are provided with gates or valves on the under side, to which hose may be attached, and connections are made with a large pipe laid beneath the track, into which the oil rushes as soon as the gates are opened. This pipe discharges the oil into a tank, from which it is pumped to the storage-tanks. In these tanks from one to two per cent. of water settles, and from them the oil is pumped into the stills.

STILLS.—A great variety of stills are in use for different purposes, and the greater the variety of products produced from the petroleum the greater will be the variety of stills in use as regards both size and form. In some establishments the old cast-iron, upright cylindrical still, with wrought-iron bottom, is still in use. To these have been added plain, horizontal wrought-iron cylinders of various sizes. One of these, as now quite generally used, is represented with the setting in the vertical section in Fig. 37, and a bank of three, as they are usually set, in Fig. 38. From these sections it will be observed that they are 12 feet 6 inches in diameter and 30 feet in length. The vapors rise into a dome 3 feet in diameter, from which they pass to the condenser through a single pipe 15 inches in diameter. No more simple form of still could be devised. The so-called cheese-box still, now in great repute, is shown with the setting in horizontal and vertical section in Figs. 39 and 40. It is 30 feet in diameter and 9 feet high, with a dome-shaped top, and works 1,200 barrels of crude oil. The bottom has a double curve, to allow of expansion; the sides are of five-sixteenths-inch wrought-iron and the bottom of five-sixteenths-inch steel, the whole inclosed in a sheet-iron jacket. The center is supported upon a cylindrical pier of brickwork, through which the products of combustion are led to the stack. The circumference is supported upon seventeen arches, in sixteen of which are fireplaces, the sides of which converge toward the center and discharge over a bridge-wall through four arches into the center of the pier just mentioned. Through the seventeenth arch passes the discharge-pipe from the bottom of the still. The vapors escape from this still through three pipes, two of which may be closed by cocks, into a sort of chest or drum (Fig. 41), from which 40 pipes 3 inches in diameter pass through to the condensing tanks. Steam is introduced into the heated vapors as they escape from both the cylindrical and cheese-box stills by placing a curved and perforated pipe of the form shown in Fig. 42 at the point where the vapors emerge from the still and enter the exit pipe. The use of steam in this manner is found to improve both the color and the odor, especially of "cracked oils".

Several attempts have been made to produce continuous distillation; but I cannot learn that any of them have proved commercially successful, although an apparatus of the kind erected in Buffalo has been put in operation and distillates have been produced that were treated and sold. This apparatus was patented by Samuel Van Syckle, of Titusville, Pennsylvania, May 22, 1877, No. 191203. It consists of a series of stills, in which the oil is maintained at a constant level by means of a tank, in which a float on the surface of the oil as it rises and falls automatically controls the flow. The first still is maintained at such a temperature that the naphthas and other light products are removed, and in the other two the illuminating oils are removed so effectually that residuum may be drawn off from the last still. I think this apparatus should be more thoroughly tested before its merits are finally judged, especially as to how far its value is modified by complexity and expense of manipulation.

Another apparatus, evidently much more simple in construction than Van Syckle's, but at the same time not calculated for handling the enormous quantities of oil refined in this country, has been patented in Germany by Herr Fuhst. (*a*)

The deodorized lubricating oils, of which Mr. Joshua Merrill, of the Downer Kerosene Oil Company, was the inventor, have been prepared by him in a still of peculiar construction, especially adapted to the treatment of petroleum and kindred substances. An accident suggested the preparation of these oils to Mr. Merrill. In

a Dingler, ccvii, 293.

November, 1867, the condenser to a still, in which a quantity of oil too heavy for illumination and too light for lubrication was being fractionated, became obstructed from some accidental cause, and the pressure became so great that the leakage caused the fires to be drawn and the whole thing to cool down. The still was started with 900 gallons, from which 250 gallons was found to be removed by the partial distillation. On removing the remaining oil, Mr. Merrill was surprised to find it different from any petroleum product he had ever seen before. "It had a bright yellow color, was clear, very nearly odorless, neutral, and dense. Further experiment showed this result to have been obtained by the removal of all the light odorous hydrocarbons without decomposing either the distillate or the oils remaining in the still; and that this had been accomplished by the moderate fire employed, and its gradual withdrawal." (*a*)

This mode of operating was immediately applied to other distillations, and in order to accomplish the result most effectually Mr. Merrill invented a method of superheating steam within the body of the oil itself. Within a still of moderate size, holding perhaps 1,000 gallons, he placed a steam coil, which terminated upon the exterior of the dome of the still. After attaching a valve, the steam-pipe is returned into the still and a perforated coil of pipe connected with it, which lies flat upon the bottom. The still is heated by direct heat, and as the temperature rises the steam, as it passes through the first coil, is heated and is distributed through the entire mass of oil as it escapes from the perforations in the second coil. The steam is regarded by Mr. Merrill as an important adjunct in this method of fractional distillation, as it acts mechanically by carrying forward the vapors into the condenser, and also prevents the overheating and "cracking" of either the oils or the vapors.

When the destructive distillation of petroleum commenced on a large scale, the slow distillation necessary to effect this decomposition led to an increase in the size of the stills until the enormous capacity of 2,000 barrels, or 80,000 gallons, was reached. These immense stills were built without covering, were freely exposed upon their sides and tops to the elements, and were heated by numerous fires, placed at equal distances from each other upon the circumference of the still, after the manner of the setting of the cheese-box still. These excessively large stills are not now being used. Refineries lately put in operation are equipped with stills holding about 1,200 barrels each.

Vacuum stills have been used to some extent, and have been employed especially in the United States by the Vacuum Oil Company, of Rochester, New York, in the preparation of the peculiar products of their manufacture. Of course the evaporation in these stills takes place rapidly and at the lowest temperature possible, insuring a fractional distillation, not a decomposition, of the oils.

CONDENSERS.—Large copper worms, similar to those used in distilleries, were at first used for petroleum stills. These were soon replaced by ordinary iron piping coiled in a cistern or tank of water, and still later very long, straight pipes were used with advantage in the use of water for cooling. Refineries lately built are provided with condensers of moderate length, 50 by 20 by 8 feet, in which there are numerous separate pipes, which receive the vapors at one end and discharge the condensed oil at the other. A condenser thus constructed may consist of forty separate 3-inch pipes, each 45 feet in length, giving an aggregate length of 1,800 feet, the oil and vapors, instead of all traversing the entire length of 1,800 feet, being divided into small portions, each of which is made to traverse the 45 feet, and is condensed. The ratio of exposed surface to cubical content is very much increased by this arrangement over a shorter pipe of larger diameter.

A very convenient arrangement for dividing distillates is shown in the section in Fig. 43. In this section *a* is the 2-inch pipe leading from the condenser, *b* is a pipe for uncondensed gases leading to the boiler furnace, *c* is the trap for holding back the gas, *d* is a wrought-iron box with a glass front *i i*, through which the flow of oil from the condenser can be observed. The glass front is on hinges, and can be opened for sampling the oils. From this box the oil passes into the pipes below, and is directed into one of the openings *g*, through which it enters the pipe *h h*, leading to the storage-tanks for distillate; *e c* are three-way cocks, and *f f* ordinary stop-cocks, by which the oil is directed to one of the six orifices *g*. By this arrangement, by simply opening or closing the cocks, the distillate can be directed to any one of six receptacles and be divided into as many different portions.

AGITATORS.—The agitators used at first were small tanks lined with lead, in which various mechanical contrivances were used to effect the thorough mixing of the oil with the chemicals. These lead-lined tanks were replaced by wrought-iron ones, and finally the method of agitating by mechanical means has been entirely superseded by agitation by means of injected air. The agitators in use in refineries lately constructed are high wrought-iron tanks of comparatively small diameter, holding several hundred barrels of oil, in which the most complete agitation is produced by a current of air injected by a blowing apparatus.

PUMPS.—The pumps used in refineries are many of them very powerful. Those used for pumping oil and water are of the Worthington or the Drake pattern, and consist of an engine and a pump combined. Some of these pumps are large enough to handle 2,500 barrels of crude oil an hour, but the majority are smaller. In addition, there are in use small blast-engines or air-pumps to force air into the agitators and into the acid-tanks. The latter are small lead-lined tanks, into which the acid is emptied from carboys or tank-cars. The acid is measured into the agitators by forcing it from the tank into the agitator under pressure of injected air.

PACKING.—Manufactured oils of all kinds are distributed to wholesale houses all over the country in tank-cars, but for the jobbing and retail trade they are packed in barrels and in tin cans. The barrels used at present hold from

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a S. D. Hayes, Am. Chem., ii, 401; C. Cbl., 1871, 783; W. B., 1871.

48 to 50 gallons, and manufactured oils are estimated at 50 gallons to the barrel. The tin cans contain 5 gallons each, and are packed in wooden cases, each of which holds two cans. In the larger establishments the packages are filled by weight, as the bulk of the oil varies with the temperature and specific gravity of the oil, as may be seen at a glance at the table accompanying this report (see page 112). The filling of the 5-gallon cans is carried on at a square, revolving table. Ten cans are closely ranged along one side of this table and brought beneath ten funnels, which deliver oil to the cans until their weight stops off the oil by tipping a balance and closing a stop-cock. The ten cans are then swung out by giving the table a quarter revolution. While these cans were being filled another ten cans were placed upon the adjoining side of the table, and when the first were swung from under the funnels the second were brought into their places. While the second ten cans are being filled a third set are being placed upon a third side of the table, and a nozzle, with a cap that screws on and off, is placed in position for soldering over the orifice through which the first ten cans were filled. The table is again swung, the third set of cans are brought into position, and are then filled; the second set are supplied with nozzles, while the nozzles of the first set are soldered on and the fourth side is supplied with ten cans. Another swing of the table, and the fourth set are filled, the third supplied with nozzles, the second soldered, and the first removed, and a fifth set is put in their places. Several thousand cans can be filled in this manner at one of these tables in a single day.

SECTION 5.—DESCRIPTION OF AN ESTABLISHMENT IN WHICH THE PRODUCTS ARE GENERAL.

The plant consists of storage-tanks for crude material; stills, heated by fire, steam, and superheated steam; agitators; chilling-house for paraffine; boilers, engines, pumps; a laboratory; cooper and tin shop. The crude oil is delivered in pipes or tank-cars to the general storage-tanks and allowed to settle. From one to two per cent. of water separates. (*a*) About 300 barrels (12,000 to 13,000 gallons) of this oil are placed in a still and "live steam", *i. e.*, at 212° F., is admitted, and the distillation carried on until the distillate marks 60° B. With crude petroleum of 45° B. the amount of this distillate will be from 12 to 15 per cent., divided as follows:

A.

	Per cent.
1. "Crude gasoline", to 80°, about	½
2. "C" naphtha, 80° to 68°, about	10
3. "B" naphtha, 68° to 64°, about	2 to 2½
4. "A" naphtha, 64° to 60°, about	2 to 2½

1 is redistilled by dry heat, and yields from 90° to 83° gasoline, which is not treated; 83° to 80° is returned to crude gasoline.

2 is treated with 4 ounces of oil of vitriol to the gallon and washed with caustic soda, all cold, and then redistilled by steam from an alkali solution. Its average specific gravity is 70°, and it is known in the trade as benzine-naphtha.

3 and 4 are also treated with acid and caustic soda. The average specific gravity of 3 is 65° to 66°, and of 4 62°.

There remains in the still from 88 to 85 per cent. below 60°. This is transferred to cylindrical cast-iron stills with meniscus-shaped wrought-iron bottoms and distilled by direct heat, with 2 per cent. of soda solution of 14°. The distillate is thus divided:

B.

	Per cent.
1. Crude burning oil, from 58° to 40°, about	50
2. "B" oil, from 40° to 36°, about	20
3. From 36° downward, about	25
4. Cokings or residuum	3
5. Loss	2
	100

1 is treated with 4 ounces of oil of vitriol to the gallon and is agitated for half an hour. It is then drawn off from the tarry residue, and after being washed with water is again agitated for an hour with 2 per cent. of alkali solution, and is then drawn off and next day washed with a large amount of water, pumped into a fire-still upon a solution of soda equal to 4 per cent. of 14°, and distilled as long as the color is good, the amount usually being about 80 per cent. This distillate is the equivalent of "Downer's standard kerosene", and has a specific gravity of 45° and a fire-test of 125° F. The remaining 20 per cent. is run above 36° to crude burning oil (B 1), and below 36° to "finished machinery oil" C, to chill and press for paraffine.

2. "B" oil is distilled like 1 on soda lye. Of the distillate, above 36° goes to crude I; below 36° to the machinery oil C, to chill and press for paraffine.

a As high as 13 per cent. of water has been obtained from residuum exported to England. It is not a legitimate mixture. C. N., xxx, 57.

3 goes to crude lubricating oil, and is treated with 4 ounces of acid to the gallon upon water at 212° F. for one hour, and is then distilled from a 2 per cent. solution of soda lye. Of this distillate above 40° goes to crude B 1, from 40° to 36° to B 2, from 36° downward, as long as the color is good, to machinery oil C, to chill and press for paraffine.

4 goes to coking-tanks.

C.—MACHINERY OIL, 36° AND DOWNWARD.

This oil is twice distilled and chilled in barrels packed in an ice-house for a week with ice and salt at 26° F. The crystalline *magma* is pressed in an hydraulic press and yields:

1. Crude scale paraffine (E).
2. Pressed lubricating oil of a specific gravity of 32°, which is partly sold as "spindle oil".
3. The portion not sold as spindle oil is placed in a still provided with coils for distilling with steam superheated within the oil itself. This still is heated with direct heat until the temperature has reached 250° or 300° F. Steam is then passed into a coil, which is immersed in the body of the oil, and is then allowed to escape into the oil through another coil, which is perforated, thus distributing the steam throughout the oil at the same temperature as the oil itself. Twenty to 30 per cent. of the lighter products, with all those having an offensive odor, ranging in specific gravity from 50° to 32°, are lifted from the still by the steam. Of this distillate, that between 50° and 40° goes to B 1, that between 40° and 32° to "crude mineral sperm" (D), and the oil left in the still is equivalent to "Merrill's deodorized neutral hydrocarbon oil", with a specific gravity of 29°. To remove fluorescence chromic acid is used instead of oil of vitriol.

D.—MINERAL SPERM ILLUMINATING OIL.

This is the trade-mark of a dense oil of 36° specific gravity, deprived of offensive odor, and adapted especially for light-house and locomotive lights. Any crude distillate from 40° to 32° is first treated with 4 ounces of oil of vitriol to the gallon, then washed with a solution of caustic soda, and distilled by direct heat over soda lye. It has a fire-test of 300° F. and but little odor, with a density of 40° to 34°, averaging 36°. Below 34° goes to machinery oil (C), to chill and press for paraffine.

E.—CRUDE-SCALE PARAFFINE.

The pressed scale equals three-quarters of a pound per gallon of the crude 32° machinery oil from the chilled mass described in C. To refine this the crude scale is melted in an open tank by live steam, blown in, with 1 per cent. of caustic soda lye, from which it is carefully drawn and then well mixed with 25 per cent. of "C" naphtha and put aside for three or four days in shallow metallic pans in a cold place. It is then again cut, bagged, and pressed.

No. 1 paraffine stock is remelted in "C" naphtha on alkaline lye, crystallized and pressed three successive times, and yields large crystals of paraffine, melting at 130° F.

No. 2 paraffine stock is treated in the same way, furnishing a product of less value in smaller crystals, melting at about 116° F., and is largely used by chewing-gum manufacturers. The oils expressed go to crude "C" naphtha

F.—COKINGS, SPECIFIC GRAVITY 28°.

These are redistilled over a 2 per cent. alkali solution, and furnish—

20 per cent. above 40° goes to B 1.

15 per cent. 40° to 36°, goes to B 2.

50 per cent. 36° and downward, as long as the color is good, goes to C.

10 per cent. cokings.

5 per cent. loss.

G.—SLUDGE (RESIDUES FROM WASHINGS).

The waste "acid sludge", 48° to 50°, is permitted to stand two days, and the oil rising upon it is drawn off ("sludge acid oil") and the acid disposed of. The sludge oil is then washed with the waste alkali and redistilled separately without fractions, yielding 80 per cent. of oil; coke and loss, 20 per cent. The coke is used as fuel, and the oil redistilled on alkali and fractioned as crude oil below 60°.

H.—AVERAGE PERCENTAGE OF COMMERCIAL PRODUCTS OBTAINED FROM CRUDE PETROLEUM OF 45° FROM NEW YORK, PENNSYLVANIA, OHIO, OR WEST VIRGINIA.

	Per cent.
Gasoline	1.0 to 1.5
"C" naphtha	10.0 to 10.0
"B" naphtha	2.5 to 2.5
"A" naphtha	2.0 to 2.5
	16.5
Illuminating oil	50.0 to 54.0
Lubricating oil	17.5
Paraffine wax = 4½ pounds per barrel	2.0
Loss	10.0
	100.0

The oils prepared by this process are all of the highest degree of excellence, and have commanded the confidence of consumers both in the United States and in all other civilized countries to a remarkable degree. There are two essential particulars in this process as a whole to which I desire to call attention. All destructive distillation is avoided so far as is possible, and great care is taken to render the different products pure as regards each other, and also as regards the effects of treatment. The products are essentially paraffine products, using that word in a generic sense to designate not only the paraffine wax, but the whole series of compounds to which it is related, from marsh-gas upward. The finishing of the burning oil by distillation over caustic soda is claimed, and I believe justly, to remove all of the substitution compounds of sulphuric acid that are only completely removed even by solution of caustic alkali when the oil is heated to a temperature above the boiling point of water. (*a*)

SECTION 6.—DESCRIPTION OF A MANUFACTORY WHERE NAPHTHAS, ILLUMINATING OILS, AND RESIDUUM ARE PRODUCED.

The following description is given after an inspection of one of the most complete establishments in the country, lately constructed and furnished throughout with an equipment of the most improved apparatus:

The oil is received in tank-cars, and an entire train is discharged at once into a 12-inch pipe, which runs the length of the siding between the rails and beneath the sleepers, connection being made with cocks underneath the car-tanks by union joints and hose. This 12-inch pipe discharges into a tank, from which the oil is pumped by a Drake steam-pump, handling 2,500 barrels an hour, which throws the oil either to the stills or to the storage-tanks, of which latter there are four, holding 35,000 barrels each. The capacity of this pump is not required for the storing of oil, but for the filling of the stills, of which there are nine, holding 1,200 barrels each. Three of these stills are cheese-box stills, and six are plain cylinder stills, 30 feet by 12 feet 6 inches, the former being set in one group, and the latter on a bench, side by side, like a bench of boilers. These stills are all covered with sheet-iron jackets, but are not otherwise protected or covered in any manner. The condensers are made in the manner described on page 163, with a large number of separate strands of pipe, which are immersed in a tank 50 by 20 by 8 feet. These strands enter a connecting pipe which emerges from the tank and enters a small building, where the discharge pipes from the nine stills are brought together side by side. Each discharge pipe terminates in a U-shaped gas-trap, and enters an iron box with a glass front, through which the flow of the oil from the pipe may be observed. The arrangement of the traps and the form of the boxes are shown in section in Fig. 43. The gas-pipes from the nine traps all connect with furnaces beneath the steam-boilers, where the gas, mixed with air, is burned after the manner of a Bunsen burner. The division of the distillates is effected by means of an arrangement of pipes and cocks shown in section in Fig. 43. Each of the nine boxes *d* (Fig. 43) discharge through this set of pipes, by which the distillate may be divided into six different qualities. These six different pipes connect under ground with the distillate tanks, which they enter at the bottom, and are sealed by the contents of the tanks. These nine sets of boxes and pipes are placed in a small building, lighted at night by an electric light, placed upon a pole at some distance off on the outside. The petroleum is put into the stills, and the crude naphtha is run off. Then that portion of the petroleum is run off which is necessary to prepare the distillate for "high-test" oils having a fire test of from 120° to 150°, as may be required, and these latter oils having been run off, the residue in the still is in a condition for "cracking". The fires are then slacked, and the distillation is run more slowly, a large amount of permanent gases being disengaged and burned under the boilers. Until the process of cracking is commenced the amount of gas disengaged is inconsiderable, so small in amount as to be scarcely worth the trouble of burning; but after cracking commences the gas generated is nearly sufficient to supply the fuel necessary for the boilers. The distillates are pumped into the agitating tank, which stands by itself, supported on a massive base of timber. It is about 40 feet in height and 12 feet in diameter. Twelve hundred barrels of distillate and 6,600 pounds of oil of vitriol are placed in this tank. The carboys of oil of vitriol are emptied into an air-tight, lead-lined tank, which is closed, and air is forced into it until a sufficient quantity of acid has been driven by the pressure into the agitator. The agitation is then carried on by forcing air into the agitator under a pressure of from 5 to 7 pounds. The acid being drawn off, the oil is thoroughly washed with water, then with a solution of caustic soda, and lastly with water containing caustic ammonia, the treatment with ammonia being supposed to complete the removal of the compounds of sulphuric acid. The oil is discharged from the agitator into settling and bleaching tanks, 40 by 5 feet, having a capacity of about 1,200 barrels each, through a perforated pipe standing perpendicularly in the center. By this process, which is called "spraying", the oils, particularly those that have been cracked, are brought up to "test" by the evaporation of the small percentage of very volatile oils that are combustible at a low temperature. These huge tanks are exposed beneath sky-lights, where the color of the oil is improved by the sunning, every particle of water or sediment settling at the bottom. From them the oil is pumped to storage-tanks in the barreling and canning house, where it is barreled in glued barrels or filled into 5-gallon cans, two of which are packed in a wooden case for shipment. From the packing-house the barrels and cases are put on board ships that lie at the adjoining

a I have drawn largely for this description upon Dr. J. Lawrence Smith in his report on petroleum to the Philadelphia Centennial Exhibition. Rep. Judges of Group III.

piers. This is the simplest process for manufacturing petroleum, consisting only of a single distillation; and the methods employed in the different manufactories throughout the country are either substantially that just described, or a combination with more or less of the processes described in the preceding section, or one or more of the special methods to be described in the section which follows.

Section 7.—MISCELLANEOUS PROCESSES.

Refining crude naphtha.—There are several firms whose business consists mainly in refining crude naphtha, the larger portion of it being divided into gasoline and C, B, and A naphthas. In 1866 Dr. Henry J. Bigelow, of Boston, requested Mr. Joshua Merrill, of the Downer Kerosene Oil Company, to prepare the most volatile fluid possible to be obtained from petroleum. Mr. Merrill redistilled gasoline by steam heat, and condensed the portions that came over first with a mixture of ice and salt, obtaining 10 per cent. of the gasoline, equal to one-tenth of 1 per cent. of the original petroleum, in the lightest of all known fluids, having a specific gravity of 0.625 and a boiling point of 65° F. This fluid was named rhigolene by Dr. Bigelow. Its evaporation at ordinary temperatures is so rapid that a temperature of 19° F. below zero has been obtained by its use. Five or six hundred gallons have been prepared by the Downer company for use in surgical operations, but none was prepared by them during the census year.

A similar material, called cymogen, has been prepared in a similar manner by other manufacturers, and has been used as the volatile fluid in ice-machines.

The distillate separated as gasoline ranges in specific gravity from 90° to 80° B., and is used for the gas-machines that carburet air.

"C" naphtha includes the distillate between 80° and 68° B., and is used for varnishes, sponge lamps, paint, and naphtha street lamps. It is sold under the name of "benzine".

"B" naphtha includes the distillate between 68° and 64° B., and is also used for varnishes and paints.

"A" naphtha includes the distillate between 64° and 60°, and is used in the manufacture of floor-cloths and patent leather. Below 60° goes to illuminating oil.

Each of the different grades of naphtha is deprived wholly or in part of its disagreeable odor by being filtered through beds of gravel and wood or animal charcoal.

"Mineral sperm."—This is an illuminating oil prepared originally by Mr. Joshua Merrill, of the Downer Kerosene Oil Company, and now chiefly manufactured by that company, and is obtained by partially cracking paraffine oils and fractionating the lighter from the heavier products in Merrill's double-coil still or some similar contrivance. It has a fire test of 300° F. and upward, is an illuminating agent of great power, and is as safe from ordinary combustion as sperm oil. This oil is used in manufacturing establishments and on ocean steamers, and is a very suitable material with which to light steamers and cars designed for the conveyance of passengers. The amount produced during the census year was 16,544 barrels.

Neutral lubricating oils.—These oils were also discovered by Mr. Merrill, as before described, and their superior quality soon led to their imitation and manufacture by other parties, although that gentleman protected his discoveries and invention by patent. Since the Downer company commenced the manufacture of these oils the general character of all of the mineral lubricating oils in the market has been greatly improved. The paraffine oils manufactured prior to this discovery were dark in color and rank in odor, but Mr. Merrill produced oils odorless and tasteless. Five per cent. of sperm oil mixed with 95 per cent. of Merrill's neutral oil could not be detected by either the odor or taste from pure sperm oil. An inspection of the tables representing the articles manufactured from petroleum during the census year will show that 79,465 barrels of paraffine oil are reported, all of which was greatly superior to the paraffine oil of 1865; of deodorized lubricating oils there were manufactured 70,415 barrels. These really superb oils are now being introduced into many manufactories by order of the insurance companies. The value of having a deodorized lubricating oil can be fully realized when it is stated that experiments have shown that when a heavy hydrocarbon containing so little as 1 or 2 per cent. of light offensive oil is employed in a warm apartment as a lubricator of machinery the entire atmosphere of the apartment will be impregnated by the pungent and disagreeable odors of these volatile products. Before the employment of these odorless oils this was a great inconvenience in factories. (*a*)

Mr. Merrill prepares lubricating oils by subjecting an ordinary paraffine distillate, from which the paraffine has been removed by chilling and pressing, to fractional distillation in his double-coiled still, but oils may be prepared that are similar, though not fully equal, to his in an ordinary still, provided care is taken not to crack them.

Filtered oils.—A very superior quality of lubricating oil is prepared by reducing petroleum and filtering the reduced residue through beds of animal charcoal. The oil is reduced to the proper degree of volatility and specific gravity and then filtered. These oils sustain a very high reputation, but precisely what relation they bear in quality to the neutral oils obtained by distillation and treatment I cannot state.

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a *Loc. cit.* Rep. of Judges of Group III, p. 153.

VACUUM OILS AND RESIDUES.—Vacuum oils are also prepared in stills for a great variety of purposes. Those most dense and with highest boiling points are prepared for oiling the interior of steam cylinders; those less dense for journals; and a less dense oil is used extensively for oiling harness and harness leather. Very dense residues prepared in vacuum stills are filtered while hot and very fluid through beds of animal charcoal, the resulting product being an amber-colored material of the consistence of butter and nearly destitute of odor. These residues are largely used as unguents under the name of cosmoline, vaseline, petrolina, etc. The details of their manufacture are difficult to obtain, for the reason that the manufacturers are engaged in suits involving patent rights to peculiar processes of manufacture and peculiar apparatus for effecting the filtration, which necessarily must be carried on at a sufficiently high temperature to insure complete fluidity of the material. These preparations will be further noticed under the chapter devoted to petroleum in medicine.

It is believed that but few, if any, general methods of any importance pursued in the manufacture of petroleum have been omitted in this chapter. It is a subject, however, embracing multitudinous details and carried on under conditions of great diversity, incident to the location of the business and the peculiar character of the crude oil used or the products which the manufacturer wishes to prepare.

CHAPTER IV.—PARAFFINE.

SECTION 1.—HISTORY.

Wagner's *Berichte* for 1869, in an historical notice upon paraffine, says:

The *Aerztliche Intelligenzblatt*, of Munich, contains the following notice: "The opinion universally held that the chemist Karl Freiherr von Reichenbach, who died in his eighty-first year, of old age, at Leipzig, January 19, 1869, was the first to investigate the paraffines, deserves the following corrections or amendments. In 1809 these bodies were observed by John Nep. Fuchs in Landshut in the petroleum of Tegernsee, and in 1819 Andrew Buchner, sr., produced them in a pure state from the oils. Buchner describes their peculiarities under the name of 'mountain' fats, whose identity with paraffine was established later (1835) by v. Kobell beyond doubt. Unqualified merit, however, belongs to Reichenbach as having first discovered paraffine in the products of the dry distillation of wood and other organic bodies." Reichenbach remains the discoverer of paraffine notwithstanding the fact that, beside Fuchs and Buchner, Saussure and Mitscherlich investigated a fatty body found in certain petroleums and tars which after the discovery of paraffine proved to be identical with this body. In all of these conditions the discourse was upon paraffine as an *educt*, and not as a *product*. Technology distinguishes the former from the latter through the name of *Belmontin*. He who first considered fossil paraffine can upon no condition lay claim to the honor of the discovery. In Moldau and in Galicia fossil paraffine has been used for centuries in making candles, as also on the Caspian sea and in the Caucasus. (*a*)

It appears from this statement, which is in accord with numerous authorities, that fossil paraffine has been known in Europe from time immemorial, and also that paraffine, as a recognized constituent of certain bodies of organic origin, was discovered by Reichenbach in 1830, (*b*) and named by him from *parum* and *affinitas*, indicating that paraffine is destitute of chemical affinity; in other words, that it is neutral, having neither acid nor alkaline properties. In the following year Christison, of Edinburgh, made known his discovery of paraffine in the petroleum of Rangoon. (*c*) He at first called it *petroline*, but after learning of Reichenbach's discovery he admitted its identity with paraffine. In 1834, Gregory published an article on paraffine and eupion and their occurrence in petroleum, in which he says:

It follows that there are some kinds of naphtha (petroleum) which contain paraffine and eupion, and are consequently the results of destructive distillation. (*d*)

In 1835, Kobell independently mentions paraffine as a constituent of petroleum. (*e*) In 1833, Laurent showed that oil distilled from shale in the environs of Autun contained paraffine. (*f*)

Although Reichenbach distilled coal in considerable quantities, and had at his disposal the resources of the immense establishment of "mines, iron furnaces, machine-shops and chemical works, etc.," on the estate of Count Salm at Blansko, Moravia, of which he was superintendent, he cannot be said to have produced paraffine on a commercially successful basis. This work was performed by Selligue, whose inventions formed the foundation upon which the technology of coal-oil and petroleum has been built. The following digest of the labors of Selligue is taken from the review of Dr. Antisell's work on photogenic or hydrocarbon oils by Professor F. H. Storer: (*g*)

In 1834 we find for the first time an article describing the process of Selligue, (*h*) although it would appear from the statements of this chemist and of others that his attention had been directed to the subject of distilling bituminous shales several years earlier.

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a W. B., xv, 709, 1869.
b *Jour. für Chem. u. Phys.* von Schweigger-Seidel, 1830, lix, 436.
c Trans. Roy. Soc. of Edinburgh, xiii, 118; *Repertory of Patent Inventions*, 1835 (N. S.), iii, 390.
d *Ibid.*, xiii, 124; *Ibid.* (N. S.), iv, 109.
e *Jour. f. Prak. Chem.*, v, 213.
f *Ann. de Chim. et de Phys.*, liv, 392.
g Am. J. S., xxx, 1860.
h *Journal des Connaissances Usuelles*, Dec., 1834, p. 285; Dingler, lvi, 40.

* * * In 1834, '35, and '36 Selligue was principally occupied with his process for making water-gas. (*a*) * * * In the following year we again find Selligue before the academy, requesting that body to appoint a committee to examine the merits of his new system of gas-lighting; his process of distilling bituminous shales on the great scale by means of apparatus, each one of which furnishes from 1,000 to 1,400 pounds of crude oil per day—this being about 10 per cent. of the weight of the shale employed, and being almost all that exists in the raw material; also of his process of separating various products from the crude oil, some of which are applicable to the production of gas, others to ordinary purposes of illumination, and others to different uses in the arts. (*b*) This petition was referred to a committee of three, Théuard, D'Arcet, and Dumas, who reported in 1840. (*c*) * * * In 1838 Selligue obtained a new patent "for the employment of mineral oils for lighting", (*d*) which, it should be observed, claims only to be an improvement upon that of Blum and Moneuse. * * *

On the 27th of March, 1839, Selligue specifies certain additions and improvements to the preceding patent. In alluding to the use of his oils in the treatment of cutaneous diseases he speaks of the three large establishments for the distillation of bituminous shale which he has erected in the department of Saône et Loire, and mentions the fact that the oil (crude) is furnished at the rate of about 2 cents (10 centimes) per pound. (*e*) * * * The clearest of all Selligue's specifications, however, is that of the patent granted him March 19, 1845, for the distillation of bituminous shales and sandstones. (*f*) After describing the various forms of apparatus used in distilling, into one of which superheated steam was introduced, he enumerates the products of distillation as follows: I. A white, almost odorless, very limpid mineral oil, somewhat soluble in alcohol, which may be used as a solvent, or for purposes of illumination in suitable lamps. II. A sparingly volatile mineral oil of specific gravity 0.84 to 0.87, of a light lemon color, perfectly limpid, almost odorless, never becoming rancid, and susceptible of being burned in ordinary lamps, of constant level (à réservoir supérieur), with double current of air, a slight modification of the form of the chimney and burner being alone necessary. This oil can also be mixed with the animal or vegetable oils. Oils thus prepared do not readily become rancid, nor do they congeal easily when subjected to cold. III. A fat mineral oil, liquid at the same temperature as olive oil. This oil contains a little paraffine; it is peculiarly adapted for lubricating machinery, and has an advantage over olive and other vegetable oils, or neat's-foot oil, in that it preserves its unctuosity when in contact with metals and does not dry up. It saponifies easily, and forms several compounds with ammonia. IV. From the oils I, II, and III I extract a red coloring matter which can be used in various arts. V. White crystalline paraffine, which needs but little treatment in order to be fit for making candles. This substance does not occur in very large proportion in the crude oil, and the proportion varies according to the different mineral substances upon which I operate. There is but little of it in petroleum and in the oil obtained from bituminous limestone. I often leave a great part of the paraffine in the fat oil and in the grease, in order that these may be of superior quality. VI. Grease. This grease is superior to that of animals for lubricating machinery and for many other purposes, since it does not become rancid, and remains unctuous when in contact with metals. VII. Perfectly black pitch—very "drying"—suitable for preserving wood, metals, etc. VIII. An alkaline soap obtained by treating the oils with alkalies. IX. Sulphate of ammonia. X. Manure prepared by mixing the ammoniacal liquor or the blood of animals with the crushed fixed residue (coke) of the shale. XI. Sulphate of alumina from the residue of the shale. In describing the methods of purification proposed by Selligue we shall make no attempt to follow their various details, our limited space compelling us to content ourselves with only the broadest generalities. Selligue sets forth at length two methods:

1st. A cold treatment, which consists in agitating the oils with sulphuric, muriatic, or nitric acid. This agitation should be thorough, he says, and should be continued for a longer or shorter time, according to the nature and quantity of the matter treated. Here follows a description of his agitators. After several hours repose the oil may be decanted, except from muriatic acid, in which case more time and a larger amount of acid is required. After the oil has been thus separated from the deposit of tar, the acid remaining in it must be neutralized by means of an alkali. "I prefer," says Selligue, "to employ the lye of soap-boilers marking 36° to 38°, since it is easy of application and produces a sure effect. I thus precipitate together the coloring matter and the tar, which would otherwise have remained in the oil. The oil is then decanted; if it is the first distillation of the crude oil, I do not allow the mixture to subside entirely, preferring to leave a portion of the alkali mixed with the oil and to distill off only three-fourths of the latter. * * * When the soda lye—in quantity slightly greater than is necessary to neutralize the acid—is added, the liquid must be agitated violently, in order that each particle of the oil may be brought in contact with the alkali; and this agitation must be continued until the color of the oil undergoes change. The oil becomes less odorous and less highly colored after each such 'cold treatment'. After having been allowed to separate from the lye, the oil is decanted off; if it has not lost much of its color the process has been badly conducted. It must be stated that the oil must not be agitated several times with the alkali, for by so doing the dark color of the oil would be restored. * * * As for the residues of the soda treatment", continues Selligue, "they should be allowed to stand at rest during some days beneath a portion of oil, which will protect them from contact with the air. The clear lye at the bottom being then drawn off may be used for other operations, while the remainder is a soap containing excess of alkali. By adding to it a little grease a soap can be made, or by adding water grease may be separated. This grease is similar to that used for wagons."

2d. A warm treatment that follows the cold, and consists of a series of fractional distillations—special operations for the purification of the "light stuffs" being resorted to. For the details of these we must refer to the original specification of Selligue—a truly classical document—which should be read by every one interested in the manufacture of coal-oils (or petroleum). (*g*) * * * As for paraffine, Selligue obtained it by subjecting the oil to a low temperature, in order that this substance might crystallize. The mixed oil and paraffine was then thrown on fine metallic filters, through which the oil flowed while the paraffine was separated. Or one may separate the oil, he says, by imbibition, but this occasions a great loss of oil, and also requires more labor.

These successive patents, extending over a period of about fifteen years, show not only that Selligue was a complete master of this department of technology, on the general principles of which but little improvement has since been made, but also that, prior to 1845, this industry had become important and extensive in France.

In England no commercial importance appears to have attached to the paraffine-oil industry until 1850, when James Young and his associates, Messrs. Binney and Meldrum, established the extensive works at Bathgate, from

a See 7 patents in *Brevets d'Invention*, lxx, 169. Of these patents two are dated 1834, two 1835, and three 1836. For a description of his process of gas-making, see also *Bul. Soc. d'Encouragement*, Oct., 1838, p. 396, or Dingler, lxxi, 29.

b *Comptes-Rendus*, 1838, vii, 897.

c *Ibid.*, x, 861, Dingler, lxxvii, 137.

d *Brevets d'Invention*, lxviii, 395.

e *Comptes-Rendus*, ix, 140; *Ann. der Pharmacie*, v. Wöhler u. Liebig, xxxii, 123.

f *Brevets d'Invention* (N. S.), loi du 5 *Juillet*, 1844, iv, 30.

g A tolerably accurate English translation of this important patent may be found in the specification of A. M. B. B. Du Buisson, 1845, specification No. 10,726 of the English patent office.

the success of which has followed the Scotch paraffine and mineral-oil industry, which, in 1878, produced from 800,000 tons of 2,000 pounds each of shale 30,000,000 gallons of crude oil. From 8,040,000 gallons of this oil was made: (*a*)

	Value.
500,000 gallons naphtha	$40,000
4,000,000 gallons burning oil	320,000
1,035,000 gallons heavy oil	82,000
200,000 gallons medium oil	16,000
Paraffine	62,000
Sulphate of ammonia, 82 per cent. products	23,000
	543,000

Specific gravity of the naphtha	0.725
Specific gravity of the lamp-oil	0.805
Specific gravity of the medium	0.840

SECTION 2.—SOURCES OF CRUDE PARAFFINE.

Crude paraffine is found fossil in Galicia, Roumania, the Caucasus, the neighborhood of the Caspian sea, and in the Sanpete valley in Utah. In all of these localities, except the last, it is found in a formation that yields petroleum and also contains paraffine. Paraffine is also a constituent of a large majority of the different varieties of petroleum found upon the earth's surface, and also of the asphaltums that occur in injected veins, such as albertite, grahamite, and the asphaltum of Cuba. As a product of destructive distillation paraffine is obtained from all kinds of bituminous coal, shales, lignite, peat, wood, and animal remains, provided the distillation is conducted at a sufficiently low temperature.

The fossil paraffine or ozokerite of Galicia is principally obtained in Boryslaw and Stanislow in the Miocene of the foot-hills of the northern slope of the Carpathians; also at Slanik, in Moldavia, near mines of rock-salt and coal. In 1875 the amount produced in these two localities was about 44,000,000 pounds. The "earth-wax" occurs partly in regular beds and partly in pockets, from which it is obtained in small pieces or masses of several hundred pounds weight. The beds containing the mineral are reached by shafts from 130 to 260 feet in depth, from which the exploitation is carried on by tunnels, as in ordinary mining. These shafts generally pass through gravel and bowlders from 25 to 30 feet, and then through blue loam and plastic clay. In this clay, at a usual depth of from 140 to 150 feet, the "earth-wax" is found in layers of from 1 foot to 3 feet thick, the purest being of a honey-yellow color, and of the hardness of common beeswax. Much of it, however, is in small pieces, which must be separated from the gangue, the smallest pieces being obtained by washing. The purer qualities, on being melted, yield a prime "earth-wax", which is manufactured into "ceresine." The poorer varieties are dark-colored, some of it being soft, containing petroleum, and some of it being hard like asphaltum. These poorer qualities are used for the manufacture of paraffine. Rarely pieces are found which are very compact and as hard as gypsum, fusing above 100° C., and, like many specimens of petroleum, are dichroic—dark-green in reflected light and pure yellow in transmitted light.

As stated above, the crude ozokerite is separated from the gangue by melting and worked into paraffine or ceresine. The "trying" is effected either by direct fire or by steam. In the former case, the ozokerite is placed in iron kettles about one and one-half meter in diameter by one meter in height, melted, drawn off, and the residue boiled with water, when all the ozokerite will rise to the surface of the water. In the latter case the melting is done by steam in the same manner as with paraffine or stearine, and needs no further description. The "tried" ozokerite is clarified by allowing it to settle for several hours and then poured into iron molds. It is shipped in this form, without any further packing, in pieces weighing from 50 to 60 kilograms (110 to 130 pounds). There are principally two kinds of commercial ozokerite, prime and second. Prime "wax" ought to be as free as possible from earthy impurities, and in small, transparent, greenish-brown to yellow pieces; the lighter in color and the more transparent the better it is. "Second wax" is dark brown, almost opaque, occasionally containing a great deal of earthy impurities, and is generally much softer than the prime. Both are used in the manufacture of either paraffine and illuminating oils or ceresine. The manufacture of paraffine from ozokerite is effected by distillation over direct fire from iron retorts with flat bottoms containing from 1,500 to 2,000 pounds. The product of the distillation are: (*b*)

	Per cent.
Benzine	2 to 8
Naphtha	15 to 20
Paraffine	36 to 50
Heavy (lubricating) oils	15 to 20
Coke	10 to 20

The paraffine is pressed, treated with sulphuric acid and caustic soda, filtered through paper and fine animal charcoal, and made into candles. The naphtha is purified in the usual way, and the heavy oils are sometimes subjected to fractional distillation, but mostly shipped as such to Vienna. The manufacture of "ceresine" consists of the removal of the impurities from the "earth-wax" by the aid of sulphuric acid and animal charcoal; but only the best kinds of ozokerite are used. The different processes are kept secret, and are also protected by patents. In general the ozokerite is melted with concentrated sulphuric acid, and the residue from the manufacture of yellow prussiate pressed, treated again with prussiate residue and filtered. One hundred parts good prime "earth-wax" yield sixty to seventy parts white wax, which in its properties very closely resembles white beeswax, and is called "ceresine". It is either further purified by repeated treatment with acid and prussiate residue, or colored with gamboge or alkanet, and thereby made to resemble common beeswax.

a *Hübner's Zeitschrift*, 1879, 12; W. B., 1879, 1170.

b This is manifestly a cracking process, and it is evidently a somewhat rude method of treating such a valuable substance. Distillation by steam would be much better.

In the manufacture of ceresine only sulphurous acid and press residues are obtained, the former of which escapes into the air, but might be utilized, thus reducing the cost considerably. The consumption of sulphuric acid in Boryslaw alone is said to amount to 2,200,000 pounds a year. The prussiate residues are obtained from the lixiviation of the crude prussiate in Moravia. Comparatively only a small quantity of earth-wax is worked in Galicia, and is shipped principally to England, Moravia, and Vienna. The ceresine is exported in large quantities to Russia, where it is sold as beeswax, a little of which is melted with it in order to impart to it the characteristic odor. Good ceresine is hardly to be distinguished from beeswax. The best method is the following: 1. Ceresine is not as easily kneaded between the fingers and becomes brittle more readily than beeswax. This test is, however, doubtful if the sample is a mixture of the two. 2. Ceresine is scarcely attacked by warm concentrated sulphuric acid, whereas beeswax is completely destroyed by it. By this test the quantities of beeswax and ceresine can be determined in a mixture of both. In many cases ceresine can be employed in place of beeswax. It is sold at $32 to $40 per 100 kilogrammes (16⅔ cents per pound) in Vienna, whereas the price of the commercial earth-wax varies from $10 to $12 per 100 kilogrammes (5 cents per pound). The whole exploitation of the ozokerite is in the hands of the Jewish population. (*a*)

The ozokerite deposits of Utah have not yet been worked sufficiently to demonstrate their importance. The crude material is of about the consistence of paraffine, and is of a jet black color, and furnishes, when purified, a pure white paraffine.

The question whether paraffine is or is not a constituent of petroleum has been widely discussed. I am not prepared to assert that crystallizable paraffine is a constituent. I have seen crystals of paraffine in petroleum that came from the wells of the Economites opposite Tidioute that I had no reason to suppose had ever been heated, or, in fact, manipulated in any manner, except to be put into barrels; yet I cannot positively assert that such was the case. Amorphous paraffine is certainly a constituent of many petroleums, and is readily obtained where petroleum is carefully distilled until the residue has the consistence of paste when cold. The amount of reduction necessary varies with the source of the petroleum used. A sample from the southeastern border of the Pennsylvania petroleum field was of an amber color, and of nearly the consistence of honey from suspended paraffine. The oil of the Bradford field is remarkable for the amount of paraffine it contains as compared with other oils of the Pennsylvania region. This peculiarity occasions a great deal of trouble with flowing wells, as the pipes become clogged with paraffine so completely as to stop the flow of oil. This is no doubt in part occasioned by the fractional condensation of the paraffine in consequence of the extremely low temperature produced by the rapid evaporation of the more volatile portion of the petroleum when it is relieved from the enormous pressure to which it is subjected in the rock. This extremely low temperature, which has been known to plug a well with ice and to produce ice under the sun of a hot summer's day, evidently condenses the paraffines having the highest melting point, and allows those more fusible to remain dissolved in the oil. (*b*) As regards the practical working of petroleum, it is of little importance whether the paraffine is an educt or a product, for if the paraffine is not already a constituent of crude petroleum, the heat required for distillation develops it. The amount of paraffine, however, that any given sample of petroleum contains or will yield is a matter of the greatest importance if the crude oil is to be made into illuminating oils. The crude oils of Butler and Armstrong counties are much more valuable for that purpose than those of McKean county, because they contain more of the members of the paraffine series of the proper specific gravity for illuminating oils and less of the dense, heavy oils and solid paraffine that have to be cracked before they can be used for illumination.

In 1849 a Mr. Reece obtained a patent for distilling paraffine from Irish peat, and works for its production were established near Ashby. While the method of treating the peat was entirely successful, the enterprise, on account of the small amount of material it was capable of yielding, was a commercial failure. It is proper to state here, however, that acetic acid and ammonia, as well as paraffine, were expected to be obtained in commercially valuable quantities. The following statement will give an idea of the proportion of these articles yielded by the peat. On the first distillation the peat yielded:

	Per cent.
Watery matters	30.614
Tar	2.392
Gases	62.392
Ashes	4.197
	99.595

The watery matters and tar yielded:

	Per cent.
Ammonia	0.287
Acetic acid	0.207
Naphtha	0.140
Volatile products	1.059
Paraffine	0.125

a J. Grabowsky, *Am. Chem.*, vii, 123. Hübner's Z., 1877, 83.

b Various methods have been suggested for removing this paraffine from the pipes. It is only slightly soluble in benzine, and neither acids nor alkalies attack it, and other solvents are equally ineffectual. Metallic mercury has been used, which must act mechanically by its weight. A plan to burn it out of the pipes by supplying a stream of oxygen has been recommended, but what degree of success, if any, attended its use I have not learned. The most common method pursued in the oil region is to pull up the pipes and blow out the plug of paraffine with steam. The pipes are often found plugged solid for hundreds of feet.

Fifty tons of peat yielded 125 pounds of paraffine, an amount too small to admit of a profitable enterprise. (*a*) The peat of Hanover yields more than 300 pounds of paraffine to 50 tons.

J. J. Beitenlohner gives the following results of the manufacture of paraffine from peat-tar. The locality of the peat is not given, nor is the amount of tar yielded:

By fractional distillation:	Per cent.
Crude and chemically combined oil	35. 3
Crude paraffine in mass	48. 2
Coke	10. 4
Gas	6. 1
	100. 0

The results of the purification of the paraffine with sulphuric acid and lye are:

	Per cent.
Paraffine	76. 3
Loss by sulphuric acid	12. 2
Loss by lye	9. 4
Loss by washing	2. 1
	100. 0

The paraffine thus obtained is subjected to distillation, the result being:

	Per cent.
Oils	25. 5
Paraffine	66. 5
Coke	2. 6
Gas	5. 4
	100. 0

The paraffine is then refrigerated and pressed, and from it are obtained:

	Per cent. in winter.	Per cent. in summer.
Coke	21. 6	18. 2
Oils	75. 3	78. 3
Loss	3. 1	3. 5
	100. 0	100. 0

This paraffine is then digested in fuming sulphuric acid, but remains soft and unctuous. (*b*) The distillation evidently cracks it.

In an elaborate research upon the products of the dry distillation of Rhenish shale and Saxony and Thuringian brown coal, H. Vohl gives the following table, showing the comparative value of shales, brown coal (lignite), and peat as sources of paraffine: (*c*)

Raw material.	Light oil or photogen: sp. gr. 0.820.	Heavy gas or lubricating oil: sp. gr. 0.860.	Paraffine.	Asphalt.	Creosote and loss by refining.
Shale:	*P. cent.*	*P. cent.*	*P. cent.*	*P. cent.*	*P. cent.*
English	24. 285	40. 000	0. 120	10. 000	25. 595
From the Romerickeberg mine	25. 688	43. 000	0. 116	12. 030	19. 166
From Westphalia	27. 500	13. 670	1. 113	12. 500	45. 300
From Oedingen on the Rhine	18. 333	38. 333	5. 000	18. 333	25. 001
Brown coal from—*					
Aschersleben, No. I	33. 500	40. 000	3. 330	18. 100	5. 070
Aschersleben, No. II	20. 500	43. 600	6. 510	19. 567	9. 823
Frankenhausen	33. 410	40. 063	6. 730	17. 321	2. 476
Münden	17. 500	26. 213	5. 063	18. 679	32. 545
Oldisleben	17. 721	26. 600	4. 430	17. 526	33. 722
Cassel, No. I	16. 428	27. 142	4. 286	14. 290	37. 853
Cassel, No. II	16. 666	21. 052	5. 263	13. 163	43. 855
Bavaria (von der Rhon)	10. 625	19. 375	1. 250	16. 900	51. 850
Tilleda	16. 666	18. 055	4. 444	11. 111	49. 722
Brown coal from—Continued.	*P. cent.*	*P. cent.*	*P. cent.*	*P. cent.*	*P. cent.*
Harbke, No. I	15. 555	11. 111	3. 555	22. 222	47. 555
Harbke, No. II	16. 666	11. 765	2. 941	20. 000	48. 627
Stockheim, near Düren	17. 500	26. 630	3. 260	16. 900	36. 710
Bensberg, near Cologne	16. 360	19. 535	3. 463	13. 173	47. 461
Peat from—					
Celle	34. 600	36. 000	8. 010	11. 540	9. 850
Coburg	20. 625	26. 578	3. 125	17. 190	32. 482
Damme	19. 457	19. 547	3. 316	17. 194	40. 486
Neuenhaus, heavy	17. 983	19. 640	5. 360	16. 071	40. 945
Neuenhaus, light	14. 063	18. 230	5. 209	18. 750	43. 748
Zurich	14. 400	8. 666	0. 424	42. 424	35. 086
Russia (Rostokina, near Pasjkina)	20. 390	20. 390	3. 367	25. 658	30. 195
Bottroes, in Westphalia	11. 000	19. 489	2. 256	26. 000	41. 255
Neuwedel, Prussia	14. 180	18. 266	3. 102	28. 260	36. 241

* These "brown coals" are lignites, nearer peat than coal.

a Frederick Field, J. S. A., xxii, 349, 411; *Am. C.*, v, 169. *b Jour. de l'Éclairage au Gas*, 1872, No. 5, Am. C., ii, 315. *c* W. B., iii, 459.

The paraffine oil industry of Scotland has already been noticed. Its present success, notwithstanding the low price of petroleum products, is mainly due to the heavy oils and paraffine produced. While I cannot indorse all the claims that are made for Mr. Young as the first inventor, as the process which he patented corresponded to that used by Selligue many years before, there is no question that he deserves the credit of having placed the paraffine industry on a solid commercial basis in Great Britain at a time when the discovery of petroleum in such vast quantities in Canada and the United States would seem to have rendered such an undertaking impossible.

At the date (1860) at which petroleum was first an article of commercial importance, paraffine and paraffine oils were being produced in the United States and Great Britain from the so-called Boghead coal, albertite, and grahamite. together with several rich cannel coals. The deposits of the three minerals above mentioned have been worked out. The last establishment in the United States using anything but petroleum was the Union Coal and Oil Company, of Maysville, Kentucky, which was operated upon the rich cannel coal of Cannelton, West Virginia, on the Great Kanawha river. It ceased operations in 1867. The deposit of Boghead mineral was worked out in 1872, since which time the extensive paraffine oil works of Scotland have been run on shale. On the continent of Europe, in Saxony, Thuringia, and Austria, an extensive and very valuable industry is conducted with shale and brown coal as the raw material. In the United States, beside our deposits of cannel and bituminous coals of enormous extent, we have thousands of square miles of shales that will furnish millions of barrels of distillate for use after our 200,000 square miles of petroleum fields shall have been exhausted.

SECTION 3.—PREPARATION OF PARAFFINE.

The preparation of paraffine from petroleum has already been described on page 165, and the treatment of the crude oils distilled from shale or coal is substantially the same, with the exception that more sulphuric acid and more numerous distillations are employed. While crude shale oils and petroleum are very similar fluids, the shale oil is much more impure and more expensive to refine. Distillation and treatment with sulphuric acid and soda lye are, with some variation in the details, the methods upon which the technologist in paraffine must rely. The subsequent treatment of the crude paraffine scales is subject to considerable variation, and an article quite variable in its properties is the result. The ordinary method of purification consists in dissolving about 2,000 pounds of crude paraffine in 80 gallons of "C" naphtha by heat, refrigerating in shallow metal pans and pressing; but this method is attended with considerable loss of naphtha, and some danger from accidental ignition. To obviate this a process was invented for treating the paraffine cold, by which it was either pulverized and then dissolved in naphtha, or the cake and naphtha were ground together into a paste and then pressed. After this grinding and pressing has been repeated a sufficient number of times, the solid wax is melted in a still with steam blown in until no naphtha comes over with the condensed water. From 3 to 5 per cent. of animal charcoal is then added, and while the mass is kept melted the charcoal is allowed to settle. As the finest particles of charcoal remain diffused through the wax, the whole is filtered hot through a wire-gauge filter, which is lined with flannel and filter paper, the filtrate passing as colorless as distilled water. (*a*)

The use of these successive solutions in naphtha is to remove the fluid oils from which the paraffine first crystallizes, which are more readily soluble in the naphtha than the paraffine itself. Mr. John Fordred in 1871 sought to accomplish the removal of these oils by kneading the paraffine with or in a slightly alkaline solution. After melting and clarifying a ton of paraffine and casting it into thin cakes of about ten pounds each, these cakes are placed in a bag, end to end, and warmed until they become plastic. The bag is then placed in a kneading machine, which is supplied with a solution of equal parts of soft soap and water at a temperature of about 100° F. On setting the machine in motion the oil and coloring matter are dissolved in the soap solution. Solutions of carbonated and caustic alkalies, both alone and mixed with soap, rosin soap, and even warm water itself, are found to answer the purpose. (*b*) Another patent claims economy in operation and safety in the use of material. A tank 12 by 6 by 2½ feet is provided with partitions, which separate it into V-shaped cells, 2½ inches wide at the top and 2 inches wide at the bottom. These cells are 1 inch apart, and start 9 inches from the top of the tank and stop 2 inches from the bottom. A grating is provided, that rests upon the top of the cells, the bars of which are 1½ inches apart. Free or closed steam-pipes are placed in the bottom of the tank, and water is filled in to a depth of 6 inches. Crude paraffine is filled into the cells and the grating secured to prevent its floating. Water is then run in until it rises to within two inches of the top of the tank, and steam is turned on until the temperature reaches within 10° of the melting point of the paraffine being treated, when it is turned off and the entire mass is allowed to become of a uniform temperature. Steam is then again turned on and the temperature very slowly (through at least 4 hours) brought to within 2° of the melting point of the paraffine, when the soft portions that have risen are skimmed off. The water is then drawn off to the top of the cells and the paraffine is melted and allowed to cool slowly through the night, when the operation is repeated. This is continued until paraffine is obtained of the required hardness, while the soft portions are returned to the crude paraffine. The hard paraffine is then melted with 7 per cent. of powdered commercial ivory-black in a steam-jacketed pan for four or five hours, until the

a Patent of Ed. Meldrum, No. 1646, 1867. *b* Patent No. 1858, 1871.

whole of the ivory-black is precipitated, when it is drawn off and cast into cakes. (*a*) Another process requires the paraffine to be clarified by settling and being cast into cakes, which are allowed to cool very slowly, in order that the crystals may form of large size. The cakes are then placed on tiles or other absorbent material and heated nearly to their melting point. The fluid and easily fusible portions are melted and flow from the crystals and are absorbed by the tile. This process may be repeated as many times as may be desired, and the paraffine may then be bleached with bone charcoal or by any other means. (*b*)

By whatever method the paraffine may be freed from the fluid and the fusible impurities, it is not white, and is afterward subjected to a bleaching process. One method has already been described; another requires that the melted paraffine be agitated in a tank by a current of air with from 5 to 10 per cent. of strong sulphuric acid, care being taken to remove the sulphurous acid evolved by a suitable ventilating apparatus. This agitation is carried on for several hours, until the experience of the operator shows the treatment to be sufficient, when the tarry mass is allowed to subside through several hours. The still slightly-colored paraffine is then digested with animal charcoal, the last traces of which are removed by filtering through a steam-jacketed filter. The apparatus by which this filtration is performed is thus described by L. Ramdohr in Dingler's *Polytechnic Journal*, 1875:

After paraffine has passed through all other stages of the purifying process, it must finally be decolorized by means of charcoal. The use of a permanent filter (eines stehenden) filled with granulated charcoal is not to be recommended for many reasons.

The filtering process must take place at a temperature of not less than from 70° to 80°; the filter also must be heated with steam, which, on account of the large dimensions, would require incommodious and expensive apparatus. But particularly against the use of granulated charcoal stands the fact that a greater part of the paraffine is retained by the charcoal, which can only be partly collected again through burning of the coal, which always is united with a considerable amount of decomposition (products) of the paraffine. But paraffine is so valuable that its manufacture cannot suffer such a great loss in material. Consequently the decolorization of paraffine takes place in a much simpler way with a fine, pulverized, and, where it is possible, freshly-heated charcoal, which usually becomes mixed with the paraffine by agitation with a wooden mixer, and the greater part of it thereupon very quickly settles to the bottom.

The fine particles of coal, notwithstanding, remain suspended a long time in the fluid paraffine, and are even not entirely removed after a day's rest, so that the paraffine must be completely cleared by filtration through paper. Paraffine that is not filtered is of a smutty gray color. In most of the paraffine manufactories I have found the arrangement of filter paper to be very primitive, and the mixing apparatus separated or divided by the filtering apparatus, so that a continuous scooping over of the paraffine to be filtered upon the filter and a continuous addition of the latter was necessary. Consequently, I give the following description of a mixing and filtering apparatus constructed by me, which I have used in two instances many years with the best results.

This has the following peculiarities in its arrangement: 1. The mixing of the paraffine with bone-black does not take place by the hand or through a mechanical stirring contrivance, but through a warm current of air previously blown into the apparatus. 2. The paraffine treated with bone-black flows of itself into the filter paper placed in a glass funnel, and after the influx has once been regulated the control of the entire apparatus by the workman is scarcely anything at all. Even if at times less penetrable paper should accidentally be placed in the filter, this, from the attention on the part of the workman, cannot easily cause an overflow of the paraffine, while the greater or lesser penetrability of the paper is easily observable during the first half hour by the regulation of the inflowing stop-cock, and this must be considered by the workman. 3. The whole apparatus is heated by waste steam. 4. The mixing and filtering apparatus occupy little room, and, *e. g.*, 25 hundred-weight of paraffine can be easily mixed and filtered in twenty-four hours.

In Figs. 44 and 45 are illustrated: A. The mixing apparatus. B. The filtering apparatus. The steam first enters the filtering apparatus, and then passes through the mixing apparatus into the open air.

The mixing apparatus A consists of a wrought-iron chest, with a turned cast-iron flange, covered with iron cement, in which are three openings for the admission of three cast-iron mixing-kettles. These kettles are fastened to the flange of the steam-chest by a few screws, in order to prevent any displacement which an insecurity of the discharging vessel would cause. The kettles, with the steam-chest, are rendered steam-tight (der dampfdichte Abschluss des Kessels) in the simplest manner by a band of rubber placed beneath the rim of the kettle.

About 75^{mm} above the deepest parts of the bottom of the kettle is cast a support 25^{mm} wide, of such a length that it, with its forward end provided with screws, projects through the tin face-plate of the steam-chest, perhaps 25^{mm} wide. At this point about 3^{mm} thickness of tin is strengthened by a disk fastened by sunken rivets and of 15^{mm} thickness, and provided with four bolt-holes for the reception of screw-tacks. From the outside a flange is tacked upon the end of the kettle support that is provided with screws, and by underlaying with hacked hemp and intimately mixed red-lead cement against the solidly-built face of the steam-chest is so placed that the four screw-holes in the flange correspond exactly with those of the opposite inner disk. After this flange is firmly drawn the end of the kettle support, which is plainly turned off or polished, shall project over the flange 2 to 3^{mm}. Now, four screw-tacks, which are supported by a six-angled truss, are brought into four screw-holes, which are at hand to receive the same, and drawn firmly and steam-proof against the outer flange, and each kettle support is provided with a 25^{mm} wide cast-iron stop-cock. In the distribution of crude paraffine, and, above all, where prepared paraffine is to be filtered, this invention applies equally well, as it completely soaks through several layers of uniform unsized paper by the avoidance of all cements.

It is recommended to provide the surfaces turned upon the lathe with fine circular grooves. In the lower portions of the steam-chests lie six pieces of thinly-drawn crude copper plates (without soldered edges) which are contrived after the manner of the tubes of locomotive boilers, and are so joined outside of the chest by cast-iron knees that they form a long pipe or hose, heated by steam, in which the air to be used for the mixing of the charcoal and paraffine is heated. The exit of this pipe stands diagonally over the mixing boiler in combination with a running tube or siphon, which, through the middle of the boiler, reaches almost to the bottom of the same, being sent off from the copper pipe through a stop-cock in diminished size. It is self-evident that the main pipe for the warmed air from the steam-boiler is to be protected from cooling.

The filter apparatus B consists first of two polished chests, partially within each other, with a common front wall. The latter also will not be touched by the steam, and this arrangement will rest or touch entirely upon the ground, in order, on this side, where the workman is busy for the most of the time, not to have a too strongly heated surface, and to make the real filtering apparatus as comfortably accessible as possible. Otherwise, were there here a double wall filled with steam, then certainly this must be protected from a too strong radiation of heat by a strong wall built in front 120^{mm} thick, and this would detract from the service of the filtering apparatus. Beside, the

a Litchford and Nation's patent, No. 890, 1872. *b* Hodges' patent, No. 3241, 1871.

arrangement chosen insures a cheaper and simpler construction. Then the greater extent of surface can be made impermeable to melted and heated paraffine only with the most extraordinary difficulty (and perhaps not at all); but all loss of paraffine by incompactness or insecurity is to be particularly avoided, so the inner filtering chest to serve for the reception of paraffine must be made of cast-iron in one piece.

The attachment of the steam-jacket is simple and plainly shown in the drawing. The bottom of the cast-iron filtering chest is inclined toward the front, and at the same time from both sides toward the middle; at the deepest point there is an exit tube, with stop-cock for the drainage of the prepared paraffine. In the interior the filtering chest has a projecting brim of perhaps 50^{mms} breadth, which on the rear wall, and at the same time on both sides, serves for the formation of steam space. Upon this edge rest 8 pieces of wrought-iron filter supports, each of which is capable of receiving two glass filters; thus there are 16 filters arranged in rows always in operation. The funnels are made of glass, because it more easily preserves the absolutely necessary cleanliness than if they were made of white tin. One need not fear the destruction of the glass if there is the proper amount of foresight shown on the part of the workman. In about twelve years there were scarcely one or two broken by me. In the midst of the filtering chest, along its length and 50 to 60^{mm} above the glass funnels of the paraffine-distributing pipe, there is a pipe 40^{mm} wide, closed at both ends, communicating through three supports with the corresponding terminal stop-cocks of the mixing kettles, and connected to both sides with eight small cast-iron stop-cocks of 4^{mm} width attached to a wrought-iron pipe. The small stop-cocks are screwed on, and for this purpose small pieces of wrought-iron have been placed with hard solder in the proper places on the distributing pipe.

The mouths of the small stop-cocks do not lie perpendicularly over the middle of the filter, but are nearly in the middle of a side, in order to prevent the perforation of the filter-point by droppings. The paper used for filtering is a thin, but tolerably firm, unsized pressed paper; it is broken after the manner of bent filters. A sheet 45 by 37^{mm} (one 40 by 40^{mm} would be more convenient) makes a a filter that will serve comfortably for the filtration of about a hundred-weight of paraffine.

When working day and night I have always had the filters renewed after using twelve hours. The very little paraffine that remains in the paper is recovered.

It is recommended to surround the warm, radiating surface of the mixing and filtering apparatus with a simple and appropriate non-conductor. This is attained by inclosing the apparatus, and only the front wall of the filter chest is provided with a wooden jacket for securing an isolated stratum of air.

The covering of the apparatus is not shown in the illustration, in order not to interfere with its clearness; likewise the conveyance of the water which falls down from the steam in both apparatus (and which forms in the best of steam spaces) is not noted, since their position depends entirely upon local surroundings.

Finally, a word concerning the restoration of fresh bone-black and the treatment of that which has been used. It is known that the fresher charcoal is the more energetically it acts. In very large paraffine fáctories it is used on this account to prepare it from the coal itself, and by use it settles.

Comparatively speaking, very little can be restored with profit, as it is used even in the largest paraffine factories. In a business of less extent one will easily see from this that it is at least unprofitable to buy the powdered preparation of coal from the charcoal factories, because one receives with it in most cases smut and dust from the sifted granulated charcoal, and has not the slightest guarantee for the quality and freshness of the preparation. I have always, on this account, secured from a neighboring charcoal factory the small quantity of 100 kilograms of freshly prepared granulated and dust-free charcoal and allowed the pieces of coal to be immediately reduced to a fine powder for use in a simply constructed pulverizing cylinder (in Figs. 46 and 47). If one has not a charcoal factory in the immediate vicinity, and has not the certainty of obtaining the granulated coal entirely fresh at all times, then it is well worth the while to buy the pieces of coal in larger quantities and to allow the same to be thoroughly heated in kettles again, previous to the use of the coal which has been just pulverized.

The pulverizing cylinder (Figs. 46 and 47) is made of cast-iron (750^{mm} long and 500^{mm} in diameter) and revolves with riveted wrought-iron pegs in corresponding metallic holes in the facing; in the surface of the jacket or cover there is an opening for filling and emptying made close with gum. The cylinder is revolved best in slow revolutions (at most but two turns per minute). Within the cylinder there lies another massive cast-iron cylinder 120^{mm} in diameter, with a length equal to that of the drum. In twelve hours an apparatus of this size will pulverize perhaps 25 kilograms in the finest manner. These dimensions can be considerably increased without disadvantage.

The bone-black I have mostly used in quantity, not over 3 per cent. of the weight, and the paraffine retained by the same amounts to about the same weight. This silt from the powdered coal and paraffine is first heated together in a thick-walled kettle with return steam, whereby a greater part of the paraffine is separated into a clear liquid, which is scooped up with a shallow ladle and placed directly upon the filter paper.

The silt which has become thin is put in a large iron kettle, in which it, with the least quantity of water (from six to eight parts), is thoroughly cooked out over an open fire and under an active stream of steam, which is used from time to time. By the cooling of the mass almost all of the paraffine separates upon the top of the water as a firm but gray-colored layer, which is taken off, melted, and filtered through the paper with the other materials. A repeated boiling of the silt is seldom necessary, and this second operation almost never pays, because of the cost of the fuel in obtaining the paraffine. The powdered coal still so obstinately retains a very small percentage of the paraffine that this must be driven off by heating the coal, if the latter is to be again used as a decolorizer, or even if it is to be useful in the manufacture of acid phosphate of lime—superphosphate.

With this view I cause it to be thoroughly heated in an inclined cast-iron retort of about 2^{m} to 3^{m} long and 800^{mm} wide, and cross-cut almost elliptically, which is provided with an appropriate receiver for the condensation of the paraffine vapor. (This vapor never remains even at the lowest possible melting point of paraffine undecomposed, but yields paraffine of a low-melting point and oil as the product of decomposition). The paraffine that has been boiled out in shallow wrought-iron chests of perhaps 12^{mm} height and 1^{m} length, whose bottom conforms to the form of the retort, and both of whose sides have small and appropriate stop-cocks, is passed into the retort, and after the ensuing evaporation of all the paraffine (which is instantly known by the cooling of the discharge pipe of the retort) during the heating is left therein four to six hours long for the partial cooling.

Then the cast-iron chests, of which two are placed behind each other in the retort, are taken out and immediately covered with an appropriate tin cover, which is everywhere made close by a covering of clay, and the heated coal-dust is left standing therein until it has become perfectly cooled.

The taking out of the retort, the putting on and sealing of the cover, must take place as quickly as possible, in order to prevent the partial reduction of the coal to ashes. (*a*)

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a Dingler, ccxvi, 244.

Powdered fuller's-earth, marl, clay, or any similar substance, mixed with melted paraffine and allowed to subside, will deprive it of color, and the paraffine adhering to the subsided particles may be separated by heating with steam and agitation. (*a*) The successful use of these natural, insoluble silicates led to experiments upon the use of artificial silicates of the alkaline earths. For this purpose silicate of magnesia was found to answer all requirements best. This material is formed by the reaction of solutions of sulphate of magnesia and silicate of soda, the resulting silicate of magnesia being thoroughly washed and dried by steam heat. It is then added to the melted paraffine, and after it has subsided and the paraffine has been drawn off the residue is treated with dilute sulphuric acid. When the paraffine separates and rises to the surface the silica is precipitated, and the solution of sulphate of magnesia lies between them. The paraffine is removed, the solution of sulphate of magnesia is washed from the silica, and the silica is dissolved in caustic soda. It will thus be seen that the material is continually renewed with the addition of sulphuric acid and caustic soda. (*b*) It is found in using these silicates, whether natural or artificial, that a red heat destroys their action, and also that they must be used at such a temperature that the water of hydration is expelled, the coloring matter apparently taking its place. Hence, if the silicate is applied at a temperature only a few degrees above the melting point of the paraffine, it will have no action upon it until the temperature has been raised above that sufficient to expel the water. (*c*)

Another method which has been suggested for the removal of the oils from the soft paraffines consists in melting them with from 5 to 10 per cent. of oleine and cooling and pressing. Paraffine is insoluble in oleine. The mineral oils dissolved in oleine are separated from it by distillation, the former distilling at 220° C. and the latter at 280° C. (*d*) Bisulphide of carbon has also been used for this purpose. (*e*)

Although great efforts are made by all manufacturers of paraffine to prepare the wax of a beautiful pearly whiteness, it is a well-known fact, particularly among the manufacturers of continental Europe, that this freedom from color is not permanent for a long period. It is probable that paraffine obtained through the careful distillation of petroleum is purer and less liable to change than that made from distillation of shale or brown coal. Paraffine is often colored for candles and other purposes. As the beautiful colors produced from aniline are insoluble in paraffine, they are first dissolved in stearine, and the stearine is then melted into the paraffine; the color can be recovered, however, by melting the mixture and passing it through a filter. Two per cent. of stearine will give a clear pink color, and 5 per cent. a full crimson. Blue may be obtained with indigo, red with logwood, green with the two mixed and also with indigo and saffron, orange with logwood and saffron, and yellow with saffron. These colors may be readily incorporated with the mass by grinding a small piece of the paraffine with the color and then working it into the mass while hot. (*f*) To color paraffine black it is recommended that the wax be digested with the fruit of the *Anacardium orientale*, which contains a black fluid vegetable fat that combines with the paraffine and does not injure its illuminating properties.

Section 4.—PROPERTIES OF PARAFFINE.

Crude fossil paraffine from Galicia is brown, greenish, or yellow, translucent at the angles, with a resinous fracture. It is usually brittle, and when softened can be kneaded like wax, becoming dark on exposure to air. It becomes negatively electric and exhales an aromatic odor with friction. It melts at 66° C. (149° F.), but its illuminating power is such that 754 ozokerite candles equal 891 of ordinary paraffine, or 1,150 of wax. In 1871 Mr. John Galletly examined a paraffine from Boghead coal which melted at 80° C. and had a boiling point near the red heat, and which therefore presented great difficulties in the way of determining its vapor density. Distillation appeared to convert about half of it into liquid hydrocarbons, but the portion that remained solid after crystallization from naphtha retained its melting point unaltered. This specimen followed the general rule that paraffines from different sources diminish in solubility as the temperature increases at which they melt. The following illustrates this point:

Melting point.	Solubility in 100 c. c. of benzole at 18° C.
Deg. C.	*Grams.*
35.0	133.0
49.6	6.0
52.8	4.7
65.5	1.4
80.0	0.1

a Fordred, Lamb & Sterry's patent, No. 610, 1868.
b Smith & Field's patent.
c Frederick Field: *On the Paraffine Industry,* J. S. A., xxii, 349; Am. Chem., v, 169.
d P. Wagerman, Poly. C. Bl., 1859, 75.
e E. Allan, Dingler, cxlviii, 317; Poly. C. Bl., 1858, 1033.
f Eng. Mech., xxiii, 259.

Although only one part of the paraffine melting at 80°, dissolved in 1,000 of benzole at 18° C., it mixes with it in all proportions above its melting point. The densities of paraffines appear to increase with their melting points, but with specimens having the same melting points it is somewhat difficult to obtain the same results.

The following are numbers obtained with paraffines from Boghead coal: (*a*)

Melting point.	Specific gravity.
Deg. C.	
32.0	0.8236
39.0	0.8480
40.5	0.8520
53.3	0.9110
53.3	0.9090
58.0	0.9243
59.0	0.9248
80.0	0.9400

In 1878 E. Sauerlandt examined the relation of the melting point to the specific gravity of paraffines from ozokerite with the following results: (*b*)

Melting point.	Specific gravity.
Deg. C.	
56	0.912
61	0.922
67	0.927
72	0.935
76	0.939
82	0.943

Sanerlandt separated his paraffines by using solvents.

Sulphuric acid attacks all the paraffines, provided the temperature is sufficiently high. It is further observed that this acid more readily attacks the paraffines with high boiling points than those the boiling points of which are lower. The carbon separated from the paraffine melting at 80° C. by the action of sulphuric acid is in so fine a state of division as to pass through filter paper. Chlorine and nitric acid both produce substitution compounds with many specimens of paraffine, but the products are by no means uniform. (*c*)

It is not an infrequent occurrence to find samples of paraffine mixed with stearic acid and stearic acid containing paraffine. As these mixtures are made legitimately, and also for purposes of adulteration, it therefore becomes necessary to determine their constituents. Any attempt to determine the constituents of such a mixture by determining the density would of course be futile, as the density of neither paraffine nor stearic acid is constant. R. Wagner has proposed the following method, which may be used either qualitatively or quantitatively: Not less than 5 grams of the mixture are taken and treated with a warm solution of hydrate of potash, which must not be too concentrated. A soap is formed with the stearic acid, while the paraffine remains unaltered. Salt is then added until the soap separates as a soda soap and takes down the paraffine with it. The soap is thrown on a filter and is washed with cold water or very dilute ethylic alcohol. The salt is first washed out, and then the soap, finally leaving the paraffine on the filter, which is dried at a temperature below 35° C., care being taken not to fuse it. The paraffine is then carefully dissolved from the filter with ether by repeated washings and the solution carefully evaporated in a weighed porcelain crucible in the water-bath at a low temperature. The residue, consisting of paraffine, is then weighed, and the stearic acid estimated by difference. (*d*)

E. Donath saponifies the mixture with potassa and precipitates with calcium chloride. The calcium soap is washed on a filter with hot water and dried at 100° C. Part of it, after powdering, is extracted with petroleum ether, the extract evaporated at 100° and weighed, when the residue represents the paraffine. (*e*)

The most approved method of determining the melting point of paraffine consists in throwing a chip of paraffine on hot water and allowing it to melt. Then the water is slowly cooled, and the temperature is noted at which the globule of paraffine loses its transparency.

It has been found impossible in the amount of time that I have been able to devote to this portion of the subject to call attention to all of the great number of specific investigations that have been made upon paraffine, and the difficulty of attempting an exhaustive discussion of the subject is increased by the obscurity of the nomenclature. Paraffine in the United States and in the languages of continental Europe is used to signify the solid hydrocarbons obtained in distillates made at low temperatures, but in England the word has been given a

a *Chemical News*, xxiv, 187.
b *Hübner's Zeitschrift*, 1878, 81; Dingler, ccxxxi, 383.
c *Chemical News*, xxiv, 187.
d *Ibid.*, xxvii, 16.
e Dingler, ccviii, No. 2, *Am. Chem.*, iv, 196.

much wider signification, it having been applied to all of the fluid products of such distillation belonging to the marsh-gas series (C_nH_{2n+2}). It appears to me probable, however, that among the solid products to which this name is applied there are to be found the higher members of the series C_nH_{2n}, as well as the series C_nH_{2n+2}, the original substance to which Reichenbach gave this name belonging to the latter series. Among other facts which lend strong support to this opinion is the readiness with which some of the paraffines are attacked by reagents, forming substitution compounds, while others are, true to their name, nearly destitute of affinity. A. G. Pouchet acted on paraffine with fuming nitric acid and obtained an acid which he called paraffinic acid. Analysis of this acid, and also of its salts, showed its composition to be $C_{24}H_{48}O_2$, which indicated that the paraffine had a composition $C_{24}H_{50}$. (*a*) The proof seems equally convincing that the paraffine melting at 80° C. examined by Galletly belonged to the series C_nH_{2n}. It is therefore to be concluded that the opinion advanced as long ago as 1856 by Philipuzzi, that commercial paraffine may be separated into a number of bodies differing in boiling points, is correct, and that definite knowledge regarding the constitution of paraffines from different sources awaits further investigation.

Chapter V.—SUBJECTS OF INTEREST IN CONNECTION WITH THE TECHNOLOGY OF PETROLEUM.

Section 1.—"CRACKING."

The importance of that reaction which has been technically termed "cracking" scarcely admits of exaggeration. To assert that it is essentially destructive distillation, and that the results of its action are oils of decreased density, the decrease dependent upon the extent to which it obtains action, explains neither the nature of the reaction nor the importance of its effects. In the elaborate report upon petroleum made by Dr. J. Lawrence Smith to the judges of the Centennial Exposition he claims that the phenomena attending the destructive distillation of petroleum were first observed by Professor B. Silliman, jr., and noted by him in his famous report of 1855. (*b*) Professor Silliman says:

> The uncertainty of the boiling points indicates that the products obtained at the temperatures named above were still mixtures of others, and the question forces itself upon us whether these several oils are to be regarded as *educts* (*i. e.*, bodies previously existing and simply separated by the process of distillation), or whether they are not rather produced by the heat and chemical change in the process of distillation. The continued application of an elevated temperature alone is sufficient to effect changes in the constitution of many organic products evolving new bodies not before existing in the original substance.

When consideration is had of the knowledge possessed by chemists concerning petroleum and similar substances at the time Professor Silliman made this unique and original investigation the above paragraph is properly regarded as remarkably sagacious and suggestive. No one in 1855 knew whether native petroleum was a homogeneous fluid decomposed by distillation, as are fixed oils, or a mixture of a great number of fluids separated by distillation, as it really is. Professor Silliman's question remained unanswered until Pelouze and Cahours, and later Warren and Storer, attempted to ascertain what manner of substance petroleum really is. Warren and Storer published their results in 1865, (*c*) and showed that they had succeeded in isolating, in a state of purity, portions of the members of three homologous series of hydrocarbons. Two of these series were isomeric, but the boiling points of the corresponding members of the two groups were about 8° C. apart. Professor J. D. Dana has regarded these hydrocarbons as educts, and has placed them in his system of mineralogy in their proper place as natural, not artificial substances. The fact that they have been isolated in such a degree of purity that considerable quantities have been obtained having a constant boiling point, a constant chemical composition, and furnishing accurate results on the determination of their vapor densities, furnishes all the testimony that chemists can reasonably ask regarding the question whether they are educts or products. The analogy found to obtain between these constituents of petroleum and those of the distillates from albertite, Boghead mineral, cannel coal, and lime soap made from menhaden oil has been considered by some chemists to indicate that, whereas the constituents of these distillates are the constituents of products of destructive distillation, petroleum must be destructively distilled in order to furnish them. Might not these unquestioned facts be so interpreted as to regard petroleum itself as a product of destructive distillation, and the similarity of these fractional distillates be also regarded as an additional proof that all of these products of a similar process, acting on similar materials, are very complex mixtures of compounds

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a C. R., lxxix, 320; J. C. S., xxviii, 50. *b* *Am. Chem.*, ii, 18. *c* Mem. A. A. (N. S.), ix, 135; see also page 54.

of carbon and hydrogen that are related to the petroleum as *educts*, and not as *products?* I think all of the phenomena connected with this subject are most satisfactorily explained upon this hypothesis.

I quote the following paragraph from the paper read by A. Bourgougnon at the meeting of the American Chemical Society, held September 7, 1876: (*a*)

During the distillation the products are more and more heavy until the heat produced decomposes the oil in the still; then the oil is dissociated, and by this dissociation, or "cracking", lighter and also more inflammable products are obtained. At the same time this decomposition is accompanied by a formation of carbon, which is deposited in the still, and gases of a very offensive odor pass off with the oil.

This is the first instance that has come under my notice in which this very proper term (*dissociation*) is applied to this reaction. The phenomena of dissociation are constantly observed throughout the entire range of technical and scientific operations. Even marsh-gas, by a sufficiently high temperature, is resolved into hydrogen and the carbon of the gas retorts; the coal is resolved by dissociation, at a red heat, mainly into marsh-gas, coal-tar, and coke; at a less elevated temperature into those hydrocarbons homologous with marsh-gas, ranging through all of the paraffine series from marsh-gas to solid paraffine wax, leaving a residue of coke. At the temperature required for this last operation a small percentage of another series of hydrocarbons homologous with ethylene appears, but none of the benzole series that characterize coal-tar. "It has been observed that the schistoils of Buxière-la-grue and of Cordesn do not contain benzole and naphthaline, because the distiller purposely works at too low a temperature". (*b*)

Antisell, in *Photogenic Oils*, page 45, says:

The tendency of destructive distillation is to produce compounds possessing more simplicity of composition than the original substance, and capable of sustaining the higher temperatures at which they form unaltered; so that, under the range of temperature indicated (300° to 2732° F.), liquids will be formed when the temperature is least, as at the commencement, and gases when the heat has arisen to the high point set down; and as in the lower ranges, where liquids are produced, the effect of this augmented heat within this lower range is to lessen the complexity of the compound by dropping or reducing its amount of carbon or of hydrogen, it is at the very lowest temperatures that the liquids containing the highest number of atoms of carbon and hydrogen will be found; and when the temperature arises to that essential to the formation of gas, this gas (a carbide of hydrogen) is produced at the expense of the complex liquids formed at first, which give off some carbide of hydrogen, and thus have their proportions simplified.

If then, as has been assumed in these pages, petroleum is the product of the destructive distillation of pyroschists at the lowest temperature possible, it naturally follows that the paraffine series, from marsh-gas up to solid paraffine, would form the bulk of the educts of petroleum. This opinion is confirmed by all that is known either by technologists or chemists concerning the proximate principles that are the *normal constituents of the Paleozoic petroleums found on the western slope of the Alleghanies;* and it is doubtless to this fact that they owe in large part their great superiority over the petroleums of other localities, because the paraffine series of compounds contain the largest proportion of hydrogen as compared with the carbon of any series known to chemists.

Now, when these compounds of the paraffine group are subjected to temperatures above their boiling points, they are dissociated, and the researches of Thorpe and Young upon the distillates of paraffine wax under pressure have shown that they are not decomposed into the lower members of the same series, but into the olefine series, the proportion of the paraffine series being comparatively small. The significance of this discovery lies in the fact that the olefines contain less hydrogen in proportion to the carbon than the paraffine group, and in combustion produce a less brilliant and luminous flame; hence it is to be inferred that while "cracking" will convert a large percentage of petroleum into illuminating oil, the oil will be inferior in quality just in proportion as it consists of cracked oils. The statement that has been made that the present process of manufacture "takes the heart out of the petroleum" for high test-oils and leaves an inferior residue for the ordinary 110° oil is not without some foundation in fact; but it is not true as a general statement, for the amount of material existing in ordinary petroleum suitable for the production of high test-oil is estimated at 10 per cent., while the whole amount of illuminating oil is about 70 per cent. Manifestly, then, the manipulation of the petroleum is a matter of great importance to the consumer of these oils. The manufacturers of reduced petroleum and of high test-oils prepare a strictly paraffine oil from the educts of the petroleum, and convert the remainder either into an 110° oil by "cracking" or into paraffine oils and wax by careful fractional condensation. The 110° oil produced by cracking alone would be much inferior to the same grade of oil produced in an establishment where the bulk of the petroleum was converted into an oil that consists of both educts and products of the distillation.

Illuminating oils are classed and sold as "Water White", "Standard," and "Prime", according to their color. The oils belonging to the paraffine series are neutral, inert oils, not readily acted upon by chemical reagents, and not readily forming substitution compounds. Sulphuric acid removes from such oils the small percentage of unstable oils which they contain and leaves them colorless and limpid or "Water White". With the standard and prime oils, consisting largely of "cracked" oils, the case is wholly different, as they contain members of the olefine group which form substitution compounds with sulphuric acid with great readiness. These compounds are not readily destroyed by solutions of caustic alkali, and therefore remain in the oil. These oils blacken when heated to 200° F., and discharge sulphurous acid (SO_2). When burned, they cause the wick to coat and discharge

a *Am. Chem.*, vii, 81. *b* *Chemical News*, xxviii, 22.

sulphurous acid with the products of combustion. This is abundantly demonstrated by the researches of the German chemist, J. Biel, (*a*) in which he compared oils manufactured from Russian and American petroleum with results shown in the following table:

Varities examined.	Specific gravity at 16° C.	Tension of vapor at 35° C.	Flashing point.	Inflaming point.	Essence or naphtha.	Burning oil.	Heavy oil.	The comparative illuminating power at—			
								6^{cm}.	9^{cm}.	12^{cm}.	14^{cm}.
		Millimeters.	*Deg. C.*	*Deg. C.*	*Per cent.*	*Per cent.*	*Per cent.*				
Standard	0.795	160	26	30	14.40	45.90	39.7	7	3.35	1.36	0.80
Astral	0.783	5	48	51	2.20	87.80	10.0	7	4.50	3.00	1.36
Imperial	0.789	13	44	46	5.50	80.00	14.0	7	6.00	3.00	1.36
Russian O	0.803	201	26	29	33.50	66.50	....	7	6.25	4.45	3.70
Russian A	0.817	73	28	30	15.40	73.20	10.5	7	5.20	4.00	3.00
Russian B	0.822	45	30	35	12.80	78.30	8.4	7	5.70	3.20	1.65
Russian C	0.821	95	25	26	15.25	71.25	13.5	7	....	....	....

I presume the Imperial oil is an oil manufactured in Germany from crude American petroleum. A comparison of these results shows the great superiority of the Astral and Imperial oils over the Standard. (*b*)

Because these oils, cracked by one distillation and necessarily imperfectly cracked and finished by treatment, are of inferior quality, it is not, however, to be concluded that cracked oils cannot be made of superior grade. The earliest practical application of destructive distillation to the manufacture of illuminating oil was made by the late Luther Atwood, of Boston, Massachusetts. He patented the product and apparatus for obtaining it in 1859, and the process was placed in operation by Mr. Joshua Merrill, of the Downer Kerosene Oil Company, before petroleum became an article of commerce. Mr. Merrill treated thousands of barrels of heavy oil, purchased from those who could not work them often at as low a price as 10 cents a gallon, and cracked them into burning oil of 45°, which, at that time, was readily sold at from 90 cents to $1 40 per gallon. The Downer company have worked this process ever since and have made more or less cracked oil, but they work at low temperatures with steam, and have never made their burning oil with one distillation. Their oils are highly finished products, and the very high reputation that they have always borne is a sufficient guarantee of their excellence. There is really upon the market a great variety of illuminating oils prepared from petroleum, some of which at double the price are cheaper than others, without regard to either their appearance or their safety.

An experiment was made in Boston some years since, which, while without results of practical value, confirmed the views stated above. It was assumed that by cracking naphtha permanent gases would be obtained, and the attempt was made to convert the naphtha into a mixture of marsh-gas and hydrogen by injecting steam into a vessel filled with the volatile liquid. The result was so far successful as to produce a considerable amount of permanent gases, and on evaporating the naphtha remaining a residue of heavy lubricating oil was obtained. (*c*)

Paraffine oil has been frequently converted into illuminating gas by allowing it to drip upon red-hot coke and by other similar processes. An analysis of such a gas in one instance showed it to consist of—

	Per cent.
CH_4, marsh-gas	54.92
C_2H_4, ethylene	28.91
H, hydrogen	5.65
CO, carbonic oxide	8.94
CO_2, carbonic acid	0.82

The presence of ethylene in such large proportion with free hydrogen indicates that at a lower temperature the homologues of that gas would probably be found in still larger proportion. (*d*)

SECTION 2.—"TREATMENT."

Next to the distillation of oils no question is of more importance than the chemical treatment which the distillates receive. It has always been claimed by the Downer company that the proper treatment for illuminating oil is washing with oil of vitriol, to which is sometimes added bichromate of potash, from which the sulphuric acid sets free chromic acid, and then washing with solution of caustic soda, and, finally, distillation over caustic soda. This treatment at one time produced oils that were unrivaled in the markets of the United States, and they have always held a very high reputation. It is, however, claimed by manufacturers of equally high

a Dingler, ccxxxii, 354; Indus. Z., 1879, p. 204; Chem. Z., 1879, p. 285.

b This is a general trade-mark, and not the exclusive property of the Standard Oil Company.

c S. Dana Hayes, A. J. S. (3), ii, 184. I accept the conclusions reached by Mr. Hayes; but the experiment was not conducted so as to exclude the possibility that the heavy oils were dissolved in small quantity in the several thousand gallons of crude naphtha used.

d Archiv der Pharmacie, June, 1874; Am. Chem., v, 431.

reputation that the finishing of oils by distillation is wholly unnecessary, if not positively detrimental. Judging from all that I can learn in reference to this subject, I conclude that the treatment that distillates should receive depends upon what they are. There are:

1. Distillates produced by reducing petroleum.
2. Distillates taken off before cracking commences.
3. Distillates that are wholly cracked.
4. Distillates that are mixtures of 2 and 3.

The first and second classes would consist almost wholly of the paraffine series (C_nH_{2n+2}) of hydrocarbons; that is, inert and neutral to chemicals. Consequently they would be easily treated, and would yield colorless and neutral oils, especially when more or less caustic ammonia is used along with or after the soda treatment. Classes three and four, however, are quite different. These consist of more or less of the olefines (C_nH_{2n}) that are not chemically inert, but form substitution compounds with readiness with such an active reagent as oil of vitriol. In these substitution compounds SO_2 takes the place of two atoms of hydrogen in the hydrocarbon, and the hydrogen unites with the atom of oxygen to form water. It is claimed by those who finish oil by distillation that these substitution compounds are not destroyed by agitation with caustic alkali. Others admit that they are not destroyed by caustic soda, but claim that they are removed by caustic ammonia. I am inclined to think that neither of the caustic alkalies will remove them. I have examined a large number of illuminating oils during the last twenty years, and I have found that a large proportion of them blacken on being heated to 200° F. and yield sulphurous acid fumes. I have never attempted to estimate this quantitatively, but the amount yielded by half a pint has in several instances been such as to be very apparent in the atmosphere about the apparatus. Such oils have not been properly treated. Half a pint is no unusual amount to consume on a winter's evening, and while in the experiments to which I have referred the sulphurous acid was disengaged suddenly and almost instantaneously, the fact that when the oil was burned it would be thrown off slowly would not lessen its quantity nor its effect upon those exposed to its influence. My own conviction is that all oils that will blacken and give off sulphurous acid should be finished by distillation over caustic soda.

The following abstract of an elaborate research undertaken by royal command, and published in Dingler's *Polytechnic Journal* and many other German scientific periodicals, has not before been translated so far as I have learned. Its importance demands for it a wider circulation. The author, H. Vohl, appears to use the term "Roh-petroleum" to designate American refined oils imported into Germany. He asks "if by the burning of petroleum there is not danger of producing unhealthful gases, and whether crude (Roh) petroleum does not itself contain injurious compounds which are kindled by its burning that are removed when it is purified?" and then continues:

The only element of crude petroleum which liberates unwholesome gases when it is burned is sulphur. No petroleum is free from it. In many cases the petroleum is polluted, in the so-called "cold treatment" with sulphuric acid, by sulphur compounds. It is particularly so when an appreciable quantity of paraffine is left in lamp oil, and because of its dark color is subjected to an additional treatment of sulphuric acid. In this way refined oil often contains or retains so much sulphuric acid that its burning develops unwholesome influences. Sulphuric acid in part forms a compound with the heavy paraffine oil which is soluble in the remaining oil, and neither through treatment by water nor by alkalies is it decomposed, so that a subsequent treatment with these substances offers no guarantee for the absence of sulphur. When oil so treated is subjected to distillation, first a clear burning oil passes over, then a rapid development of sulphurous acid gas, often accompanied with coloration of the contents of the retort. Finally, after a limited separation of sulphur has taken place in the neck of the retort, sulphureted hydrogen comes over, and a carbonaceous mass with acid reaction remains. An erroneous opinion is held in many places that a strong blue reflection possessed by many kinds of petroleum is an indication of its superior quality and usefulness. Petroleum has this peculiarity when it contains an appreciable quantity of paraffine oil. Most hydrocarbons resembling retinols have these blue reflections, with a high melting point. None of the different kinds of petroleum investigated were free from sulphur or sulphuric acid, and therefore it can be assumed with justice that petroleum burning-oil free from sulphur belongs to the exceptions.

Petroleum, wherever a tranquil light is necessary, has superseded illuminating gas; besides, it is cheaper than coal-gas, so that it is entirely out of the question that the consumption of petroleum should decrease to any important extent, and therefore so much the more necessary in order to direct attention to these sulphur contents, that the removal of the injurious contents must be provided for. Among those who make use of petroleum for illuminating purposes inflammation of the eyes and catarrhal troubles often appear, for which physicians can never afford relief, because the source of the trouble is unknown to them.

The series of experiments embraced the following determinations, beside the sulphuric acid:

(*a*) The specific gravity of the oil at 15° R. water =1.000.

(*b*) The temperature (R.) at which the oil gives off inflammable vapors.

(*c*) The contents in oils of specific gravity 0.740.

(*d*) The contents in paraffine oils of specific gravity, 0.850, solidifying at + 15° R.

(*e*) The consumption of the oil, in grams, per hour in a lamp with a plain burner, with a wick 18^{mm} broad and 2^{mm} thick, having a capillary attraction of 8^{cm}.

In order to determine whether the sulphur is contained as sulphuric acid or as a substitution compound of sulphuric acid with an hydrocarbon, he heated the oil a long time at the boiling point in a glass retort with a piece of sodium or potassium. The bright surface of the alkaline metal is soon covered by a yellowish layer, so that one can safely conclude upon a sulphureted compound in the oil. After cooling add distilled water drop by drop until the excess of alkaline metal becomes oxidized and the sulphur, as sulphide of potassium, passes into solution. Then stir the fluid with a glass rod that has been immersed in a solution of nitro-prusside of sodium. The presence of the smallest quantity of sulphur will immediately color the solution a beautiful violet-blue. (*a*)

a Dingler, ccxvi, 47; W. B., xxi, 1053.

TABULAR STATEMENT OF EXAMINATION OF OILS BY H. VOHL.

No.	Specific gravity.	Temperature at which inflammable vapors are given off.	Per cent. contained in oils of specific gravity 0.740.	Per cent. contained in oils of specific gravity 0.850.	Hourly consumption of oil in grams.	Per cent. of sulphuric acid contained.
		Deg. R.				
1	0.780	23.0	24.964	14.195	16.78	0.994
2	0.790	28.0	18.330	19.519	15.46	2.001
3	0.790	28.0	3.050	5.022	15.00	1.884
4	0.780	27.0	19.889	14.987	16.50	0.946
5	0.805	24.0	22.133	28.666	17.11	1.560
6	0.790	23.0	25.950	9.669	17.20	0.876
7	0.800	27.0	25.345	11.500	14.88	0.998
8	0.790	22.0	35.460	11.590	17.90	1.014
9	0.795	23.5	25.203	12.100	17.12	0.914
10	0.795	27.0	15.233	5.410	14.50	0.348
11	0.800	24.0	25.575	35.769	16.00	3.114
12	0.790	19.0	32.440	19.711	16.14	1.440
13	0.790	19.5	29.580	28.711	17.25	2.100
14	0.790	19.0	33.216	26.461	10.89	1.210
15	0.785	18.0	34.706	3.506	17.98	0.346
16	0.779	8.0	48.051	20.512	19.38	1.950
17	0.790	19.0	38.193	23.367	18.25	2.146
18	0.800	27.5	20.950	32.550	16.50	2.200
19	0.798	25.5	20.600	26.480	17.33	0.216
20	0.795	23.0	21.400	27.140	17.50	0.220
21	0.790	23.0	25.400	35.440	14.20	0.389
22	0.795	24.0	24.116	36.880	14.29	0.401
23	0.790	22.0	36.118	13.400	17.55	0.991
24	0.790	19.0	35.661	14.014	17.24	0.973
25	0.800	27.0	16.033	6.880	15.36	0.310
26	0.795	26.0	18.000	8.446	16.02	0.300
27	0.795	26.0	17.880	9.001	15.98	0.310
28	0.780	9.0	48.336	20.330	19.66	1.977

The amount of sulphur indicated by this table is surprisingly large, but I think it should have been computed as sulphur rather than as sulphuric acid. As sulphuric acid it is already oxidized and would not decompose at 200° F. and appear as sulphurous acid. It is compounds that will burn into sulphurous acid gas, and not sulphuric acid, that render these oils noxious. No examination that I have ever made has led me to think sulphuric acid (SO_3) is present in illuminating oil.

SECTION 3.—"SLUDGE."

"Sludge" is the name applied to the refuse acid and alkali solutions from the agitators. When petroleum first began to be extensively manufactured, many attempts were made to recover both the acid and the alkali from these spent solutions. The acid forms a black, tarry mass, and the alkali a sort of soapy curd, that forms flocks of a rusty color, and also compounds that pass into solution, as well as sulphate of soda. By evaporating the soda sludge to dryness and calcining to burn out the organic matter an impure carbonate of soda is obtained that can be converted into caustic soda by the ordinary process. The sulphate of soda and other impurities thus accumulate in the soda solution and finally render its action imperfect. As this simple process for recovering the soda has never been used to any considerable extent, I infer that it has never, on the whole, been considered profitable. There was used during the census year an amount of soda crystals, soda-ash, and caustic soda estimated to be equivalent to 3,500 tons of soda-ash, all of which ran to waste.

The sludge acid is recovered by first heating it, when it separates into an oily superficial layer and a heavy layer beneath containing the acid. This acid liquid is drawn off and evaporated and concentrated like chamber acid, the black carbonaceous matter being destroyed at the high temperature required for concentration. This process is also very simple, but it produces abundant suffocating fumes and disagreeable odors, and in the neighborhood of dense populations is justly considered a great nuisance. At Cleveland, Ohio, and near Titusville, Pennsylvania, there are establishments for recovering spent acid, to which the acid sludge is carried in tank-cars. The manufacturers of petroleum are paid an amount sufficient to induce them to put their sludge into tank-cars rather than to allow it to run to waste, and the recovered acid is returned to them at the ruling price for sulphuric acid. Sludge acid is sold to the manufacturers of commercial fertilizers in localities where the refineries are convenient to such establishments. Much, however, is allowed to run to waste; it is run into rivers and lakes, and, in the neighborhood of New York, is conveyed in barges outside of New York harbor and emptied into the sea. The amount of this material that has been thrown into Oil creek and the Allegheny river is enormous. It has lodged upon the rocks and on the gravel along the creek and stained them black; and it floats upon the river continually, often communicating its peculiar odor to the atmosphere above. I have also noticed it from the deck of a Sound steamer floating on the East river, its peculiar odor being perceptible at the level of the deck nearly all of the distance from Blackwell's island to the Battery. During the census year 45,819.5 tons of sulphuric acid were used in the manufacture of petroleum products. Of this vast quantity 21,158.75 tons were recovered, 22,162.5 tons were sold to manufacturers of fertilizers, and 2,498⅛ tons were "run to waste", which phrase means discharged into lake Erie, the tributaries of the Ohio river, the Delaware river, Chespeake bay, or the ocean.

The effect of both acid and alkaline sludge upon fish was investigated by Dr. Stevenson Macadam, and the results were communicated in 1866 to the British Association for the Advancement of Science. He made dilute solutions of different strengths and immersed fish in them with the following results:

> 1, a fish placed in the acid sludge died in five minutes; 2, in one part sludge and three of water, it died in ten minutes; 3, in one part sludge and twenty of water, it died in fifteen minutes; 4, in one part sludge and one hundred of water, it died in fifteen minutes; 5, in one part sludge and one thousand of water, it died in two hours; while in one part sludge to ten thousand parts of water the fish were not killed for twenty-four hours, but were apparently sick and prostrate. The spent-soda liquor which has been employed in treating oil which has been previously acted upon by acid is decidedly alkaline and caustic in its nature. It has extracted from the oil and holds in solution more or less carbolic acid and its homologues, and the poisonous nature of the spent-soda liquor is doubtless augmented by the presence of these acids. A sample of this soda liquor which was flowing from a paraffine oil manufactory, and which contained extra water, proved destructive to fish in ten minutes; with three parts of water it killed fish in twenty minutes; with twenty parts of water, the fish were dead in twenty-five minutes; with one hundred parts of water, the fish were dead in thirty minutes; diluted with one thousand times its volume of water, the soda liquor proved destructive to fish in twenty hours; while with ten thousand parts of water the fish were not killed, but were apparently slightly sick. (*a*)

He also found that shale oil, Pennsylvania petroleum, and their manufactured products, were all deleterious to fish; but the shale oil was more injurious than petroleum.

If these sludge solutions were mixed, and as a result sulphate of soda instead of free sulphuric acid and caustic soda were discharged into the streams, the injurious effects upon animal life would without doubt be lessened; but even in that case the discharge of such vast quantities of mineral and organic poisons into streams the waters of which are used by thousands of the inhabitants of the towns upon their banks cannot be viewed as anything less than a public misfortune, if no regard whatever is had to the fish with which the streams are stocked. The extent of such injury as a problem in public health, as compared with other interests, is properly a subject of inquiry for the physician.

SECTION 4.—FIRES.

The attention of the public was called to the great danger of allowing large quantities of either crude or refined oil to be stored within the limits of large cities by the disastrous fires that occurred in Philadelphia in March, 1865. A quantity of oil, amounting to what would now be considered only a few thousand barrels, was stored in some open sheds on a lot that was not otherwise occupied. This oil was set on fire, as was supposed by an incendiary, very early on a cold morning early in March. The flames spread rapidly, and as the barrels burst the contents accumulated in a pool of burning oil that soon overflowed the lot, and, filling the frozen gutters, ran down a narrow street in the neighborhood in a rivulet of flame as high as two-story houses. Houses were set on fire, and their occupants, fleeing for life, were overtaken by the stream of fire and burned before they could escape. In this way several lives were lost. This catastrophe led to the enactment of laws forbidding the storage of petroleum within the limits of large cities, and in the case of Philadelphia the railroad carried a branch track to tide-water below the city for its delivery and shipment.

Petroleum refineries have been considered especially liable to destruction by fire, yet some of the oldest establishments in the country have received very little injury from that source. The amount of capital invested in the manufacture of petroleum during the census year was $27,325,746. Of this, $21,196,246 was used twelve months, $318,000 eleven months, $2,315,000 ten months, $2,019,000 nine months, $727,000 eight months, $100,000 seven months, $510,000 six months, $100,000 five months, $36,000 four months, and $4,500 three months, equal to $25,781,327 used for twelve months. During the same time the losses from fire in the refineries of the country amounted to $104,631, or less than one-half of 1 per cent. When to this invested capital is added the total value of manufactured products that passed through these establishments, equal to $43,705,218, the total being $71,100,964, these losses are insignificant. The refineries lately constructed are for the most part uncovered, and the material about them that can burn is reduced to a minimum; but the older refineries that have not burned are inclosed in very substantial buildings, provided with ample means for completely filling them with steam in case of any accidental ignition of the oil. Really the danger from fire depends upon the want of care exercised by those who have charge of the refineries more than upon any especial appliances for preventing or extinguishing them. The great fire in Titusville in June, 1880, and caused by lightning. Against the occasional destruction of property by the elements no amount of foresight or precaution will prevail.

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a *Chemical News*, xiv, 110.

SECTION 5.—THE SPECIAL TECHNOLOGY OF CALIFORNIA PETROLEUM.

The earliest attempts to manufacture the petroleum of southern California were made by Mr. Gilbert, of San Buenaventura, about 1860, who distilled the malthas of the Ojai ranch and obtained from them a small quantity of oil of inferior quality that could be used for illumination. When I commenced my experiments in 1865 upon the same material I was soon convinced that it was quite different from the petroleum with which I was familiar on the Atlantic coast. The yield of oil of a specific gravity suitable for illuminating purposes was small in quantity, and burned in the lamps in use for Pennsylvania oils with a dull and smoky flame. The proportion of oil of medium specific gravity was very large, and the heavy oils, while of very low specific gravity, were not unctuous, and were destitute of lubricating properties. One of these denser distillates, with a specific gravity of 16° B., was a mobile fluid-like water or an essential oil. When the Hayward Petroleum Company and Stanford Brothers commenced the manufacture of petroleum from their springs and tunnels in San Francisco they encountered the same difficulties on a large scale. The oils were all of inferior quality, and the "middlings", as they were called, were so large a proportion of the distillate as to prove a very great obstacle to the success of the enterprise.

Professor Silliman secured a barrel of the Ojai malthas and carried it to Boston, where he worked it in the experimental apparatus of the Downer company. From the report of his results I make the following abstract:

The crude oil is very dark. At ordinary temperatures (60° F.) it is a thick, viscid liquid, resembling coal-tar, but with only a very slight odor, and with a density of 0.980 or 13½° B. It retains, mechanically entangled, a considerable quantity of water. The tar froths at the commencement of distillation from the escape of watery vapor. It yields by a primary distillation no product having a less density than 0.844, or 37° B. at 52° F. Distillation to dryness gave:

	Per cent.
Of oil having a density of 0.890 to 0.900	69.82
Coke, water, and loss	30.18
	100.00

This first distillate, having a density of about 0.890 at 60° F., gave, when subjected to slow distillation, a product having a density of 0.885, which, after treatment with oil of vitriol and soda lye and redistillation from soda, had a density of 0.880. This distillate was then fractionated, and yielded:

	Per cent.
Light oil of specific gravity 0.835 at 60° F	21.58
Heavy oil of specific gravity 0.880 at 66° F	37.41
Heavy oil of specific gravity 0.916 at 64° F	34.53
Coke	6.48
	100.00

In another experiment, undertaken with a view to "cracking", treating, and redistilling with soda, the products were expressed in percentages of the whole amount operated upon as follows:

	Per cent.
Naphtha of specific gravity 0.760 at 60° F	11.33
Oil of specific gravity 0.836 at 60° F	66.22
Oil of specific gravity 0.893 at 60° F	12.67
Oil of specific gravity 0.921 at 60° F	3.56
Loss	6.22
	100.00

Further experiments by distillation under pressure gave:

	Per cent.
Light oil, specific gravity 0.825 at 60° F	19.20
Heavy oil, specific gravity 0.885 at 60° F	25.86
Heavy oil, specific gravity 0.918 at 60° F	38.14
Coke and loss	16.80
	100.00

No paraffine could be detected by refrigerating any of these heavy oils in salt and ice. (*a*)

On returning from California to New England, in 1866, I brought with me a few gallons of several of the petroleums and malthas of the neighborhood of San Buenaventura. It was my intention to treat these samples in an apparatus similar to that used by Mr. Merrill, but the small quantity of each specimen at my disposal rendered that operation very difficult, and I subsequently determined to distill them under pressure, after the manner patented by Young. I contrived a small retort, with a valve of peculiar construction, described in the *American Journal of Science* for September, 1867. (*b*) These specimens of petroleum, numbered I, II, and III, were subjected to this treatment. No. I came from a tunnel in the Sulphur mountain (see Fig. 6), with a specific gravity 0.9023; No. II, from the Pico spring, with a specific gravity 0.8932; and No. III, from the Cañada Laga spring, with a specific gravity 0.9184. They were first subjected to distillation under a pressure of about 30 pounds per square inch in a

a A. J. S., xliii, 242; C. N., xvii, 257; B. S. C. P., 1868, 77. *b* A. J. S. (2), xliv, 230; C. N., xvi, 199; W. B., 1867, 725.

measured quantity of 1,500 c.c. The distillate obtained was then fractionated until the specific gravity of the distillate averaged 0.810 or 43° B. The heavy residue in the retort was again distilled under pressure and fractionated to a distillate of specific gravity 0.810. The heavy residue in the retort was then treated for lubricating oil. The results tabulated as follows:

1,500 c. c. of crude oil for each experiment.	First pressure distillation.	Coke and loss at distillation.	First fractionation of sp. gr. 43° B.	Heavy residue for re-distillation.	Yielding by second pressure distillation.	Second fractionation of sp. gr. 43° B.	Total crude illuminating oil.	Three per cent. loss in treating illuminating oil.	Total yield of refined oil.	Total crude lubricating oil.	Three per cent. loss in treating lubricating oil.	Total refined lubricating oil.	Yield of refined illuminating oil.	Yield of refined lubricating oil.	Loss in refining.	Loss in distillation.
Cubic centimeters:																
I	1,365	135	630.00	735.00	681.00	184.00	814.00	24.42	789.58	497.00	14.01	482.09	789.58	482.09	39.33	189.09
II	1,315	185	850.80	464.20	408.78	102.19	952.99	28.69	924.40	306.59	9.19	297.40	924.40	297.40	37.78	240.42
III	1,240	260	605.00	635.00	571.60	142.87	747.87	22.43	725.44	428.63	12.85	415.78	725.44	415.78	35.28	323.50
Percentages:																
I	91.00	9.00	42.00	49.00	45.40	12.27	54.27	1.63	52.64	33.13	0.99	32.14	52.64	32.14	2.62	12.60
II	87.66	12.34	56.72	30.94	27.25	6.81	63.53	1.91	61.62	20.44	0.61	19.83	61.62	19.83	2.52	16.03
III	82.66	17.34	40.33	42.33	38.10	9.52	49.85	1.49	48.36	28.58	0.86	27.72	48.36	27.72	2.35	21.57
Cubic centimeters:																
IV	1080.00	232.50	250.00	830.00	747.00	186.75	436.75	13.10	423.65	560.25	16.80	543.45	423.65	543.45	29.90	503.00
Percentages:																
IV	72.00	15.50	16.70	55.30	49.80	12.40	29.10	0.90	28.20	37.40	1.10	36.30	28.20	36.30	2.00	33.50

The specimen of maltha (IV) examined was taken, it is supposed, from the same pool on the Ojai ranch as that examined by Professor Silliman. Its specific gravity was 0.9906. The air, hydrogen sulphide, and water was removed by allowing the maltha to flow slowly from one vessel through a second vessel, in which it was heated sufficiently to expel these impurities, and from which it flowed into a receiver. The loss by this treatment was 12½ per cent. The purified maltha was then treated precisely like the oils, with the results as given above.

As these results, both with malthas and oils, were conducted on a small scale, the percentage of loss is much greater than would be experienced on a commercial scale.

A comparison of the results of the distillation of the malthas and oils appear at first sight to give the latter great preponderance in value over the former; but it should be borne in mind that the malthas contain 12½ per cent. of volatile impurity not contained in the oils. After making due allowance for this fact, it will be observed that the total amount of crude distillate is in all cases very nearly in the same proportion to the pure bitumen contained in the crude materials. These crude distillates yield easily to treatment with the ordinary amount of sulphuric acid and soda lye. The purified oil is very transparent and the most free from color of any that I have seen. Indeed, were it not for its opalescent properties, and the peculiar manner in which light is refracted by it, this oil could not be distinguished by the eye from pure water. I do not claim to have produced oils the burning qualities of which are superior to other California oils, but I think them in no way inferior to the best that have been produced from unadulterated California petroleum. The best refined California petroleum that I have made, as also the best that I have seen from other sources, fails to produce a light of such intense whiteness as the best refined Pennsylvania oils, although they are quite equal to the average upon the market. It is my opinion that this difference is due to admixture of some series of hydrocarbons, *containing a large amount of carbon in proportion to the hydrogen, in such quantity as to render the combustion incomplete, and thus give rise to a yellow flame.* (*a*)

An examination of Russian petroleum in 1881 by Kurbatow and Beilstein has shown the presence of an homologous series such as was here predicted, which contains more hydrogen than the benzole series and less hydrogen than the paraffine series. There is a great similarity between these Tertiary Russian petroleums and the California petroleums of the same geological age, and it is altogether probable that they both contain these "additive compounds of the benzole series". I am informed that during the last ten years or more there have been a number of thousands of barrels of petroleum refined in Santa Barbara and Ventura counties which has been sent into Arizona and Mexico, but was not of such a quality as to compete in the San Francisco market with oils manufactured on the Atlantic coast. On the whole, so far as I can learn, the oils manufactured from crude California petroleum are uniformly of inferior quality.

a S. F. Peckham, *Geo. Surv. of California:* Geology II, Appendix, page 73.

CHAPTER VI.—STATISTICS OF THE MANUFACTURE OF PETROLEUM DURING THE CENSUS YEAR.

SECTION I.—INTRODUCTION.

The statistics that form the subject of this chapter were obtained by means of a schedule of questions which were placed in the hands of the different manufacturers, and the answers have been consolidated into the totals as here given. Great care has been taken to include all parties engaged in the manufacture during the whole or any part of the census year, and it is believed that the list is complete. It is further believed that the schedules have been filled with as much care and regard to accuracy as could be expected under the circumstances. Several firms had gone out of the business at the time the statistics were compiled, and others had kept their books in such a manner as to render the compilation of such statistics difficult. It is believed, however, that in those instances where absolute accuracy was found to be impossible approximately correct estimates have been given. These instances constituted but a small percentage of the bulk of the business, which is carried on by large corporations and firms, who conduct their business systematically. The statistics furnished by these concerns have been compiled at much labor and expense, and in many instances are careful transcripts of annual or biennial balances and records kept in the regular course of conducting the business. As statistics of this character constitute a large proportion of the whole number, and as the remainder are carefully computed and estimated, the totals are believed to represent in a practically accurate manner the details of the business of the country for the census year.

The following-named firms and corporations have furnished statistics:

Name.	Location.
Portland Kerosene Oil Company	Portland, Mains.
Downer Kerosene Oil Company	Boston, Massachusetts, and Corry, Pennsylvania.
Oriental Oil Company	Do.
Maverick Oil Company	Do.
Pierce & Canterbury	Do.
S. Jenney & Sons	Boston, Massachusetts, and Brooklyn, New York.
G. F. Gregory	Do.
Charles Pratt & Co	Do.
Empire Refining Company	Do.
Sone & Flemming	Do.
James Donald & Co	Do.
Wilson & Anderson	Do.
Bush & Denslow	Do.
Franklin Oil Works	Do.
Devoe Manufacturing Company	Do.
McGoey & King	Do.
Queens County Oil Refining Company	Do.
James A. Bostwick	Brooklyn, New York.
Long Island Oil Works	Do.
Lombard, Ayres & Co	New York city.
Cheesboro' Manufacturing Company	Do.
Leonard & Ellis	Do.
A. C. Bunce & Co	Do.
Hudson River Oil Works	Bergen county, New Jersey.
Bayonne Refining Company	Bayonne, New Jersey.
Pennsylvania Refining Company	Philadelphia, Pennsylvania.
Malcom, Loyd & Co	Do.
William L. Elkins & Co	Do.
Harkness Refining Company	Do.
Webster Bros. & Wilson	Do.
Atlantic Refining Company	Do.
Excelsior Oil Company	Do.
United Oil Company	Baltimore, Maryland.
J. Parkhurst, jr., & Co	Do.
Camden Consolidated Oil Company	Baltimore, Maryland, and Parkersburg, West Virginia.
Solar Oil Company	Williamsport, Pennsylvania.
S. Bailey & Co	Danville, Pennsylvania.
Reading Oil Company	Reading, Pennsylvania.
Binghamton Oil Company	Binghamton, New York.
Vacuum Oil Company	Rochester, New York.
Buffalo Oil Works	Buffalo, New York.
Standard Oil Company	Cleveland, Ohio.
Pioneer Oil Company	Cleveland, Ohio.
Merriam & Morgan	Do.
L. D. Mix	Do.
American Lubricating Oil Company	Do.
Republic Refining Company	Do.
Backus Oil Company	Do.
William H. Doan	Do.
Schofield, Schurmer & Teagle	Do.
Forest City Varnish, Oil, and Naphtha Co	Do.
J. H. Heisel & Co	Do.
J. R. Timmins & Co	Do.
Acme Oil Company	Titusville, Pennsylvania.
Keystone Oil Company	Do.
White Star Oil Company	Do.
Crystal Oil Works	Miller's farm, Pennsylvania.
Imperial Refining Company	Oil City, Pennsylvania.
Mutual Refining Company	Reno, Pennsylvania.
Empire Oil Works	Do.
Eclipse Oil Company	Franklin, Pennsylvania.
Relief Oil Works	Do.
Franklin Oil Works	Do.
German Refining Company	Brady's Bend, Pennsylvania.
William Bradin	Millerstown, Pennsylvania.
Holdship & Irwine	Pittsburgh, Pennsylvania.
Standard Oil Company	Do.
Paine, Ablett & Co	Do.
E. J. Waring	Do.
A. D. Miller	Do.
J. A. McKee & Sons	Do.
Central Refining Company	Do.
D. P. Reighard	Do.
Andrew Lyons & Co	Do.
Wallover Oil Company	Smith's Ferry, Pennsylvania.
Samuel Hodkinson	Steubenville, Ohio.
Marietta Refining Company	Marietta, Ohio.
Ohio Oil Works	Do.
Argand Oil Company	Do.
Richard Patton	Do.
O. M. Lovell	Do.
Isaiah Warren & Co	Wheeling, West Virginia.
L. D. Crafts	Parkersburg, West Virginia.
Sweetzer Oil Company	Do.
S. P. Wells & Co	Do.
Chess, Carley & Co	Louisville, Kentucky.

SECTION 2.—CAPITAL, LABOR, AND WAGES.

The total amount of capital invested in the manufacture of petroleum during the census year was $27,325,746. Of this amount, $21,196,246 was employed the entire year and $6,129,500 for periods varying from one to eleven months, averaging $4,585,081 for twelve months. The total average amount of capital employed throughout the year was $25,781,327. (See page 183.)

The total number of hands employed was 12,231. The average number was: Men, 9,498; women, 25; children, 346; total, 9,869. Some of these men were employed in establishments that were in operation less than twelve months. The average number of men employed for twelve months was 8,032. Of the 9,498 men, 8,818 were employed by day and 680 by night. This latter number does not represent all of the labor employed at night, as in many establishments the work was not performed by men who worked constantly at night, but by men who were divided into sets and alternated, one set working during the day for one week, and at night the following week. In other establishments the work was divided from twelve at noon to twelve at night.

The wages paid for skilled labor varied from $1 50 to $3 per day, averaging about $2 25, and in general no difference was made in the wages of those who worked by day from those who worked at night. Ordinary laborers were paid from $1 25 to $2 per day, averaging about $1 50; coopers from $1 50 to $2 50, averaging about $2 25, and tinsmiths from $1 30 to $2 25, averaging about $2. The highest wages were paid on the Atlantic coast and the lowest on the Ohio river. The total amount paid in wages during the census year was $4,381,572.

SECTION 3.—MATERIALS EMPLOYED IN MANUFACTURING PETROLEUM.

The total amount of crude petroleum manufactured during the census year was 731,533,127 gallons, equal to 17,417,455 barrels of 42 gallons each. This crude oil was valued at $16,340,581, equal to 92.9 cents per barrel. During the year there was received by the manufacturers in—

	Gallons.
Barrels	20,363,918
Barges	42,433,388
Tank-cars	437,740,951
Pipe-lines	227,941,728

This oil is estimated to contain on an average 1 per cent. of water, and was mainly third-sand oil; but it includes also nearly all of the second-sand oil, and a portion of the first-sand. It does not include any of the heavy oils that are used as natural oil, and but a small portion, if any, of the mixed oils.

In the manufacture of this oil there was consumed the following kinds and amounts of fuel:

			Value.
Anthracite coal	tons	179,997	$446,922
Bituminous coal	tons	504,667	580,983
Wood	cords	1,471	6,355
Coke	bushels	303,596	13,218
Naphtha	gallons	2,892,164	42,315
Residuum	gallons	11,765,705	229,215
Total valuation of fuel used			1,319,008

Anthracite coal was very generally used in the Atlantic cities, but not to the exclusion of bituminous coal. Naphtha and residuum do not appear to have been used as fuel except in special cases. This fuel was used in the distillation of the oil and in the production of steam for use both as power and in distillation.

In the treatment of the distillates there were used of—

			Value.
Sulphur	tons	3	$180
Sulphuric acid	do	45,813¼	1,206,052
Hydrochloric acid	pounds	3,424	68
Total value of acids			1,206,200

Of this vast quantity of sulphuric acid the "sludge" of 22,162½ tons was sold to fertilizer and chemical manufacturers, that of 21,158⅝ tons was returned to the manufacturers to be restored, and that of 2,498⅛ tons ran to waste. Of this amount, 1,389 tons of the 2,498⅛ tons that ran to waste were thrown into the Atlantic ocean and rivers and bays that enter it, 839⅝ tons were thrown into the Ohio river and its tributaries, and 269½ tons into lake Erie. The proportion of sulphuric acid that is thrown to waste is now much less than it was formerly, but the nearly 5,000,000 pounds wasted during the census year is a large quantity with which to pollute our rivers and bays. The 1,678,000 pounds thrown into the tributaries of the Ohio river is a large contamination in the waters of even so large a river, and in addition to the acid the sludge oils cannot fail to increase its deleterious effects.

The alkali treatment was effected by means of—

			Value.
Soda-ash	tons	410.9	$10,427
Caustic soda	do	772.3	85,064
Sal-soda	pounds	96,643.0	1,423
Aqua ammonia	do	160,160.0	8,697
Lime	bushels	797.0	159
Total value of alkalies			105,770

The sludge of all of this alkali was run to waste on the Atlantic coast, into the Ohio and its tributaries, and into lake Erie.

The filtered oils and residues required the use of 1,990 tons of bone-black, valued at $62,815. The packages used were in part manufactured and in part purchased by the petroleum refiners, and were as follows:

		Value.
Barrels: Made	3,292,698	$4,040,502
Purchased	6,424,608	7,577,805
Total	9,717,306	11,618,307
Tin cans: Made	23,496,916	2,700,630
Purchased	344,173	93,367
Total	23,841,089	2,793,997
Packing cases: Made	1,607,297	189,511
Purchased	4,845,504	717,400
Total	6,452,801	906,911

The total number of all packages and their value was as follows:

Barrels	9,717,306	$11,618,307
Cans	23,841,089	2,793,997
Cases	6,452,801	906,911
Total packages	40,011,196	15,319,215

Where barrels are not made they are being continually repaired. The number of coopers employed was 2,062, and of tinsmiths, 353.

The following is the total cost of materials:

	Value.
Crude oil, 17,417,455 barrels	$16,340,581
Fuel	1,319,008
Acid	1,206,200
Alkali	105,770
Bone-black	62,815
Packages	15,319,215
Bungs, paint, hoops, glue, etc	645,412
Total	34,999,001

SECTION 4.—THE PRODUCTS OF MANUFACTURE.

There were manufactured of the volatile products of the distillation of petroleum of a specific gravity above 87° Baumé 293,423 gallons, valued at $29,117. This material was first called rhigolene, but a similar product has been called cymogene, and has been used in ice-machines. It is to be presumed that this material was used for that purpose. Of gasoline there was manufactured 289,555 barrels, valued at $1,128,166; of naphthas the following-named qualities and quantities:

Specific gravity.	Quantity in barrels.	Value.
Degrees.		
60	1,290	$3,600
62	109,472	225,609
63	18,945	43,039
65	0,148	17,339
68	7,300	20,975
70	918,374	1,188,291
71	1,617	4,657
71–72	0,899	18,110
72	6,048	3,931
73	38,777	45,945
74	19,565	54,110
75	8,109	34,425
76	11,699	39,315
68–70	12,525	16,282
65–70	260	789
60–72	42,302	109,417
C8–78	3,490	8,500
65–76	85	60
Total	1,212,626	1,833,395

An inspection of the table on page 188 shows that the different grades of naphtha, as determined by the specific gravity, command very different prices. The following table shows the fire-test and quantities of illuminating oils manufactured:

Fire-test.	Quantity in barrels.	Value.
Deg. F.		
100	2, 059	$6, 435
110	6, 083, 026	19, 035, 913
112	913, 979	2, 621, 777
115	90, 814	313, 560
120	2, 107, 220	7, 096, 218
110–120	5, 948	16, 844
130	510, 522	1, 507, 884
135	2, 036	11, 233
140	15, 000	85, 000
150	1, 170, 725	5, 494, 833
110–150	28, 270	108, 557
155	1, 960	7, 350
160	1, 627	9, 949
175	22, 843	164, 914
150–175	46, 220	359, 144
Total	11, 002, 249	36, 839, 611

It will be noticed that the three grades of 110°, 120°, and 150° include the larger proportion of the illuminating oils. The specific gravity of these oils varies from 45° to 50° Baumé, the high-test oils having usually the highest specific gravity. But a comparatively small quantity of oils having a fire-test above 200° F. was produced.

Fire-test.	Barrels.	Value.
Deg. F.		
260	1, 940	$8, 245
285	300	3, 000
300	14, 304	191, 480
Total	16, 544	202, 725

These oils are of a specific gravity of 36° to 39° Baumé.

The lubricating oils are prepared by various parties of different specific gravities. Petroleums reduced especially for cylinders are made very dense, and vary from 25° to 28° Baumé. Of these oils there were produced 26,018 barrels, valued at $371,020. Petroleums reduced for journals are prepared in greater variety. Of these there were:

Specific gravity.	Barrels.	Value.
Degrees.		
28	8, 184	$30, 327
28–30	105, 095	506, 957
29	63, 705	300, 203
29–34	26, 657	179, 510
38	1, 200	7, 020
Total	204, 841	1, 024, 017

The distilled lubricating oils are in equally large variety. Of the deodorized lubricating oils there were produced:

Specific gravity.	Barrels.	Value.
Degrees.		
25	16, 460	$148, 140
26	2, 017	9, 580
28	68	340
29	12, 440	149, 280
28–33	30, 430	304, 232
Total	70, 415	611, 572

The paraffine oils reported are in still greater variety of specific gravity and price, ranging from about $2 to nearly $12 per barrel; the latter value being assigned to an exceptionally dense oil of specific gravity 20° Baumé. Of these oils there were produced:

Specific gravity.	Barrels.	Value.
Degrees.		
20	2,524	$24,230
20–27	8,733	33,297
24	532	4,668
25	26,293	165,555
26–28	6,000	45,000
27	3,187	6,055
28	31,462	124,077
33	714	5,141
Total	79,465	408,023

Of paraffine wax there was produced 7,889,626 pounds, valued at $631,944, an average valuation of about 8 cents per pound, of which 900,000 pounds were made into candles by one firm.

Of residuum there was produced and sold 229,133 barrels, valued at $297,529.

The products of manufacture other than those already enumerated were chiefly petroleum ointment, harness oil, and other vacuum products, as follows:

The paraffine ointment manufactured had a value of more than	$100,000
Harness oil	34,513
Other products	193,584
	328,097

SUMMARY OF PRODUCTS OF THE MANUFACTURE OF PETROLEUM AND THEIR VALUE.

Article.	Barrels.	Value.
Rhigolene	5,868	$29,117
Gasoline	289,555	1,128,166
Naphtha	1,212,626	1,833,395
Illuminating oil	11,002,249	36,839,613
Mineral sperm	16,544	202,725
Reduced petroleum, for cylinders	26,018	371,020
Reduced petroleum, for journals	204,841	1,624,017
Deodorized lubricating oils	70,415	611,572
Paraffine oil	79,465	408,023
Residuum	229,133	297,529
	13,136,714	
Paraffine wax	*7,889,626	631,944
Miscellaneous products		328,097
Total		43,705,218

* Pounds.

Section 5.—BUILDINGS, MACHINERY, ETC.

There were in use during the census year 374 boilers, of an aggregate capacity of 12,744 horse-power. The machinery was driven by 285 steam-engines, in addition to which there were 200 steam-pumps. These pumps were of very varied capacity and construction. Many of them were small, requiring only a few horse-power to run them, while others were very powerful machines, capable of handling hundreds of barrels of oil per hour. The number of buildings in use were reported at 866, and varied in character from rude sheds to substantial brick buildings, their aggregate value being $1,899,288, while the machinery was valued at $3,737,998. The losses reported as occasioned by fire and other acccidents aggregate $104,631 43, a loss on the capital in use in the business during the year of four-tenths of 1 per cent.

An attempt was made to ascertain the quantities of the different products packed by the manufacturers for export, but a number of the returns contained so many errors that the results were worthless.

SUMMARY OF STATISTICS OF THE MANUFACTURE OF PETROLEUM DURING THE YEAR ENDING MAY 31, 1880.

Capital invested	a $27,325,746
Capital in use for twelve months	$25,779,688
Total number of hands employed	12,231
Average number of men employed	9,498
Average number of women employed	25
Average number of children employed	346
Total average number of hands employed	9,869
Total amount paid in wages	$4,381,572
Value of crude material	$34,999,001
Value of manufactured products	$43,705,218
Boilers in use	374
Horse-power of same	12,744
Engines in use	285
Pumps in use	200
Number of buildings	866
Value of buildings	$1,899,288
Value of machinery	3,737,998
Loss during the census year from fire, etc	104,631

STATISTICS OF PETROLEUM REFINING DURING THE YEAR ENDING MAY 31, 1880.

ESTABLISHMENTS:	
Number of firms and corporations	86
CAPITAL:	
Amount of capital invested	$27,325,746
HANDS EMPLOYED:	
Average number of men	9,498
Average number of women	25
Average number of children	346
Total	9,869
WAGES:	
Total amount paid	$4,381,572

MATERIALS:

		Quantities.	Value.
Oil.			
Crude oil used (b)	gallons	731,533,127	$16,340,581
Fuel.			
Anthracite coal	tons	179,997	446,922
Bituminous coal	do	504,667	580,983
Wood	cords	1,471	6,355
Coke	bushels	303,596	13,218
Naphtha	gallons	2,892,164	42,315
Residuum	do	11,765,705	229,215
Chemicals.			
Sulphur	tons	3.0	180
Sulphuric acid	do	45,813.5	1,206,052
Hydrochloric acid	pounds	3,424.0	68
Soda-ash	tons	410.9	10,427
Caustic soda	do	772.3	85,064
Sal-soda	pounds	96,643.0	1,423
Aqua ammonia	do	160,160.0	8,697
Lime	bushels	797.0	159
Bone-black	tons	1,990.0	62,815

a This differs from the sum given in the Compendium ($27,395,746), an error of $70,000 having been detected after that was printed.
b The 731,533,127 gallons of crude oil used are equal to 17,417,455 barrels of 42 gallons each.

Packages.

		Quantities.	Value.
Barrels	number	9,717,306	$11,618,307
Tin cans	do	23,841,089	2,793,997
Cases	do	6,452,801	906,911
Bungs, paint, glue, etc			645,412
Total value of raw material			34,999,101
PRODUCTS:			
Rhigolene	barrels	5,868	$29,117
Gasoline	do	289,555	1,128,166
Naphtha	do	1,212,626	1,833,395
Illuminating oil	do	11,002,249	36,839,613
Mineral sperm	do	16,544	202,725
Reduced petroleum, for cylinders	do	26,018	371,020
Reduced petroleum, for journals	do	204,841	1,024,017
Deodorized lubricating oils	do	70,415	611,572
Paraffine oil	do	79,465	408,023
Residuum	do	229,133	297,529
Paraffine wax	pounds	7,889,626	631,944
Petroleum ointment, harness oil, etc			328,097
Total value of manufactured products			43,705,218
MISCELLANEOUS STATISTICS:			
Boilers in use			374
Horse-power of same			12,744
Engines in use			385
Pumps in use			200
Number of buildings			866
Value of same			$1,899,288
Value of machinery			3,737,998
Loss during the census year from fire and other accidents			104,631

PART III.

THE USES OF PETROLEUM AND ITS PRODUCTS.

PART III.

CHAPTER I.—THE USE OF MINERAL OILS FOR LUBRICATION.

SECTION 1.—INTRODUCTION.

Wagner's *Berichte* for 1879 contains a very full discussion of the subject of lubrication and lubricating oils. It is there remarked:

A mineral oil which, without admixture of another oil or body, as a lubricator is of unquestionable advantage. It must possess the following characteristics: 1st, it must possess the necessary consistence; 2d, it must not harden; 3d, it must not contain any mineral or organic acid (creosote); 4th, it must begin to evaporate and inflame at a high temperature (not less than 150° C.); 5th, it must also, at a low degree of cold, show no separation of paraffine; 6th, it should possess only a faint odor.

He further says:

American lubricating oils are sold under the names of "Lubricating oil", "Eclipse oil," "Globe oil," "Valvoline;" also so-called "Natural lubricating oil", which is natural West Virginia oil reduced in a vacuum, together with complex mixtures and material produced by patent processes from residuum. The lighter and clearer oils are spindle oils, those more heavy are machine oils, and the specifically heaviest in consistence and evaporating point are used for cylinders under the name of cylinder oil. The higher the specific gravity of these oils the less their fluidity and the higher their evaporating point. The specific gravity of the American lubricating oils varies from 0.865 to 0.915 at 15° C. They stiffen according to quality between —6° and —30° C., most of them between —10° and —12° C. With the exception of the West Virginia Globe oils, which are sometimes found to evaporate at 200° C., they inflame between 250° and 360° C., and boil mostly above 360° C. (*a*)

This may be taken as a fair representation of the subject as presented in the United States as well as in Germany. Although there have been those who have advocated the use of mineral lubricators for many years, it is only quite recently that any general admission of their claims to superiority has found expression. The whole question of lubrication is under discussion, and has been made the subject of a large number of memoirs during the last few years. Among these may be mentioned a very full discussion of the subject that appeared in *Le Technologiste* in 1868, two works that appeared in Germany in 1879, one by E. Donath (*b*) and the other by M. Albrecht, (*c*) and a work that was issued the same year by Professor R. H. Thurston, of the Stevens Institute of Technology, at Hoboken, New Jersey, published by Trübner & Co., of London. (*d*)

During the year 1878 the Boston Manufacturers' Mutual Fire Insurance Company commenced a general research upon oils and their relation to losses by fire, the results of which, as made public by the company, are embraced in a lecture given before the New England Cotton Manufacturers' Association at their semi-annual meeting held October 30, 1878, by Professor J. M. Ordway, of the Massachusetts Institute of Technology, (*e*) and in a paper presented by Mr. C. J. H. Woodbury to the American Association for the Advancement of Science at their meeting in Boston in 1880, and published in their proceedings for that year. From these two papers as embodying the latest results obtained, which are emphasized by the test of actual experience, I shall quote liberally.

The contract under which Professor Ordway undertook this research required that the investigation should have reference to—

1. The power of the oils to diminish friction under various pressures and at various rates of speed.
2. The tendency of the oils to oxidize while in use for lubrication, and their consequent deterioration in efficiency.
3. Their tendency to rapid oxidation when largely extended by absorbent fibrous substances, and their consequent liability to induce spontaneous combustion.

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a W. B., 1879, 1139.

b *Die Prüfung der Schmiermaterialien*, Ed. Donath, Leoben, 1879, Otto Protz.

c *Die Prüfung von Schmierölen*, M. Albrecht, Riga, 1879, G. Deubner. Hübner's Zeitsft., 1878, 67.

d *Friction and Lubrication.* Determination of the laws and coefficients of friction by new methods and new apparatus, by R. H. Thurston: London, 1879. Trübner & Co.

e Proceedings of the semi-annual meeting, held at Boston, October 30, 1878.

4. Their proneness to emit combustible vapors when rubbed or moderately heated, or kept long in partially-filled reservoirs.
5. Their tendency to corrode metallic bearings.
6. Their specific heat, or relative rapidity of heating and cooling when exposed to the same heating or cooling influence.
7. The relative length of time that a pint of each will last in doing a given kind of lubricating work.
8. Their relative fluidity or the thickness of layers retained between two surfaces subjected to a given pressure.
9. Their compatibility with each other when successively used on the same bearing.
10. Liability to separate into constituent parts by long standing or by freezing.
11. Their freedom from non-lubricating sedimentary matter.
12. Ease of removal from bearings after becoming thickened by floating dust or abraded particles of metal, or by accidental overheating.
13. Their tendency to diffuse unpleasant or unwholesome odors.
14. Ease of ignition and rapidity of combustion when they are inflamed.
15. The probability of perfect uniformity in successive lots supplied by the manufacturer.
16. The possibility of securing an unlimited supply at moderate prices.
17. Suitableness for oiling wool before weaving and spinning.
18. Ease of removal from yarn or cloth in the operations of scouring.
19. Their suitableness for the manufacture of soaps.
20. Their effect on leather and wool.

Professor Ordway remarked that the report he had to make referred particularly "to certain chemical properties and the facility of oxidation of different oils". His samples were procured directly from the mills using them, and were referred to him marked with numbers; the examination, therefore, was entirely unprejudiced. A few additional samples were procured from reliable manufacturers, and samples were imported from Paris, France. These were used in comparison. After the examination was well under way a list of names was furnished him, so that in his report he was able to give the oils the names by which they were known in commerce. Of the one hundred and eighteen oils in the list twenty-four were designated "spindle" oil, some of which were called "light" and some "heavy", fourteen as sperm, eleven as lard, nine as paraffine, five as machinery, three as olive, three as stainless, two as neat's-foot, six as wool oils, five as mixtures of paraffine and sperm, three as mixtures of paraffine and neat's-foot, and two as mixtures of sperm and spindle.

SECTION 2.—SPECIFIC GRAVITY.

Sections 2, 3, 4, and 5 are largely quotations from an extemporaneous lecture by Professor Ordway, which constitutes the best statement of the subject that has yet been made public.

A simple test of oils, but one of exceedingly limited value, is the specific gravity. We have determined the density of nearly all by cooling to 60° F. and weighing in a flask of known capacity. The results are as follows:

"SPINDLE" OILS.

No. 17 = 0.840	No. 21 = 0.880	No. 71 = 0.890
51 = 0.848	9 = 0.886	16 = 0.890
76 = 0.848	52 = 0.887	79 = 0.893
74 = 0.850	31 = 0.887	80 = 0.894
4 = 0.850	47 = 0.890	87 = 0.898
66 = 0.870	49 = 0.890	38 = 0.913
68 = 0.880	53 = 0.890	48 = 0.916

"SPERM" OILS.

No. 11 = 0.880	No. 44 = 0.886
26 = 0.880	75 = 0.886
28 = 0.880	77 = 0.886
32 = 0.880	35 = 0.887
54 = 0.880	40 = 0.890
56 = 0.880	34 = 0.890
58 = 0.886	36 = 0.896

These agree very closely with the true sperm oils which were procured from disinterested persons or from the shops. I got several specimens from cargoes newly arrived, taken from the casks before the vessels were unloaded, and these varied in specific gravity from 0.877 to 0.888, the latter being crude head oil, rich in spermaceti. So, if specific gravity is any indication, the oils sold as sperms are very much like genuine sperm.

"PARAFFINE" OILS.

No. 65 = 0.880	No. 27 = 0.905
59 = 0.884	45 = 0.905
85 = 0.888	69 = 0.905
63 = 0.890	2 = 0.910
43 = 0.894	

"LARD" OILS.

No. 10 = 0.914	No. IV = 0.918
19 = 0.916	VII = 0.918
13 = 0.917	VI = 0.920
81 = 0.917	Pure lard = 0.919

"STAINLESS" OILS.

No. 3 = 0.860	No. 1 = 0.890
70 = 0.874	

"NEAT'S-FOOT" OILS.

No. 50 = 0.910	No. 6 = 0.914
Pure neat's-foot = 0.920	

MACHINERY OILS.

No. 86 = 0.878	No. 61 = 0.895
39 = 0.878	24 = 0.899
33 = 0.887	

With regard to other oils than sperm, specific gravity gives no definite indication, because mineral oils may be mixed, and in that way we may get an oil of high density, yet containing oil of low specific gravity. All I can say at present is that sperm oil is very light, of about specific gravity 0.880; and lard oil should have a specific gravity of about 0.920. Lard oils are pretty thick, and petroleum oils of about the same specific gravity are also thick, and neither density nor thickness would betray an admixture. Though a great many people rely on the specific-gravity test, it is not to be depended on by itself, though it may occasionally be useful in connection with other tests.

SECTION 3.—CONTENT OF VOLATILE MATERIAL.

As to the mineral oils, we soon observed that they are some of them volatile at the ordinary temperature of the air. It is somewhat the same with petroleum oils as with water. Water evaporates at all temperatures, from the freezing point up, and so do the petroleum oils. Those that have a high boiling point do so very little, indeed; but those having a low boiling point, if left in the air in the latter part of June or July, evaporate completely in two weeks. This was rather a striking thing, as showing that it is unsafe to leave these oils exposed to the air, where there is much surface exposed, in a warm room, for we may get an explosive vapor over the whole, and if any one goes near it with a lamp there will be trouble. But this was carried further. What takes place at the ordinary summer temperature will take place more rapidly at higher temperatures; and in making our experiments we must exaggerate a little, in order to get quickly at results. Therefore we put some of these oils into an oven and observed how much they lost in twelve hours. This, I believe, is a somewhat new line of investigation, and the results are rather striking. Some of them were left for four hours, some for eight hours, and some for twelve hours; but we have finally settled upon twelve hours and 140° F., which is not a very high temperature, and which we may often have near a steam-pipe; and, in order to prevent one trouble which occurs in testing oils in this manner, we were obliged to suck up the oil in filtering paper. If you pour some oil into a watch-glass it will in time creep over the edge, and a little will be lost, and we suffered somewhat from that circumstance. We found it better to take a small watch-glass, which had been weighed carefully, and pour in oil enough to saturate a bit of paper; the paper prevents the creeping. So, in making these experiments, we took a watch-glass, put into it a piece of dry filtering paper about two-thirds as large, weighed the whole, dropped in some oil, weighed it, and put the glass into a hot oven at 140°, and observed the loss. All of the oils have been tried in this manner, and some of them give results which, to say the least, are very striking. * * * The first one was a spindle oil, at 50 cents per gallon; it lost only 1.3 per cent. The next was a spindle oil that lost 1.5 per cent., and the amount gradually increases, so that in the 43d of the table we come to an oil that lost 10 per cent. * * * And again, the percentage rises to the last, a so-called "spindle oil", at 48 cents per gallon, which lost nearly 25 per cent. What would you think of an oil which lost, by exposure to a heat which is not very great, 24.6 per cent. in twelve hours? It seemed as though all the oils which lost over 10 per cent. must be oils not to be recommended, to say the least. I think the insurance companies would say they ought to be condemned; and there is a pretty large number of such oils among those which were examined. There are twenty out of the one hundred and eighteen which lost over 10 per cent. by exposure to this moderate temperature. When the temperature is carried up to about 200° the loss in some cases was about 37 per cent. Of course it is a matter of judgment which of these should be considered safe and which should not. For my own part, I should rather not use any oil which evaporated over 5 per cent. under such circumstances. This matter has some connection with the flashing point, as one would suppose, and the flashing point is the test which has been most relied on in regard to petroleum oils. I should say, in speaking of these oils, that those that are marked sperm and lard and neat's-foot, instead of losing, gained at most 2½ per cent.—they gained all the way from nothing to 2½ per cent. All the oils of animal and vegetable origin (I mean those which were so marked) lost nothing, but gained a little. In some cases they may have been mixed with a small quantity of petroleum oil. We find that, in the case of a heavy petroleum oil mixed with a light petroleum oil, we may expose the mixture to the boiling point of the latter oil without evaporating much. The heavy oil has a power of holding back.

SECTION 4.—THE FLASHING POINT.

Now the flashing point is a matter which is determined in the case of ordinary kerosene very easily by heating the oil in a water-bath. In the case of these lubricating oils we must resort to a higher temperature and put them in an oil-bath. In this case we take a beaker, * * * hang it in oil, and expose it to a gradually raised temperature, until when we wave a small flame over the surface there will be a slight explosion. The flashing point of all the oils under examination is considerably above the boiling point of water, but some of them are not above the point to which oils might get in contact with the steam-pipe, or pretty near a pipe heated by high-pressure steam; and we all know that in factories, and in various other places, there is a possibility of oils, as well as other things, dropping upon the steam-pipe, or coming very close to the pipe itself. Of course such an oil, with such a flashing point, would be liable under such circumstances to diffuse an explosive vapor in the room. Perhaps, under any ordinary circumstances, it would not take fire, but under some circumstances it is liable to particular danger; for it so happens in a great many of these experiments, when we want to get an accident, we cannot do it, and we have to wait until nature takes its own course. I remember some years ago trying to get an explosion with ordinary kerosene, and we found it extremely difficult, and with kerosenes which are of low flashing point it is difficult to get a condition of things in which an explosion will take place; but we know that these explosions are happening every day. With regard to the flashing points, we have tried all; we have tried, by way of comparison, a great many of those which we procured directly from the manufacturer, and which we suppose we know something about. The flashing points vary from 239° to 450° F., but on putting the figures side by side with those that represent the loss by evaporation we find the flashing point does not indicate the loss we should expect by evaporation. There is a wonderful difference. I find there is one which lost by evaporation 4.6 per cent., and it had the same flashing point as one that lost by evaporation 13.8 per cent. We find another one which lost 9.4 per cent., and yet it flashed at the same heat as one that lost 24.6 per cent. by evaporation. This would seem to show that the flashing point is not to be so much relied upon. I place a good deal more reliance on the other experiments, to long exposure in contact with the air at a given temperature; and the flashing point I should set down as one of the things that may give uncertain results. If any oil has a low flashing point it ought to be rejected; but, at the same time, an oil bearing a high flashing point may be mixed with a certain amount of a lighter oil, which will freely evaporate when exposed to the air more rapidly than another oil with a low flashing point.

SECTION 5.—SPONTANEOUS COMBUSTION.

Of course those oils, which, on being exposed twelve hours to a high temperature (140°) gain something, gain it from the air on oxidation; and they are found to be, as a general thing, either of animal or vegetable origin. * * * I believe the sperms gain rather more than the lard or neat's-foot. Of course this oxidation is a matter which is of considerable importance with reference to spontaneous combustion; and we have attempted to make experiments on spontaneous combustion, which is a matter depending on the oxidation of oil when spread out over a great surface. We imbibe fibers with the oil in such a way that they are not dripping with the oil, but simply dampened with it, and then expose them to hot air, and in the course of time, whether the fiber is cotton, or jute, or wool—in time they will all take fire when we have used an animal or vegetable oil. It is rather difficult to carry out these experiments on a small scale, because we use only a handful; but when you have a large basketful of waste there is no difficulty. In order to make up for the tendency to loss it was necessary, of course, to heat the soaked waste to a temperature which might be considered rather high. We have made experiments at 140° F., and we have made them at 190°, and we have made them above the boiling point of water; in all cases it was below the igniting point of the oils. To make experiments on spontaneous combustion we took a given weight of cotton-waste, about a handful, and imbibed it with its own weight of the oil to be tried; for it is quite an important matter that the experiments should be made with the same quantity of oil, and that the oil should be spread out in the same way throughout. When the waste is imbibed with its own weight it does not appear very greasy. It is not in a dripping condition, but in a state where it is still ready to imbibe. It is said by those who have made such experiments in Europe that equal weights of cotton and oil are the best; and I should suppose that to be the case, as then the air has the freest access to a large surface of the oil. The cotton, of course, is only matter which serves to spread out the oil, and to act as a non-conductor to prevent the heat from being radiated. We made experiments on spontaneous combustion at 200° and at 220°, but not as many of them as could be desired.

One of the important things was to determine the accuracy of the trials made in Europe a few years ago. There were some experiments, published in the *Bulletin of the Industrial Society of Mulhouse*, in 1875 and 1876, experiments made by Mr. Coleman, of Glasgow, and by Dolfus, in Alsace. The experiments of these gentlemen show that when an animal or a vegetable oil is mixed with a small percentage of petroleum oil the tendency to spontaneous combustion is diminished very much, and if with a large quantity of mineral oil the spontaneous combustion refuses to take place. There is, however, in this latter case an oxidation. They found in their experiments, when they took an oil which consisted of thirty parts of petroleum and seventy parts of an animal or vegetable oil, that the oil would heat up when exposed to steam heat, but when it arrived at a certain point it would go down. There is an oxidation, therefore, in such a case; but the petroleum prevents its oxidizing so fast as to allow the heat to accumulate and set the mass on fire. This, of course, is a very important point; and it was important to determine whether their results apply to the oils we have as well as those commonly met with in Europe. They use more vegetable oil, whereas sperm oil does not seem to be so common there as it is here. They found that all the oils tried by themselves would undergo spontaneous combustion, but when they contained from 30 to 50 per cent. of a mineral oil spontaneous combustion would no longer take place under the circumstances to which they exposed them.

We have made experiments with cotton-waste and cottonseed oil mixed with petroleum oil, and have found that cottonseed oil mixed to the amount of 25 per cent. with 75 per cent of petroleum oil will take fire spontaneously; so it seems that although spontaneous combustion is retarded in a great degree, it is not entirely prevented, even by a pretty large admixture of petroleum oil in the case of such oils as cottonseed and linseed, which are peculiarly prone to oxidation. When we came to take lard oil a careful experiment was made, which showed that 33 per cent. of petroleum oil (for this purpose what is commonly called spindle oil was taken) mixed with 67 per cent. of lard oil would not undergo spontaneous combustion at the temperature at which the experiment was made; whereas with 32 per cent. it did undergo spontaneous combustion. It would be very desirable to carry out these experiments to that degree of nicety in all cases, but you can easily see, when we are obliged to expose these oils to long-continued heat, and have an apparatus which must be isolated from the wood work around, we cannot have a great many of them going on at a time, and an experiment lasts from six to eight hours. Generally it takes to finish up one of these experiments on spontaneous combustion six hours. Some of them will take fire in three hours, but the heat does not accumulate enough with most until they have been kept in the oven for five or six hours. A great deal remains to be done in this line. * * * We all know cottonseed oil is one of those oils we have to fear, and it happens to be one of those whose spontaneous combustion cannot be prevented by a slight admixture of petroleum oil. But the experiments of Dolfus (*a*) and Coleman (*b*) were correct, it seems. We had no reason to doubt they were correct, but the experiments we made were made at a little higher temperature; and although the oil, mixed in the proportion of 70 parts of oil and 30 of petroleum oil, may not take fire spontaneously when the temperature is maintained at 110° F., yet it may when it is maintained at 190° F.; and, of course, cotton-waste is liable to be exposed sometimes to a steam heat, and a steam heat may range up to 300° F., so that even when the oils are mixed with petroleum oil there is danger. Still, it is a fact that the admixture of even 10 per cent. of one of the heavy petroleum oils does diminish very much the tendency to oxidation or to spontaneous combustion, and that is a fact, of course, of immense importance. * * * We have tried the different animal and vegetable oils, some of them mixed with larger or smaller proportions of petroleum, but that investigation is still unfinished.

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a Bull. Soc. Ind. de Mulhouse, 1876.   *b* C. N., xxx, 147; W. B., 1871, 1874, 1875.

SECTION 6.—FLUIDITY.

There is another matter which might be of some importance, but we have not been able to deduce from our trials any data of practical value; that is, the relative fluidity of the oils. There is a wonderful difference in this respect, and we found all the lighter oils, that is, the lighter paraffine and spindle oils, are very much more fluid than the sperms of corresponding specific gravity. The specific gravity and fluidity have little relation to each other; there is some, but no exact correspondence. (*a*) The mode of experiment for this purpose is to take a small pipette, of which the globe holds about a cubic inch. The globe is filled by sucking the oil up to the neck, and the liquid is then allowed to flow out through a very small aperture thirty-seven thousandths of an inch in diameter, and the time of flow is noted. The experiments must be made in a room which is kept at a uniform temperature.

In this way ran out—

	Min.	Sec.
Sperm	3	43
Linseed	5	42
Poppy	6	49
Cottonseed	7	31
Sesame	8	14
Lard	9	24
Olive (mere *goutte*)	9	26
Neat's-foot	9	29
Rape	9	55
Navette	10	9
Colza	10	0
Castor, over two hours.		

There is another point which we would like to draw some deductions from if we could, but so far we have not found any particular law. If we immerse wicks in these oils, or filtering paper, which amounts to the same thing, of course, the distance which the oils will ascend or be carried up by capillary attraction is a matter depending on the fluidity of the oil, and this does not seem to have any exact relation to the flowing out through a small aperture. It is contrary to what I should have expected. * * *

SECTION 7.—CHEMICAL TESTS.

There have been various chemical tests proposed from time to time for oils, but in our investigation we were obliged to go on the supposition that almost nothing had been done, from the simple fact that the oils which have been experimented on in former times, in France particularly, have been mixed, and oils which are no longer in use. (*b*) We have experiments relating to the adulterations of olive oil and linseed oil and rape, but those adulterations are out of fashion, and they used certain tests which give comparative indications only; there is nothing absolute about them. One of these tests is nitrate of mercury, which acts simply from containing in solution a certain quantity of nitrous acid. Another test is strong oil of vitriol, and another is caustic soda, and another is chloride of zinc. We can get very little aid or comfort from these old experiments. The nitrate of mercury test is of some trouble to carry out. And finally a very much better fluid has been invented by Jules Roth. He used a fluid which absorbs nitrous acid in considerably larger quantities than nitrate of mercury, and which could be kept for a considerable length of time. It is made by passing nitrous fumes, formed by acting on lumps of iron with nitric acid, into sulphuric acid at 46° B. The charge up of the acid takes some eight, ten, or twelve days. It is a slow operation, but when it is well carried out you get a greenish or bluish liquid, which has a wonderful effect on some oils, and although there is nothing absolute to be learned by this, it gives comparative indications of great value. It seems that all those oils that oxidize readily are not effected by this test, whereas those that keep better, that are not so prone to grow rancid, will thicken and become quite hard when tested with it.

In making these experiments we generally take a small wine glass and put in a little of the liquid and about the same amount of the oil that is to be examined, and then they are whipped together and allowed to stand for some time. If the oil is a good one, one that doesn't oxidize readily, we shall find that the product is very stiff; even if you turn it upside down very little liquid will come out, and it is more like wax or tallow than the original oil. The sample I have in my hand is olive; this is good olive oil, and you may see from the appearance of this that I find considerable difficulty in pushing a rod into it; it is as stiff as beef tallow. Good olive oil will do this, but if adulterated with even 1 per cent. of these other oils the product is softer. Olive oil hardens very readily indeed, and good lard oil also hardens with promptness. This is a specimen of lard oil; I can push the rod through this without very much trouble. Here is one that is mixed with 5 per cent. of petroleum. You will observe on comparing these two that the petroleum oil has undergone such a change that it is colored yellow. The color indicates something. Here the lard oil is thoroughly white and will remain so; whereas if there is an admixture of petroleum oil, however little, it will be pretty sure to turn yellow, and the product is softer than the other. I have here another which is a mixture of cottonseed and olive oil. Here you see a perfectly fluid oil; there is a little thickening from the acid below, but it still remains in a fluid condition; and this contains one-third of cottonseed and two-thirds of olive. By taking great pains we can distinguish 5 per cent. of admixture very well.

These, of course, for illustration, have been exaggerated a little bit. That is, I have taken larger quantities than would be necessary if I were going to make an exact trial to determine how much can be used without interfering with the fluidity. I have here a mixture of lard oil with 20 per cent. of cottonseed that has thickened, but not very much. Now, when we take this same test and apply it to rape-seed oil, it remains perfectly fluid. Of course rape-seed oil, were it mixed with olive or lard oil, would diminish the consistency of the product very much indeed. Here is neat's-foot oil. One would suppose it would be very much like lard, but it is not; it remains fluid without the oxidation surface or crust. This hardening usually takes place in the course of six or eight hours. The best way is to let them stand and watch them and see at what rate the hardening goes on. If you find one hardens in four hours, you will find that it is a pretty good olive or lard oil; if it is six hours, it may be mixed; if it is eight hours, it is more likely to be mixed, and sometimes it is necessary

a An oil distilled from California malthas of a specific gravity of 16° B. flowed like an essential oil.—S. F. P.

b This statement of Professor Ordway explains why the investigations that have been made prior to the last few years are of so little value at present.

to let them stand until the next day; then we have a little hardening. (*a*) In the case of petroleum oils we have a very peculiar effect. Here is one of them: it has become very highly colored; the petroleum oil itself becomes colored, and the fluid below becomes colored, and we can distinguish it by this discoloration. And there is another test, too. Whenever you have whipped up a petroleum oil with this liquid, and have let it stand for some hours, ten or twelve hours, there will be a matter like this sticking to the rod; a waxy, sticky substance, something that is neither oil nor wax; it is not paraffine; precisely what it is I don't know; it is a matter which still remains to be investigated. All of the petroleum oils that we have examined, without exception, I think contain more or less of the matter which gives this precipitate, and the heavier the oil the greater the amount of the precipitate; but even the light spindle oils and kerosene itself will show a definite coating on the rod or else a definite coating on the surface of the liquid itself. We have here a test in Roth's liquid, which is a very good indication of something. We cannot say positively when we have an oil hardened in this way what the oil is, but we can say what it is not, and that sometimes is a very important thing. If it purports to be so and so, we can see whether it is so and so or something else. * * *

Mr. ATKINSON. I should like to put one question at this point to Professor Ordway that I think is important. I believe you have reached the conclusion in respect to the amount of that gummy substance in a petroleum oil that it largely depends on the point to which the distillation has been carried, and that the double distilled and refined oils contained the least? * * *

Professor ORDWAY. That is so; there are specimens here to show that. There is one here which has been distilled once, and another which has been distilled twice. It cannot be seen across the room; but if any one examined these closely he will see that the precipitate on the surface of the liquid below is greater in one case than in the other, and the discoloration is about the same.

Mr. ATKINSON. I think I am also right in asking you whether or not that is not the substance which probably causes the staining of the cloth and the varnishing of the windows and of the polished parts of the machinery?

Professor ORDWAY. It may be that substance. I should not be willing to say positively it is until we have made further experiments. This is a subject which has not been investigated, I believe; and it is quite important that we should spend time and find out what it is. It is something objectionable, it seems to me. It is said by some of the manufacturers of paraffine oil that a little of this in an oil does no harm; but that is not a point we should take for granted. While it may not do any harm in respect to lubrication, it may have something to do with the staining. Here is a substance which is got on oxidation. It has kept on turning brown, and that brownness may go on to a certain point where it will effect a permanent stain on the cloth. I am reasoning theoretically, but I think there are good grounds for saying, if an article of this sort is allowed to stain cotton or wool, and allowed to remain for some time, this substance will become precipitated and go on oxidizing and make a permanent defect. This is a point which it is very desirable to have further light on; and we can only get at it by a long series of trials, for the amount which we get of this is not very great. This is a body which is carried forward by the vapor; for all vapors have a great carrying power, and although the boiling point of this substance is probably very high when oils are distilled, a little is carried forward even by kerosene itself.

There are other chemical tests which so far we haven't had the time really to carry out. * * * Among other things it would be desirable to find out something by saponification, and experiments in saponification are slow. We generally have to boil for ten, twelve, or even fifteen hours; and, when you undertake to saponify a dozen oils, you see it would take a good many individuals to carry on those experiments in a short time. * * * There has one thing turned up which I was not aware of before: that sperm oil does not saponify readily. We have taken pure sperm oil, and we find it is exceedingly difficult to saponify more than 47 or 48 per cent. of it. I mention this because some might be tempted, after making an experiment of this sort on an oil of an unknown origin, to think it was not a sperm oil. This peculiarity arises, I suppose, from a difference in the composition of sperm from other oils. Precisely what it is I don't know, because there has been very little written on the subject of sperm oil; and it opens up, unexpectedly to me, a new field for investigation, and I think the character and quality of sperm oil ought to be investigated by scientific men. Here is this fact which is admitted by a great many people: that sperm oil, of all the animal and vegetable oils, is the best lubricator. It is not because it contains more oleine, but it is something in the character of the oleine. After we have eliminated all the spermaceti, we get a peculiar oil which is different from the other animal oils, but I think it is *sui generis*. We have saponified a great many of the oils. Those which saponify with most ease are lard oils. Neat's-foot saponifies pretty readily. When we take those that are mixed with petroleum, we can saponify all the way from 5 per cent. up, according to the proportion of the petroleum. I am not able at present to give any particular directions about saponification, for this is a matter which requires to be understood so as to present it to people in ordinary life, and I think it can be made a very good test of the character of oils, but in order to do it there must be a great deal of experiment. * * * At present all I can say is, a good many of the oils we have examined saponify very readily; and these turn out to be, according to the descriptive lists, lard oil or something similar to lard oil. There are a good many of them which didn't saponify at all; and, on reference to descriptive lists, they are found to be paraffines.

When the oils are poured on a brass plate and allowed to run slowly down for a length of time some of them get quite green; they color the brass; they are decidedly acid in their character. In looking over these results I noticed that all the oils which are acid are either sperm or neat's-foot, and all of the sperm—I mean all those that purport to be sperm and neat's-foot—are acid in their character, whereas the other (the petroleum oils) don't show any acid reaction. (*b*)

Following the close of Professor Ordway's remarks, Mr. Edward Atkinson and the professor engaged in a discussion of the practical value of the flashing and evaporation tests as applied to lubricating oils. The following is a summary of their conclusions: The flashing point is no indication of the lubricating power of an oil, but has an important bearing on insurance. No oil should be used about a manufacturing establishment that "can diffuse from the bearings an explosive vapor into the atmosphere". While there are some manufacturers of oils that can be depended upon, it is found that oils purporting to come from some others differ widely in quality. Several specimens of oil having the same name differ greatly in flashing point and other characteristics, yet the price remained about the same, and was evidently intended for the same article. While it appears to be difficult for unskillful manufacturers to prepare oils of uniform quality, there are others whose product varies but slightly, and it was somewhat remarkable that some of them having the low flashing point were high-priced, while others having a low flashing point were

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a I have quoted Professor Ordway fully, although the text does not relate to petroleum, because of the great value of his experiments.

b This long quotation, reported from an extemporaneous lecture, and consequently somewhat diffuse in style, has been introduced here as the best statement of the subject treated that has yet been made public.—S. F. P.

among the lowest-priced oils on the market. It was found that many of the best managed corporations, ignorant of their true character, were using oils with a high flashing point. But, in addition to the element of safety from the use of these oils, which rapidly evaporate, is found the question of profit.

The cost of oil per 1,000 pounds of cloth of about No. 33 yarn, in mills in which there is no reason in the character or kind of machinery for a variation exceeding 25 per cent., appears to vary from 68 cents to $2 58 per thousand, while the quantity used varies from 1.03 to 3.36 gallons per 1,000 pounds. It does not appear that this variation has any particular connection with the price of the oil. * * * But since we have begun to compare the results of the tests of evaporation and flashing point a very distinct relation of these tests to the actual cost of oil per 1,000 pounds of cloth is foreshadowed, and if we can establish this rule a great point will have been gained.

The following striking illustration is given of the probable effects of the use of a lubricating oil from which the volatile material had not been completely removed: (*a*) The fire caught in the basement and communicated with striking rapidity with a weaving-room up one flight of stairs in which woolen fabrics were being woven and in which there were "no peculiarly combustible conditions". The flames flashed instantly from one end of the room to the other, striking like a stroke of lightning the gas-meter, placed on a shelf some six or eight feet from the floor at the farther end of the room, melting all the solder, and dropping the connecting pipes from the meter, while a towel that was hanging 2 feet under it was not scorched. The wool oil and the lubricating oil being both examined, the former was found to be pure lard oil, while the latter was one which had evaporated from the evaporation plate completely in five days. There was an oil on those bearings in that woolen weaving-room that did evaporate with extreme rapidity; there was a fire that flashed through the room giving the appearance of flames. Of course evaporation is waste, and is not only injurious, but unprofitable.

The following paper, upon the "Separation of Hydrocarbon Oils from Fat Oils", by Alfred H. Allen, is given here as the latest and best English contribution to the literature of this subject: (*b*)

The extensive production of various hydrocarbon oils suitable for lubricating purposes, together with their low price, has resulted in their being largely employed for the adulteration of animal and vegetable oils. The hydrocarbons most commonly employed for such purposes are:

1. Oils produced by the distillation of petroleum and bituminous shale, having a density usually ranging between 0.870 and 0.915.
2. Oils produced by the distillation of common rosin, having a density of 0.965 and upward.
3. Neutral coal-oil, being the portion of the products of distillation of coal-tar boiling at about 200° C., and freed from phenols by treatment with soda.
4. Solid paraffine, used for the adulteration of beeswax and spermaceti, and employed in admixture with stearic acid for making candles.

The methods for the detection of hydrocarbon oils in fat oils are based on the density of the sample, the lowered flashing and boiling points, the fluorescent characters of the oils of the first two classes, and the incomplete saponification of the oil by alkalies. The taste of the oil and its odor on heating are also useful indications.

If undoubtedly fluorescent, an oil certainly contains a mixture of some hydrocarbon, but the converse is not strictly true, as the fluorescence of some varieties of mineral oil can be destroyed by chemical treatment, and in other cases fluorescence is wholly wanting. Still, by far the greater number of hydrocarbon oils employed for lubricating purposes are strongly fluorescent, and the remainder usually become so on treatment with an equal measure of strong sulphuric acid.

If strongly marked, the fluorescence of a hydrocarbon oil may be observed in presence of a very large proportion of fixed oil, but if any doubt exists the hydrocarbon oil may be isolated. As a rule, the fluorescence may be seen by holding a test-tube filled with the oil in a vertical position in front of a window, when a bluish "bloom" will be perceived on looking at the sides of the test-tube from above. A better method is to lay a glass rod, previously dipped in the oil, down on a table in front of a window, so that the oily end of the rod shall project over the edge and be seen against the dark background of the floor. Another excellent plan is to make a thick streak of the oil on a piece of black marble or glass smoked at the back, and to place the streaked surface in a horizontal point in front of and at right angles to a well-lighted window. (*c*) Examined in this manner, a very slight fluorescence is readily perceptible. If at all turbid, the oil should be filtered before applying the test, as the reflection of light from minute particles is apt to be mistaken for true fluorescence. In some cases it is desirable to dilute the oil with ether and examine the resultant liquid for fluorescence. An exceedingly small amount of mineral oil suffices to impart a strong blue fluorescence to ether.

The quantitative analysis of mixtures of fat oils with hydrocarbon oils has till recently been very uncertain, the published methods professing to solve the problem being for the most part of very limited applicability, and in some cases wholly untrustworthy.

When the hydrocarbon oil in admixture happens to be of comparatively low boiling point, it may often be driven off by exposing the sample to a temperature of about 150° C., but the estimation thus effected is generally too low, and often quite untrustworthy.

When it is merely desired to estimate approximately the proportion of hydrocarbon oil present, and not to isolate it or examine its exact character, Kœttstorfer's titration process may be used, as suggested by Messrs. Stoddart. But the best and most accurate method of detecting hydrocarbon oils in, and quantitatively separating them from, fat oils, is to saponify the sample, and then agitate the aqueous solution of the soap with ether. (*d*) On separating the ethereal layer and evaporating it at or below a steam heat the hydrocarbon oil is recovered in a state of purity.

Either caustic potash or soda may be employed for the saponification, but the former alkali is preferable, owing to its greater solubility in alcohol and the more fusible character of the soaps formed. A convenient proportion to work with consists of 5 grms. of the sample of oil and 25 c. c. of a solution of caustic potash in methylated spirit, containing about 80 grms. of KHO per liter. Complete saponification

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a In this case the volatile oils appeared to constitute the bulk of the lubricator used.

b *Oil and Drug News*, October 18, 1881. Read at the 1881 meeting of the British Association.

c "Either of these plans is infinitely superior to the polished tin-plate usually recommended. In short, the background should be black, not white."

d "According to my experience, treatment of the dry soap with ether, petroleum spirit, or other solvent is liable to cause error from solution of the soap itself, if much hydrocarbon oil be present."

may usually be effected by boiling down the mixture in a porcelain dish, with frequent stirring, until it froths strongly. In the case of butter, cod-liver oil, and other fats which undergo saponification with difficulty, it is preferable to precede this treatment by digestion of the mixture for half an hour at 100° C. in a closed bottle. After evaporating off the alcohol, the soap is dissolved in water, brought to a volume of 70 to 80 c. c., and agitated with ether. The ethereal solution is separated, washed with a little water, and carefully evaporated The agitation with ether must be repeated several times to effect a complete extraction of the hydrocarbon oil from the soap solution.

The foregoing process has been proved to be accurate on numerous mixtures of fat oils with the hydrocarbon oils. The results obtained are correct to within about 1 per cent. in all ordinary cases. In cases where extreme accuracy is desired, it is necessary to remember that most, if not all, animal and vegetable oils contain traces of matter wholly unacted on by alkalies. In certain cases, as butter and cod-liver oil, this consists largely of cholesterin, $C_{26}H_{44}O$. (*a*) The proportion of unsaponifiable matter soluble in ether, which is naturally present in fixed oils and fats, rarely exceeds 1½ per cent., and is usually much less. Sperm oil, however, constitutes an exception, yielding by the process about 40 per cent. of matter soluble in ether. (*b*) This peculiarity has no practical effect on the applicability of the process, as sperm oil, being the most valuable of commercial fixed oils, is never present without due acknowledgment of the fact. Spermaceti and the other waxes yield, after saponification, large percentages of matter to ether, and hence the process is not available for the determination of paraffine wax in admixture with these bodies, though it gives accurate results with the mixtures of paraffine and stearic acid so largely employed for making candles. The following figures, obtained in my laboratory by the analysis of substances of known purity and of mixtures of known composition, show the accuracy of which the process is capable. The process was in each case on about 5 grms. of the sample in the manner already described.

The results are expressed in percentages:

Composition of substances taken.				Unsaponifiable matter found.
Fat oil.	Results.	Hydrocarbon oil.	Results.	
	Per cent.		*Per cent.*	*Per cent.*
Olive	40	Shale oil	60	58.03
Olive	80	Shale oil	20	19.37
Olive	40	Rosin oil	60	59.42
Olive	80	Rosin oil	20	19.61
Rape	86	Shale oil	16	15.95
Cottonseed	60	Rosin oil	40	39.74
Linseed	60	Rosin oil	40	39.32
Castor	60	Rosin oil	40	38.88
Cod-liver	70	Rosin oil	30	30.80
Cottonseed	48	Coal-tar oil	52	52.60
Lard	60	Paraffine wax	40	39.54
Lard	20	Paraffine wax	80	80.09
Olive	100			*1.14
Rape	100			*1.00
Castor	100			0.71
Cod-liver	100			1.82
Palm	100			0.54
Butter fat	100			0.46
Sperm	100			41.49
Spermaceti	100			49.68
Japan wax	100			1.14
Lard	100			*0.23
Cacoa butter	100			0.22

* These experiments were not made strictly by the same process as the majority.

The following table indicates the general behavior of the constituents of complex fats, oils, and waxes when the aqueous solution of the saponified substance is shaken with ether:

Dissolved by the ether.	Remaining in the aqueous liquid.
Hydrocarbon oils; including—	Fatty acids. } In combination with the alkalies used.
Shale and petroleum oils.	
Rosin oil.	Resin acids. } In combination with the alkalies used.
Coal-tar oil.	
Paraffine wax and ozokerite.	Carbolic and
Vaseline.	c Cresylic acids. } In combination with the alkalies used.
Neutral rosins.	
Unsaponified fat or oil.	Glycerol (glycerine).
Unsaponifiable matter; as cholesterin.	
Spermyl alcohol; from sperm oil.	
Cetyl alcohol; from spermaceti.	
Myricyl alcohol; from beeswax.	

The hydrocarbon oil having been duly isolated by saponifying the sample and agitating the solution of the resultant soap with ether, its nature may be ascertained by observing its density, taste and smell, behavior with acids, etc.

a "The process affords a very rapid and simple means of isolating cholesterin. Thus, on dissolving the traces of unsaponifiable matter left by butter in a little hot alcohol, and allowing the liquid to cool, abundant crystals are deposited, which may be identified as cholesterin by their microscopic and chemical characters. A sample of butterine gave no cholesterin."

b "I am investigating this interesting fact, and have obtained full confirmation of Chevreul's observation that sperm oil when saponified yields a peculiar solid alcohol instead of glycerine. It is distinct from cetyl alcohol, and distills, apparently without decomposition, at a very high temperature."

c "In a previous research I found that carbolic and creslyic acids were wholly removed from their ethereal solutions by agitation with caustic soda."

SECTION 8.—PRACTICAL RESULTS OF THE INVESTIGATIONS OF PROFESSOR ORDWAY.

In a circular issued in 1880 Mr. Edward Atkinson treats the subject of oil as follows:

In the two years and little more that have elapsed since the question was taken up for the mere purpose of abating some of the dangers of fire the following changes have occurred. * * * In 1878 a request made for information was responded to by the managers of one hundred mills, who gave the quantity and price of the oils used for lubrication, the pounds of cotton goods manufactored in preceding periods of six or twelve months, and other data. These returns were compiled, and it appeared that in fifty-five mills, operated on about the same fabric, and among which there was no good reason for a variation of over 20 per cent. either in cost or quantity of oil used, the actual variation was about 350 per cent. It will also be remembered that a large portion of the waste of oil consisted in evaporation, whereby the atmosphere was sometimes charged with combustible vapors, by which some fires that might otherwise have been easily subdued were made very dangerous. It was for the special purpose of discovering the facts in this particular matter and applying the remedy that the inquest was first entered upon.

It is a great satisfaction to be able to state that within the first year after we agitated this subject a settlement was made in a patent lawsuit, the principal manufacturers of lubricating oil agreeing to pay a royalty for the right to use superheated steam in their preparation, and by that or other methods a great change for the better was made. The volatile and dangerous oils do not now appear to be upon the market, or, at any rate, are apparently no longer offered to members of our company to any extent. They are very easily detected and avoided; and we still stand ready to examine any and all samples, and to inform all our members of the names of dangerous oils, and to warn them against the vendors.

Very soon after the change in the process of manufacture a sharp competition ensued in the sale of good oil, and a considerable reduction of prices followed.

The change in practice has been very great during the last two years. We have lately called upon the same mills that gave us data in 1878 to make a similar return for six or twelve months ending in 1880, and have received answers from 78.

From the 78 returns we get the following results:

The product of cotton goods in these mills for a period averaging $8\frac{1}{13}$ months prior to June 30, 1878, was 102,874,748 pounds, or 12,653,720 pounds per month. For a period averaging $8\frac{2}{13}$ months prior to June 30, 1880, it was 110,166,595 pounds, or 13,550,620 pounds per month. Increase in product, 7.09 per cent. The quantity of oil used in the first period was 176,766 gallons, or 1.72 gallons to each 10,000 pounds cloth. In the second period, 173,481 gallons, or 1.57 gallons to each 10,000 pounds cloth. Decrease in the consumption of oil, 8.72 per cent. The cost of oil and grease for lubrication in the first period was $103,162 25, or $10 03 to each 10,000 pounds cloth. In the second period, $73,482 71, or $6 67 to each 10,000 pounds cloth. Decrease in the cost of lubrication, 33 per cent.

If the cost of lubrication had been $10 03 for each 10,000 pounds in 1880, the gross sum would have been	$110,497 19
The actual cost was	73,482 71
Difference for $8\frac{1}{13}$ months	37,014 48
or, for 12 months, in round figures	55,000 00

The above seventy-eight mills represent an annual consumption of 400,000 bales of cotton, which constitutes about 30 per cent. of the consumption of the cotton factories insured in this or in other mutual companies. If the decrease of cost in these mills represents an average of the whole, the lubrication of machinery in cotton-mills insured by us costs $180,000 less annually than it did at the time this investigation was entered upon. The change has been computed first on fifty-three, then on sixty-five, and last on seventy-eight mills, with substantially uniform results. We may therefore infer a general rule.

Of course we cannot claim all this saving as the direct result of our work, because there has been a great decline in the prices of oils, ranging from 10 to 40 per cent., except so far as that reduction may be attributed to this investigation. One of the largest dealers to whom these figures have been submitted attributes two-fifths to the reduction of price, and the remainder to the saving of waste and to the more general use of a uniform quality of fine mineral, or so-called paraffine oil, at a substantially uniform range of prices. in place of a considerable use of mixed oils under fancy names, and at all sorts of prices. In comparing particular cases, we find this view confirmed; but, if we may not assume so much of the savings as would amount to three-fifths, or $100,000 a year, yet we may fairly claim, as the direct result of changes made in consequence of this investigation, a sum equal to all the losses and expenses of this company for the two years that have elapsed since our work began to have an influence, especially an influence on the manufacture of oil.

SECTION 9.—DETERMINATION OF THE VALUE OF LUBRICATING OILS BY MECHANICAL TESTS.

During the discussion that followed the lecture given by Professor Ordway, previously quoted, Mr. Edward Atkinson remarked as follows:

I will now say, also, that inasmuch as we have obtained three frictional machines—two American and one English—all of which may prove unsuitable, it has occurred to us to establish the rule of lubricating power on spinning-frames actually in operation by the application of thermometers to every spindle. * * * Three small frames have been provided, which are to be started and operated with full bobbins, and with thermometers applied to the steps and bolsters; we will then use the different oils upon them, and see if we can establish by the ratio of heat evolved any rule as to the lubricating power of each oil. In a rough-and-ready way we have applied that test to the shaft of the elevator in our office building, and there are several results that have been obtained that prove that there is a very simple method available to almost anybody. I caused some thermometers to be prepared, and mounted them in copper cartridges filled with water, and then had the journal-box of the shaft bored, and one of these thermometers placed so as to rest against the shaft as it is in use, and then hung another one in precisely the same way alongside.

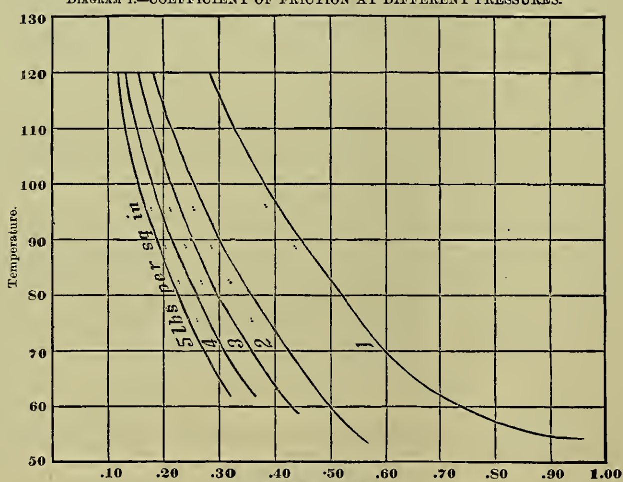
The first shaft that we tried was belted both ways, and had no serious bearing upon its journal. The second shaft is the principal shaft operating about four hundred turns, and working the elevator with the belt bearing down upon it. Under the first oil we tried the shaft heated about 30° F. In hot days, when the atmosphere of that room was at 100°, the shaft showed 128° to 130°. We then tried some light spindle oil which we didn't think fit for a heavy-bearing oil, yet that carried the heat down about 10°. We then tried some plumbago mixed with paraffine by Mr. Toppan; it was very difficult to get it on, but that worked it 10° cooler than the first oil. We then tried another oil, which heated so rapidly that we took it off at once; we didn't dare to run it. We then tried another and got down to 17° above the temperature of the room. It is a very simple matter; * * * and I think it will prove a good way for testing oils on a bad bearing, which almost every man has somewhere in his mill.

The management of the further mechanical tests was placed in the hands of Mr. C. J. H. Woodbury, of Boston, who embodied his results in a paper read before the annual meetings of the American Society of Mechanical Engineers and the American Association for the Advancement of Science for 1880. The following abstract of this paper, which presents results which "have been accepted as a long step in advance of anything ever attained before", is introduced here with the permission of the author: (*a*)

The resistance existing between bodies of fixed matter, moving with different velocities or directions, presents itself in the form of a passive force, which results in the diminution or the destruction of apparent motion. Modern science has demonstrated that this destruction is only apparent, being merely the conversion of the force of the moving body into the oscillation of the resisting obstacle, or into that molecular vibration which is recognized as heat. Direct friction refers to the case where the two bodies are in actual contact, and mediate friction where a film of lubricant is interposed between the surfaces, and it is this which applies to nearly every motion in mechanics where bodies slide upon each other. The coefficient of friction is the relation which the pressure upon moving surfaces bears to resistance. * * * In this report of my work upon the measurement of friction of lubricating oils I shall restrict myself to a description of the apparatus designed especially for the purpose, the method of its use, and the results obtained with a number of oils in our market which are used for lubricating spindles. Previous trials of nine different oil-testing machines in use showed that none of them could yield consistent duplicate results in furnishing the coefficient of friction. The operation of these machines, by their failure to obtain correct data, adduced certain negative evidence, which established positive conditions as indispensable in the construction of a machine capable of measuring the friction of oils. The following circumstances must be known or preserved constant: Temperature, velocity, pressure, area of the frictional surfaces, thickness of the film of oil between the surfaces, and the mechanical effect of the friction. In addition to the foregoing conditions, the radiation of the heat generated by friction must be reduced to a minimum, and the arrangement of the frictional surfaces must be of such a nature that no oil can escape until subjected to attrition. To measure the frictional resistance at the instant of a given temperature, and at a time when both temperature and friction are varying, requires a dynamometer which is instantaneous and automatic in its action.

The apparatus consists of an iron frame supporting an upright shaft, surmounted by an annular disc made of hardened tool steel. Upon the steel disc rests one of hard bronze (composed of the following alloy: copper thirty-two parts, lead two parts, tin two parts, zinc one part) in the form of a cylindrical box. Water is fed in at one side, and a diaphragm extending nearly across the interior produces a uniform circulation before discharge. Although this use of water is original with the writer in the method of its application, its first employment to control the temperature of the bearing surfaces of oil-testing machines is due to Monsieur G. Adolphus Hirn, and is described

DIAGRAM 1.—COEFFICIENT OF FRICTION AT DIFFERENT PRESSURES.



by him in a paper on the subject of friction, read before the Société Industrielle de Mulhouse, June 28, 1854. M. Hirn, however, confined his attention chiefly to the determination of the mechanical equivalent of heat, as measured by the amount of heat imparted to the circulating water, expressed in the work of friction. His investigations of lubrication with this apparatus were confined to the friction of lard and olive oils at the light pressure of about $1\frac{1}{10}$ pounds to the square inch. Mr. Charles N. Waite, of Manchester, New Hampshire, has independently, and I believe originally, made use of water in a friction machine, and has performed good work in the limit of his experiments.

A protection of wool batting and flannel, to guard the discs against loss of heat by radiation, diminishes the escape of heat to about two degrees per hour, which loss is not appreciable when observations are taken within a few seconds' interval. A thin copper tube, closed at the lower end, reaching through the cover, extends to the bottom of the disc; the bulb of a thermometer is inserted in this tube, and measures the temperature of the discs; an oil tube runs to the center of the disc, and a glass tube at the upper end indicates the supply and its rate of consumption, and also serves to maintain a uniform head of oil fed to the bearing surfaces. The rubbing surfaces of both discs were made to coincide with the standard surface plates in the physical laboratory of the Institute of Technology (Boston, Massachusetts), and their contact with each other is considered perfect.

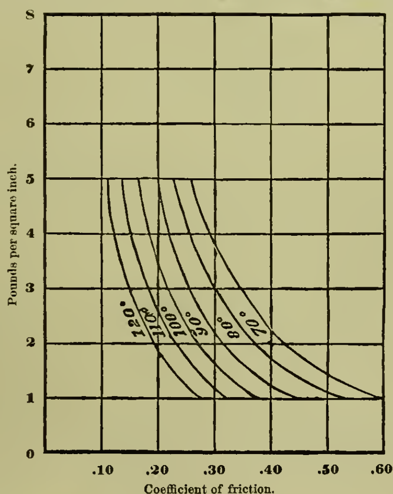
a The tables which accompany this paper are not introduced here. They may be found in the proceedings of the American Association for the Advancement of Science for 1880, pages 197–221.

After this surface was finished the bronze disc was treated with bichloride of platinum, which deposited a thin film of platinum upon the surface. Upon the application of the discs to each other the steel disc rubbed off the platinum from all parts of the surface, showing the perfection of contact. This nicety of construction enables a film of oil of uniform thickness to exist between the surfaces, and the resistances are not vitiated by the collision of projecting portions of the disc with each other. The rounded end of the upper shaft fits into a corresponding depression in the top of the upper disc. This method of connection retains the disc over the proper center, yet it is allowed to sway enough to correct any irregularity of motion caused by imperfection of construction or wear of the lower disc. To obtain the desired condition of pressure, weights are placed directly upon the upper spindle. The axes of the upper and lower spindles do not lie in the same straight line, but are parallel, being about one-eighth of an inch out of line with each other. Such construction, giving a discoid motion, prevents the disc from wearing in rings and assists in the uniform distribution of the oil. An arm is keyed through the lower part of the upper spindle and engages with projections upon the upper disc. Upon this arm, which is turned to the arc of a circle, whose development is two and one-half feet, a thin brass wire is wrapped and reaches to the dynamometer, so that the tension of the dynamometer is tangential and the leverage is constant for all positions of the upper disc within its range of motion. The dynamometer consists of a simple bar of spring steel fastened at one end and bent by the pull applied at the other. Its deflection is indicated by a pointer upon a circular dial, the motion of the spring being multiplied about eighty times by a segment and pinion. The whole is inclosed in a steam-gauge case.

When completed, the machine was subjected to a long series of tests with the same oil, to determine the accuracy of the results and the best method of procuring them. The operation of the machine under equal conditions with the same oil gives results which are as closely consistent with each other as could be expected from such physical measurements. As an example, four tests of the Downer Oil Company Light Spindle at 100° F., and on different days, gave 0.1145, 0.1094, 0.1118, 0.1094: mean, 0.1113. * * * Much of the irregularity, slight as it is, is due to the variable speed of the engine. Concurrent results were obtained under equal circumstances, but the coefficient of friction varied, not merely with the lubricants used, but also with the temperature, pressure, and velocity. The results of my own experiments on mediate friction do not agree with the laws of friction as given in works on mechanics, but the coefficient of friction varies in an inverse ratio with the pressure, as shown graphically in the diagram (page 204).

These curves belong to the hyperbolic class of a high degree; but I have not been able to deduce an equation which will answer to the conditions of more than one, because the law of the curves is modified by a constant, dependent upon the individual sample of oil used. A little difference in the sample would cause a difference in the line of curve. Reference is made to diagram 2, showing the coefficient of friction under equal ranges of temperature and velocity, but with a different series of pressures.

DIAGRAM 2.—CURVES SHOWING CHANGES OF COEFFICIENT OF FRICTION UNDER VARYING CONDITIONS.



Coefficient of friction at 100° and 500 revolutions per minute:

Pressure per square inch.	Coefficient of friction.
1 pound	0.3818
2 pounds	0.2686
3 pounds	0.2171
4 pounds	0.1849
5 pounds	0.1743

The ratio of the changing coefficient varies with the temperature at which the range of results is taken.

Friction varies with the area, because the adhesiveness of the lubricant is proportional to the area, and the resistance due to this cause is a larger fraction of the total mechanical effect with light than it is with heavy pressures.

The limit of pressure permitting free lubrication varies with the conditions; for constant pressures and slow motion it is believed to be about 500 pounds per square inch, while for intermittent pressures, like the wrist-pin of a locomotive, the pressure amounts to 3,000 pounds per square inch. It has been stated that about 4,000-foot pounds of frictional resistance per square inch is the maximum limit of safe friction under ordinary circumstances.

As the results of this preliminary work indicated that the coefficient of friction varied with all the circumstances, it was necessary to simulate the conditions of specific practical applications to determine the value of a lubricant for such purposes.

It was decided to begin these investigations with spindle oils, and therefore the machine was loaded with 5 pounds to the square inch and run at about 500 revolutions per minute, as the oil is then submitted to conditions of attrition corresponding to those met with in extremes of velocity and pressure, in the case of a Sawyer spindle running at 7,600 revolutions per minute, with a band tension of 4 pounds, and the results subsequently given refer only to the friction under these conditions, except when definitely stated to the contrary.

This particular spindle was selected because, of the 5,000,000 ring spindles in the United States, about 1,500,000 are of this manufacture, and in a large number of the remainder the conditions of lubrication are quite similar.

In a Sawyer spindle the step measures $\frac{5}{8}$ by $\frac{15}{100}$ inch, and receives $\frac{7}{8}$ of the pull due to the band. If that tension is 4 pounds, $3\frac{1}{2}$ pounds are transmitted to the step, whose projected area is $\frac{9}{16}$ square inch. The pressure per square inch is, therefore, $5\frac{1}{4}$ (say 5) pounds.

The diameter of the spindle at bolster is 0.28″, or 0.8976″ in circumference. At 7,600 revolutions per minute its velocity amounts to 6,685″, or 557 feet, per minute; and the mean area of the discs of the oil machine must revolve at this speed.

To illustrate, let—

R = outer radius of disc = 2.656 inches.
r = inner radius of disc = 1.435 inches.
n = radius of circle bisecting the area.

$$\text{Fractional area of annular disc} = \pi(R^2 - r^2) \quad (1)$$
$$\text{area of outer half} = \pi(R^2 - n^2) \quad (2)$$
$$2\pi(R^2 - n^2) = \pi(R^2 - r^2) \quad (3)$$
$$2\pi R^2 - 2\pi n^2 = \pi R^2 - \pi r^2 \quad (4)$$
$$2R^2 - 2n^2 = R^2 - r^2 \quad (5)$$
$$-2n^2 = -R^2 - r^2 \quad (6)$$
$$2n^2 = R^2 + r^2 \quad (7)$$
$$n^2 = \frac{R^2 + r^2}{2} \quad (8)$$
$$n = \sqrt{\frac{R^2 + r^2}{2}} \quad (9)$$
$$\text{Length of line bisecting the area} = 2\pi n = \sqrt{\frac{4\pi^2(R^2+r^2)}{2}} \quad (10)$$
$$= \sqrt{2\pi^2(R^2+r^2)} \quad (11)$$
$$= \sqrt{2 \times 9.87(7.05+2.11)} \quad (12)$$
$$= \sqrt{19.74 \times 9.16} \quad (13)$$
$$= \sqrt{180.8184} \quad (14)$$
$$= 13.45 \text{ inches.}$$
$$= 1.12 \text{ feet.}$$

To give a desired fractional velocity of 6.685 inches per minute the discs must revolve at 6,685 divided by 13.45 = 497 (say) 500 revolutions per minute. To recapitulate: By revolving the disc at 500 revolutions per minute, with a pressure of 5 pounds per square inch, the oil is submitted to conditions of attrition corresponding to those in the extremes of velocity and pressure met with in a Sawyer spindle revolving at 7,600 revolutions with a band tension of 4 pounds.

My reason for giving such a detailed statement is, because the value of investigations upon this subject must be measured by the precision with which all the conditions are observed.

The apparatus is used in the following manner to measure the coefficient of friction of oil: After cleaning with gasoline and wiping carefully with wash leather, the discs are oiled and run for about five hours, being kept cool by a stream of water circulating through the upper disc. From time to time they are taken apart, cleaned, and oiled again. After using any oil, even if the discs are afterward cleaned, the results with the oil subsequently used give the characteristics of the previous oil, and it is only after thirty-five to forty-five miles of attrition that these results become consistent with each other, each succeeding result, meantime, approaching the final series. This seems to indicate that friction exists at the surface of the two discs, between the film of oil acting as a washer and the globules of oil partially embedded within the pores of the metal. If the dense bronze and steel retain the oil despite attempts to remove it, how much longer must it require to replace the oil in machinery with a new variety whose merits are to be tested? These experiments confirm the wisdom of the increasing use of cast-iron for journals, as its porosity enables it to contain and distribute the lubricant.

When the discs are ready to test the oil the apparatus is cooled by the circulation of water, the flow of which is stopped when the machine is started. At every degree of temperature the corresponding resistance is read on the dynamometer. When the thermometer indicates a temperature of sixty degrees, the counter is thrown in gear and the time noted. When one hundred and thirty degrees is reached, the counter is thrown out of gear and the time noted. This not only gives the velocity of the rubbing surfaces, but the number of revolutions required to raise the temperature a stated number of degrees, and is a close criterion of the oil. The coefficient of friction is the ratio of the pressure to the resistance, and is deduced in the following manner:

P = Weight on discs.
R = Outer radius of frictional contact.
r = Inner radius of frictional contract.
N = Number of revolutions per minute.
W = Reading on dynamometer.
φ = Coefficient of friction.

In the friction of annular discs the portions of the surface near the perimeter have a greater leverage than those near the center. The mean sum of these moments is found by the calculus.

Let e be the radius of any infinitesimal narrow ring or band. Then will—

Width of band $= de$ . . . . (1)

Length of band $= 2\pi e$ . . . . (2)

Area of band $= 2\pi e de$ . . . . (3)

Moment of band $= 2\pi e^2 de$ . . . . (4)

The expression for the area of an annular disc is $\pi(R^2-r^2)$ . . . . (5)

To express the moment of a ring in terms of an annular surface, divide Eq. 4 by Eq. 5, as follows:

$$\frac{2\pi e^2 de}{\pi(R^2-r^2)} = \frac{2e^2 de}{R^2-r^2} = \frac{2}{R^2-r^2} e^2 de = \text{Moment in terms of disc} \qquad (6)$$

$$\text{Moment of whole disc} = \frac{2}{R^2-r^2} \int e^2 de \qquad (7)$$

$$\text{Integration of whole disc } \frac{2}{R^2-r^2} \left\{ \frac{e^3}{3} \right\}_r^R \qquad (8)$$

$$\text{Substituting the limits } R^2-r^2, \frac{R^3-r^3}{3} \qquad (9)$$

$$\text{and calling the work of friction} = \varphi P \qquad (10)$$

$$\text{Statical moment of friction of disc} = \frac{2\varphi P(R^3-r^3)}{3(R^2-r^2)} \qquad (11)$$

$$\text{Mechanical effect} = \frac{4\pi\varphi P(R^3-r^3)}{3(R^2-r^2)} \qquad (12)$$

$$\text{Foot pounds at any velocity} = \frac{4\pi\varphi P(R^3-r^3)N}{3(R^2-r^2} \qquad (13)$$

As previously stated, the dynamometer exerts a pull at the end of a lever whose development is $2\frac{1}{2}$ feet.

$$\text{Resistance of dynamometer} = \frac{5W}{2} \qquad (14)$$

$$\text{Resistance of dynamometer in foot pounds at any velocity} = \frac{5WN}{2} \qquad (15)$$

Then as the total friction = the resistance of the dynamometer,

$$\text{Eq. } 13 = \text{Eq. } 15$$

$$i.\ e., \quad \frac{4\pi\varphi PN(R^3-r^3)}{3\ (R^2-r^2)} = \frac{5WN}{2}$$

Simplifying we have

$$8\pi\varphi PN(R^3-r^3) = 15WN(R^2-r^2) \qquad (16)$$

$$8\pi\varphi P\ (R^3-r^3) = 15W\ (R^2-r^2) \qquad (17)$$

$$\varphi = \frac{15W(R^2-r^2)}{8\pi P(R^3-r^3)} \qquad (18)$$

$$\text{Separating the constants, } \varphi = \frac{15(R^2-r^2)W}{8\pi(R^3-r^3)P} \qquad (19)$$

and $R = 0.2214$ feet

$r = 0.1211$ "

$R^3 = 0.01083$		$R^2 = 0.0489$	
$r^3 = 0.00177$		$r^2 = 0.0146$	
$R^3 - r^3 = 0.00906$, log.	7.9571282	$R^2 - r^2 = 0.0343$, log.	8.5352491
$\pi = 3.1416$, log.	0.4971499	$(R^2 - r^2)$ log.	8.5352491
8 "	0.9030900	15 log.	1.1760913
	9.3573681		9.7113404
	9.7113404		
	0.3539723 = 2.259		

$$\varphi = \frac{2.259W}{P} \qquad (20)$$

This equation was solved for each reading of the dynamometer with five pounds pressure on the square inch, and the results tabulated in a convenient form for computing the coefficient of friction from the observed results.

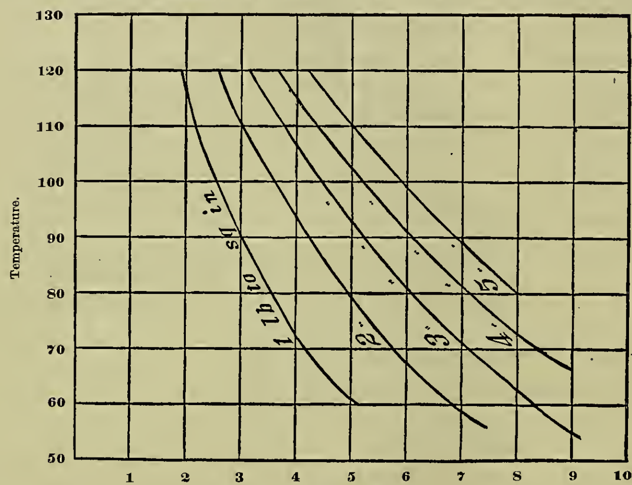
The table on page 208 shows the resistance of friction at 100°, 500 revolutions, for various pressures.

RESISTANCE OF FRICTION AT 100°.

Pressure pounds.	Resistance on dynamometer. Pounds.	Equivalent band tension.
1	2.62	0.8
2	3.68	1.6
3	4.48	2.4
4	5.28	3.2
5	5.98	4.0

For further detailed results, reference is made to diagram 3.

DIAGRAM 3.—RESISTANCE OF FRICTION AT DIFFERENT PRESSURES.



These results seem to be intimately relevant to the most desirable limit of tension to the spindle-band methods of operating cotton-spinning machinery. By weighing the band tension in various mills it was found that the practice of tying bands lacked uniformity. As an example of this variation: in one mill the bands of a single coarse frame are reported to vary from 1 to 16 pounds. In another mill, on finer work, a number of spindles had a range of from ½ to 2½ pounds, and in a third mill the band tension was between the limits of ¼ to 5 pounds. The effect of atmospheric changes upon the fiber of textile bands renders it impossible, with the present method of constructing frames, to keep them at a uniform tension, but this variation can be reduced by a little care. Is it not worth while for each spinner to learn the proper band tension required for his special work, and then keep within those limits? The whole power required to run the frame would not vary in direct proportion to the varying resistance due to the friction of spindles at various pressures, because the resistance of the friction in other parts of the frame connected with the spindles, the actual spinning of cotton fibers, and the alternate contraction and expansion of the bands, are conditions which are more nearly constant, and in no case do they vary in proportion with the friction of the spindle, yet the variation is large, as shown by the following experiment made with the frame:

Mr. George Draper, in a communication to the *Industrial Record* of June 1, 1879, gives the following valuable data on this subject: A frame of Sawyer spindles was taken spinning No. 30 yarn, ordinary twist, the front rolls running 95 revolutions per minute. The rings were of 1⅝ inches diameter, and the traverse of the yarn on the bobbins 5¼ inches. The dynamometer was applied, and the power required to drive the spindles, with a side pull of the bands averaging 2 pounds to a spindle, was ascertained. The bands were then cut and a new set put on with a side pull of 3 pounds per spindle, and the frame tested again, all things remaining as before. The operation was then repeated at 4, 5, 6, 7, 8, and 9 pounds side pull per spindle, with the result shown in the following table.

Calling the amount of power required to drive the spinning frame with—

2 pounds tension on the bands	= 100
3 pounds tension on the bands	= 117
4 pounds tension on the bands	= 131
5 pounds tension on the bands	= 144
6 pounds tension on the bands	= 159
7 pounds tension on the bands	= 177
8 pounds tension on the bands	= 197
9 pounds tension, considerably more than double.	

The lubricant used is one of the most important factors in the cost of power. In the present condition of engineering science it is impossible to state what exact proportion of the power used by a mill is lost in sliding friction, but in a print-cloth mill only about 25 per cent. of the power is utilized in the actual processes of carding, spinning, and weaving the fiber, not including the machinery engaged in the operation, leaving 75 per cent. of the power as absorbed by the rigidity of belts, the resistance of the air, and friction. The coefficient of friction, under the conditions submitted by my oil-tester, varies, at 100°, 500 revolutions from 7.56 per cent. in the case of 32° Ex. machinery oil manufactured by the Downer Oil Company, to 24.27 per cent. in the case of neats'-foot oil; and the result of this investigation confirms me in the opinion that the successful operation of a spinning frame is far more closely dependent upon the individual management in respect to the conditions of band tension, lubrication, and temperature of the spinning-room than all other causes combined. Not that some forms of spindle are not superior to others, but that, without wise supervision, the most desirable forms of spindle must fail to show the merits due to the skill of their promoters. It may be stated that, within a close approximation, the lubricating qualities of an oil are inversely proportional to its viscosity; that is, the friction decreases with the cohesion of the globules of the oil for each other. The endurance of a lubricant is in some degree proportional to its adhesion to the surfaces forming the journal. An ideal lubricant in these respects would be a fluid whose molecules had a minimum cohesion for each other and a maximum adhesion for metallic surfaces. The viscous oils will also adhere more strongly to metals, and hence, under the conditions of heavy bearings, it is obligatory to use such thick lubricants, knowing that the employment of an oil with great frictional resistance is infinitely preferable to the attempt to use an oil so limpid that it could not be retained between the bearings. With light pressures the more fluid oils are admissible, and in all cases the oils should be as limpid as the circumstances will permit. Oils with great endurance are apt to give great frictional resistance, and in the endeavor to save *gallons* of oil many a manager has wasted *tons* of coal. The true solution of solving the problem of lubricating the machinery of an establishment is to ascertain the consumption of oil and the expenditure of power, both being measured by the same unit, viz, dollars.

The fluidity of the oils was measured by the following apparatus: A pipette was placed within a glass water-jacket, where the temperature was controlled and kept constant by circulation from a reservoir kept at the desired temperature. The capacity of the bulb is twenty-eight cubic centimeters and the orifice measures three and a half inches long and 0.039 of an inch in diameter.

The oil was drawn into the bulb of the pipette, and after the whole was brought to the desired temperature the time required for its discharge was accurately noted by a stop watch.

These observations were made on each of the oils for a series of temperatures varying from 50° to 150° F.

If the fluidity of an oil is the measure of its lubricating qualities, these observations would not be identical with the frictional results, because the pressure in this case was that due to a head of about five inches of oil, or about one-sixth of a pound to the square inch and rubbing against a glass surface; while with the frictional machine the pressure was five pounds to the square inch, and the surfaces bronze and steel.

In both cases, however, the character of the surfaces and the pressures were uniform conditions, and therefore they would not affect the relations of either set of experiments in their consistency with each other. If the lubrication and fluidity of oils followed the same law of variation with the temperature, the results of one would be directly proportional to those in the other, provided that all other conditions were preserved constant. Such comparisons showed that the relations of the fluidity to the lubricating qualities did not follow any uniform ratio.

At a low rate of temperatures the fluidity increased faster than the lubricating quality of the oil; between about 70° and 110° the coincidence was quite close; at higher temperatures the fluidity does not increase so fast as the lubrication. There was not a very close correspondence between the fluidity of oils at the same coefficient of friction.

The result of these investigations upon the relation of fluidity to lubrication seems to indicate that fluidity is a concomitant rather than a cause of the anti-frictional qualities of a lubricant.

In the case of mining drills operated by condensed air, an intense cold is produced at the liberation of air, and on some such bearings kerosene oil is the only lubricant which can be used. I think it extremely probable that at these low temperatures the viscosity of kerosene oil is equal to that of lubricating oils at the average temperature of bearings in general use. On the other hand, only the most viscous oils can be used in such extremely high temperatures as the cylinder and steam-chest of steam-engines.

According to the results which I have obtained, the coefficient of friction at 50° is about 75 per cent. in excess of that at 75°, and it seems to me that the manager of every mill which is run by steam ought to consider the question of the temperature of the mill in early morning during the winter months, whether, as a matter of economy, it is cheaper to warm a mill by increased friction on Monday morning, or to keep the mill and machinery warm during the interval from the preceding week.

The humidity of the atmosphere is an important factor in the mechanical operation of textile machinery, as well as in the fabrication of cotton. A year ago I submitted to the New England Cotton Manufacturers' Association measurements showing the effects of humidity on textile bands, and I am also of the opinion that there is a difference of friction in machinery due to atmospheric influences upon the lubricant.

Possibly the moisture condensed upon the cold metal from the atmosphere becomes commingled with the oil and thereby reduces its viscosity, diminishing the friction.

The question of endurance of oils has not been given in these experiments, because the consumption of oil varies with the temperature, and it is proposed to investigate the matter subsequently by running the machine and controlling the temperature of the discs to 100° by the circulation of water. The amount of oil consumed could be very easily measured by the difference in the level of the glass feeding-tube or the weight of the oil required to preserve it at that level during the experiment.

In the detailed results the friction is given for the whole range of temperatures, but in the following summary 100° has been selected as the temperature which most nearly corresponds to the heat of spindle bearings.

To ascertain these temperatures, holes were drilled in the rails of a spinning frame, passing as near the bolsters and steps as possible; the bulbs of thermometers were inserted in these holes, and while the frame was in operation 2,586 readings were taken, covering a period of four weeks. The temperature of the air was noted from a thermometer placed in the middle of the frame.

The mean temperature of the bolsters was 8.10° F., and of the steps 6.74° F., above the temperature of the room.

Other experiments were made to learn the temperature of the bearings of the shafting. Holes about half an inch in diameter were bored in the upper cap of such journals, and a thin copper tube, closed at the lower end, inserted and extended nearly to the shaft. This tube contained water, and the temperature was measured by a thermometer placed therein. The temperature of the room was measured by a thermometer hung near the bearing. There were journals in good running order whose temperature at the frictional surfaces was 140° F. This method of using thermometers was first suggested by Mr. Edward Atkinson, and I consider it the most accurate test of the anti-frictional qualities of a lubricant at the service of those in charge of machinery.

Great pains have been taken to procure pure samples of the oils experimented with, and they were obtained directly from the manufacturers; and to the courtesy of Mr. Thomas Bennett, jr., I am indebted for a large number of samples of sperm oils which were procured by him directly from the whale-ships or refiners.

The following table gives the coefficient of friction at 100° F. and 500 revolutions, with a pressure of 5 pounds to the square inch:

No. of sample.	Kind of oil.	Coefficient of friction at 100°.	No. of sample.	Kind of oil.	Coefficient of friction at 100°.
1	Mineral oil	0.1635	100	Mineral oil	0.1309
28	Mineral oil	0.1732	3	Lard	0.2181
10	Mineral oil	0.1187	4	Bleached winter sperm A	0.1067
14	Mineral oil	0.1233	5	Bleached winter sperm B	0.1217
19	Mineral oil	0.1208	6	Bleached winter sperm C	0.1170
7	Mineral oil	0.1113	9	Bleached winter sperm D	0.0956
20	Mineral oil	0.1132	18	Bleached winter sperm E	0.1141
8	Mineral oil	0.0756	17	Unbleached winter sperm	0.1147
2	Mineral oil	0.1476	21	Seal oil	0.1608
11	Mineral oil	0.1403	22	Neat's-foot	0.2427
12	Mineral oil	0.1201	23	Mixed animal and mineral oil	0.1608
15	Mineral oil	0.2243	24	Mixed animal and mineral oil	0.1377
95	Mineral oil	0.0973	25	Mixed animal and mineral oil	0.1190
96	Mineral oil	0.0950	90	Paraffine	0.1247
13	Mineral oil	0.1190	92	Paraffine mixed with one-fifth sperm	0.1185
16	Mineral oil	0.1103	93	Paraffine mixed with one-third neat's-foot	0.1347
91	Mineral oil	0.1360	94	Unknown sperm	0.1397
98	Mineral oil	0.1189			

Chemical examinations of these oils by Mrs. Ellen H. Richards, of the Women's Laboratory, Institute of Technology:

No. of sample.	Flash of vapor.	Loss of evaporation in 12 hours at 140° F.	Nitro-sulphuric acid test.
	Degrees.	*Per cent.*	
10	338	1.3	Dark yellow, with much cake.
7	314	2.7	Dark yellow, some cake.
8	284	5.5	Slightly yellow, only a few flakes of cake.
2	316	3.7	Dark yellow, thin layer of cake.
11	324	3.9	Slightly yellow, not on brown specks.
12	318	3.3	Yellow, not a single flake, no solid matter.
15	286	7.2	Turned dark, gives a black layer of gum.
13	322	1.9	Quite an amount of cake.
16	282	5.0	Do.
3	....	+0.4	Hardened with much acid to a white solid mass.
9	....	+0.3	Thickened up a little, like jelly.

With castor oil the friction was so great as to throw off the belt driving the machine; and as the time alloted for this work expired on that day, other arrangements for a wider belt could not be made, and it can only be said that its friction exceeds that of any other oil given in these tables. * * *

The anti-frictional properties of these oils under the conditions of these experiments are expressed in the following order:

No. of sample.	Kind of oil.	Coefficient of friction at 100°.
8	Mineral	0.0756
9	Bleached winter sperm	0.0956
16	Mineral	0.1103
7	Mineral	0.1113
18	Bleached sperm	0.1141
17	Unbleached sperm	0.1147
13	Mineral	0.1190
12	Mineral	0.1201
19	Mineral	0.1208
2	Mineral	0.1476
21	Seal	0.1608
28	Mineral	0.1732
3	Lard	0.2181
15	Mineral	0.2243
22	Neat's-foot	0.2427

It is no disparagement to the qualities of an oil that it is low in the foregoing list, except so far as it relates to the resistance of friction under these conditions. For circumstances of great pressure and slow motion, I am of the opinion that the order of the list would be varied; and if the question of endurance were only to be considered, still another change in the order would be necessary.

A portion of a lot of unbleached sperm oil (sample 17) was bleached expressly for these tests (sample 18), but the results of the two are so nearly uniform as to be practically identical. The result of bleaching does not affect the anti-frictional properties of the oil, although it undoubtedly reduces its gumming qualities. The friction of sperm oil is subject to sudden variations, which occur at certain temperatures for the same sample of oil. The explanation of this lies in the fact that sperm oil consists of a large number of varieties of spermaceti, each of which is liquefied at certain temperatures, at which the oil is relieved of waxy, or at least gelatinous particles, and becomes a more perfect lubricant. * * * *

The friction of lard oil for high temperatures exceeds that of any other lubricant in the list; and this adhesive quality enables it to remain on tools used for cutting iron.

In conclusion, it may be stated that the data necessary to determine the safety and efficiency of a lubricant comprise:

1. The flashing point of its vapor, which is ascertained by slowly heating a sample over an oil bath, quickly passing a small flame over the oil and noting the temperature at which the vapor first flashes. The danger from an oil does not arise from the point at which the oil actually ignites, but at the lower temperature, when the inflammable vapor bursts into flames, which communicate fire to a distance limited only by the extent of the vapor.

2. The quantity of such volatile matter is important both as respects safety and value. The heat of friction liberates that portion of the oil which is volatile at the temperature of the bearings, filling the mill with a dangerous noxious vapor, and also dissipates in the air a portion of the oil which is paid for by the gallon, but does not serve to give any return of value in lubrication. The quantity of matter volatile under 140° F. is measured by heating a known weight of oil in a watch-glass and maintaining a constant temperature of 140° F. for 12 hours. This simulates the conditions of the temperature of the bearings mentioned previously and the maximum time that it would be consecutively heated. In the case of mineral oils the loss from evaporation varied from less than 1 up to 30 per cent. With animal and vegetable oils there is a slight gain in weight, due to oxidation.

3. The tendency to spontaneous combustion is estimated by a uniform amount of cotton-waste smeared with a certain quantity of oil. A thermometer whose bulb extends to the center of the mass indicates any rise of temperature due to oxidation. Any gain of weight during the preceding evaporation test shows a liability to spontaneous ignition.

4. Freedom from acid is an important factor in oil, because acid is a cause of corrosion of metals, and will tend to remove the oil from the frictional surfaces when adhesion is indispensable. The presence of acids is shown by corrosion of copper.

5. The anti-frictional properties of an oil can be measured only by direct trial under the desired conditions of pressure, velocity, and temperature. The results of these experiments show that a lubricant must have a certain adhesion to the frictional surfaces to maintain free lubrication, but beyond that point the adhesiveness of the oil resists the motion of the surfaces, increasing the friction. A thick oil gives greater frictional resistance than a thin one; and when ease in running is the object the most limpid oil should be used consistent with the specific circumstances of the bearing. In general terms, the specific gravity of an oil gives no indications of its value as a lubricant in qualities of viscosity, body, or endurance. * * *

When this paper was read at the meeting of the American Society of Mechanical Engineers, Professor R. H. Thurston spoke as follows:

Mr. Woodbury in his paper made some reference to the fact that the coefficients of friction, as ordinarily stated, are not found to be strictly correct; in other words, that there are no such losses in ordinary practice. Then he has shown you here how seriously the temperature of the lubricant affects the coefficient of friction. You will notice that the work done is all at extremely light pressures. It is simply due to the pull of the band, and the resultant of that and the resistance of the work of the spindle. It is exceedingly light, and it is for that reason that we get what appeared to be extremely high coefficients of friction. In the table exhibited you will see that the coefficients run from 7½ up to about 20 per cent., the highest figure being lard oil and a special grade of machinery oil, which are each about 22 per cent. Now, a fact which was not brought out so strongly by the paper as it might have been is, that this coefficient is also affected very largely by the pressure per square inch put upon the journal, and what I intended specially to remark upon was the fact that these coefficients do not represent the values of the coefficients obtained in ordinary engine work, but are the coefficients obtained in extremely light work, as in the spinning-frames of cotton-mills. If we use the same lubricating material, and the same surface pressure, rising above that to fifty pounds, we will find the coefficients come down in value to a fraction of the figures given on the scale. Carrying the pressure up to a very common figure, such as we might get with any machine work, of 100 or 200 pounds, we will find that the coefficient is reduced. I have had occasion to make tests of various kinds of oil between various sorts of surfaces, and, under varying pressures and temperatures, up to pressures of 1,500 pounds to the square inch, and for a very short period of time 2,000 pounds to the square inch, and at temperatures which ran from the ordinary atmospheric temperature to above the boiling point of water, and I find that upon the crank-pins of steam-engines, such as are sometimes used on the North River boats, carrying the pressure of a thousand pounds to the square inch, instead of a coefficient of friction of 5 per cent. we get one-tenth of 5 per cent.—one-half of 1 per cent. for the coefficient of friction—so that the field explored by Mr. Woodbury is limited to these extremely low temperatures. They do not represent the results as ordinarily obtained, or exceptional results obtained by putting on tremendously high pressures, so that if we take the very best of lubricating materials—sperm oil is the best I have ever found for heavy pressures—and put a pressure upon it of a thousand pounds to the square inch, then, instead of the text-book coefficients of friction, all the way from 4 to 7 per cent., we get figures that run to one-tenth of that amount. I have obtained coefficients of friction with sperm oil as low as one-fourth of 1 per cent.

The pressure, therefore, at which you are working is one of the very important elements in determining what is to be the coefficient of friction to be assumed in design.

Now, I spoke of this partly as a commentary on this paper and partly as a commentary on that of Mr. Hoadley. Mr. Hoadley shows us that we may divide the circumference described by the crank-pin by horizontal and vertical lines, and he calls the upper and lower of the two sections of his circumference the work-doing parts of the traverse of the crank-pin, and the end sections he calls the work-using sections.

Now he shows us what is the effect of friction in reducing the efficiency of engines where we put full pressure on the crank-pin at either end of the stroke; but it must be observed, as a commentary upon that statement, that these figures are very much smaller than we have been accustomed to assume. The friction of the crank-pin in a well-made engine, with a good bronze box, running on good steel journals, ought to come down to a fraction of 1 per cent. That being the case, we get the result that Mr. Porter indicated, that the loss of power at the two ends of the stroke becomes insignificant, more insignificant than I presume he had supposed.

A remark was also made by another member of the society upon our determinations of the value of lubricating oils for steam-cylinders. In a long series of experiments, which I have had occasion to make on lubricating oils to be used in steam-cylinders, I have taken oils furnished in the market for that purpose and tested them at the temperature of the steam-cylinder, bringing them up to a temperature of 250° or 300°, and some cases 350°, and I found that the value of the oil for lubricating purposes within the steam-cylinders is by no means the same as its value for lubricating on the crank-pin and other external parts not subjected to high temperatures, and that the oil giving the best results on the crank-pin may give poor results in the cylinder.

In several cases I have found that oils that were among the best for ordinary use were among the poorest for cylinder work, while other oils that were not nearly so good for external use were among the very best for use within the steam-cylinder. So no one can tell what is the value of an oil for the purpose to which he applies it until he subjects it to a test under precisely those conditions.

Mr. Woodbury presented us with the results of work done under the precise conditions of actual use. He runs the spindles at the ordinary speed, and runs them as in ordinary spinning frames, and then measures the friction, and the data he gives are of course absolutely reliable as determining the results to be met with under that set of conditions. That is one reason why we may rely so absolutely, I presume, upon his results. He has determined under these conditions what is the comparative value of a large number of oils; but I wish to renew his caution that we are not to take these results, which represent the relative value of oils for spindles, as representing the relative value of those oils for crank-pins or the lubrication of steam-cylinders. Another remark was made in the paper, apparently incidentally, that a man may save a considerable amount of money in the purchase of his oils, while losing at the same time a vastly greater amount in paying his coal bills, and that leads to the question how are we to determine the money value of these oils? It is evident that the value to the dealer is not at all likely to be just its value to the purchaser. The money value of the oil to the consumer is something less than the money value of the work that it is going to save him in friction, or the money value of the work that it is going to save him in friction added to the money value of the work it is going to save him in repairs and incidental expenses. If you will take the trouble to determine the cost of the power in any mill or machine-shop in the country, and then assume a change in the coefficient of friction from an average of, we will say, 2 or 3 per cent. to an average of 5 per cent., and see what you can afford to pay for oil that will avoid that increase of friction, you will find probably in every case in which you make the calculation that you can better afford to pay the highest prices in the market for the best oils than to take as a gift the oils which give you the highest coefficients of friction.

I took occasion some time ago to work that up in a specified case—that of Mr. Sellers' shop—I don't remember now what the figures were, but the result was such as to show that we could better pay a good many times the value of the best sperm oil in the market to reduce losses by friction than to take the cheapest oils in the market with the increase of those losses.

The difference between the lowest coefficients and the highest coefficients is about 1 to 3.

But when you are calculating the cost of the power required to overcome this friction, you will find that even slight differences are sufficient to justify you in making your estimate of costs in taking the very highest-priced oil, even if it gives you a very little decrease in the coefficient of friction.

In a circular issued near the close of the year 1880 by Mr. Atkinson, he gives a summary of the results obtained in the research conducted by Mr. Woodbury, and remarks:

Another result of this work has been the invention of the machine on which we can now ascertain the anti-frictional properties of any oil with absolute certainty, and by the use of which we have obtained measurements of the coefficient of friction with an accuracy and uniformity that have never been approached before. * * * Our machine having been adjusted in velocity and other conditions to those of a Sawyer spindle operating at 7,600 turns per minute under a band tension of 4 pounds, it appeared that the difference in power required to overcome the resistance of the parts varied as follows:

The resistance or power required to operate the frictional machine at 100° F., when lubricated with Downer Oil Co. 32 extra machinery oil, amounted to 756, and under the same conditions, with the exception of the substitution of neat's-foot oil as a lubricant, the resistance amounted to 2,427, or three and twenty one-hundredths times as much.

In respect to the same oil at different degrees of temperature in the bearing, the resistance at 50° is about 75 per cent. in excess of that at 75° F.

In respect to the best oil and poorest lubricant at 100° F., the difference is 321 per cent.

In respect to a difference of pressure varying from 1 pound to 5 pounds, the difference is 229 per cent.

By means of experiments applied to a small Sawyer spindle-frame, which could not be reduced to such precise accuracy, but which marked the great variations in power according to the greater or less tension of the bands, other results were reached of the same general character, fully confirming the above conclusions.

The general conclusions reached are, therefore, that although, as a matter of course, there must be a marked difference in power needed between a well-planned and constructed and a badly-constructed spinning-frame, yet, when it is a question between two well-constructed frames, * * * the greatest differences in details (of construction) do not make as much difference in the power required as may be made in the adjustment and tension of the bands or in the quality and condition of the oil, and hardly as much as may be made by variations in the temperature and condition of the atmosphere and of the machine, or in the quality and condition of the stock in use. The uniform tension of the band appears to be the factor of the greatest importance, and the structure of the bobbin of the least, provided the spindle is long enough and heavy or stiff enough to keep the bobbin true and to prevent it from springing under the varying conditions of the atmosphere.

In respect to the best quality of oil to be used on spindles—that is to say, the best oil to be used on light bearings at very high velocity—a few simple rules may now be laid down dogmatically, so far as rules are to be made by experiments on a single machine or from laboratory experiments.

1. A mineral oil that flashes at less than 300° F. does not possess the best qualities for lubrication, and is unsafe in proportion to the lesser degree at which it flashes.

2. A mineral oil that evaporates more than 5 per cent. in ten hours at a heat of 140° F. is hazardous in proportion to the increased percentage of volatile matter, and is also more unfit to be used as a lubricant the more rapidly it evaporates, because the remainder will either become thick and viscous, requiring a high heat in the bearing to make it operate at all, or else, if the oil does not contain such a residuum liable to become thick and heavy, it will leave the bearing dry.

3. All the mineral oils—and also sperm, lard, and neat's-foot oils—appear to reach a nearly uniform coefficient of friction at very greatly different degrees of heat in the bearings. Several kinds of the best mineral oils and sperm and lard oils show a uniform coefficient of friction at the following degrees of heat:

TEMPERATURE AT WHICH THE COEFFICIENT OF FRICTION IS THE SAME.

	Deg. F.
32° machinery (an exceedingly fluid oil)	76
Light spindle	105
Heavy spindle	125
Various samples of sperms	96 to 114
Valvoline spindle	127
White valvoline spindle	122
White loom	111
German spindle	112
A spindle	107
Neat's-foot	170
Lard oil	180

4. Lubrication seems to be effective in adverse ratio to viscosity, *i. e.*, the most fluid oil that will stay in its place is the best to use. Lard oil heated to 130° lubricates as well as sperm at 70° or the best mineral oil at 50°. But of course it is a great waste of machinery to work oil of any kind up to an excessive heat, and there must be the least wear in the use of oil that shows the least coefficient of friction at the lowest degree of heat.

5. The quantity of oil used is a matter of much less importance than the quality. The mill that saves gallons of oil at the cost of tons of coal or dollars of repairs plays a losing game. Mr. Waite's experiments on very heavy bearings at Manchester go far to prove that a considerable quantity of thin fine oil keeps the bearings much cooler and requires less power than a smaller quantity of thick viscous oil. Here let it be observed that a superstition that prevails in favor of using castor oil to cool a hot bearing is without any warrant. No vegetable oil is fit to use as a lubricant; and castor oil is the worst of all, because the most viscous. If used, it will surely set the mill on fire, as it did in the only case of which we have a record.

6. The rule of best lubrication is to use an oil that has the greatest adhesiveness to metal surfaces and the least adherence as to its own particles. Fine mineral oils stand first in this respect, sperm second, neat's-foot third, lard fourth.

7. Cast-iron holds oil better than any other metal or any alloy, and is the best metal to use for light bearings, perhaps for heavy.

8. It has been proved by Mr. Waite's experiments that a highly-polished bearing is more liable to friction than a surface finely lined by filing. The lines left by the file serve as reservoirs for the oil, while the high polish leaves no room for the particles between the metal surfaces.

So far as laboratory experiments may serve as a guide in practice, it therefore appears that fine mineral oils may be made to serve all the purposes of a cotton-mill, and such is the practice in some of the mills that show the very best results in point of economy; next, that the best animal oil to mix with a fine mineral oil, in order to give it more body, is sperm oil; this again accords with the practice of many of the mills in which the greatest economy is attained. Lard and neat's-foot oil are used to give body to mineral oil in some of the best mills; but the results of our work seem *not* to warrant this practice, unless there is some peculiarity in the machinery that makes it more difficult to keep a less viscous or tenacious oil on the bearings. All the mixed oils sold under fancy names we believe must, of necessity, consist of certain proportions of the oils heretofore named, as none of the vegetable or fish oils are fit to be used, and there are no other animal oils that can be had in any quantity. It appears that all varieties of mineral oils are or have been used in print-cloth mills, and are all removed in the process of bleaching, as practiced in print-works. All mineral oils stain more or less, and give more or less difficulty to the bleacher when dropped upon thick cloth or cloth of a close texture. On this point we have been able to establish no positive rule; but as very many kinds are and have been used in mills working on such cloths and are removed we are inclined to the belief that this question is not of as great importance as it has been assumed to be.

These exact results have been obtained under conditions of great velocity and low pressure. Professor Thurston's remarks, quoted on a previous page, apply to the conditions of friction under great pressures and slow motion. We have not, however, yet subjected the lubrication of heavy bearings to so exhaustive a research. Dr. C. B. Dudley, chemist to the Pennsylvania Railroad Company, has been devoting much time recently to the investigation of lubricants for railroads. His results have not been made public. This road and other leading railroads of the country are among the heaviest purchasers of natural lubricating oils that will not thicken at a low temperature. Oils of this quality, as well as reduced oils, are very largely used on railroads, as also some of the petroleum mixtures, such as the "pine-tar compound", the "galena oils", and the "plumbago oils".

A report of a committee of the Railway Master Mechanics' Association of the United States, appointed to examine into and report on the subject of lubricants, recommended a good quality of natural earth oils as the best to use for lubricating machinery and journal boxes. It is less expensive and of a better quality than other oils. When treated so as to reach 28° of gravity, it was found to work with perfect success. It had been reported favorably on from Canada in the north to Kentucky in the south. A test of various oils had been made with the oil-tester on the Lake Shore road; sperm, lard, and tallow were used, and none of them were found to possess qualities which render their use advisable. In their experiments the committee used a machine the size of a regular axle-box, and 50 drops were poured in at a temperature of 60°, and the wheel was allowed to revolve at a rate of speed equaling 35 miles per hour until a temperature of 200° was reached. The length of time, number of revolutions, and amount of friction were all noted. Attention was called to the result obtained from tests with paraffine oil which costs from 25 to 30 cents per gallon, and which has been used on railroads in preference to lard oil. Paraffine oil costing 25 cents, with which six experiments had been made, showed that twenty-four minutes were required to reach the maximum temperature, during which time it gave 11,685 revolutions; castor oil, costing $1 25, which required twenty-eight minutes to reach the temperature allowed, gave 12,946 revolutions; manufactured oils—A, B, and C—costing 35 cents, 90 cents and 25 cents, respectively, required nineteen and one-half minutes, giving from 9,285 to 9,653 revolutions; sperm and tallow required only seventeen minutes to reach 200° temperature, with less than 8,000 revolutions. (*a*)

Paraffine oil that does not boil under 370° C. has been considered the best material for lubricating cylinders at high temperatures. Mineral oil, purified by being shaken with chlorinated soda, from which it is decanted and then shaken repeatedly with milk of lime, and again decanted and then distilled with one-third its volume of solution of caustic soda, is used for the lubrication of watches. (*b*)

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a *Iron Monger*, Supplement, Dec. 13, 1879. *b* Poly. Cbl. 1859, 575.

CHAPTER II.—THE USES OF PETROLEUM AND ITS PRODUCTS FOR ILLUMINATION.

SECTION 1.—INTRODUCTION.

Crude petroleum has been used in Japan and Burmah for purposes of illumination from an immemorial period. In Burmah the Rangoon tar or oil was burned in earthen lamps. In Persia pencils of dried dung were saturated with the oil and burned, the pencil serving as a wick. In Parma and Modena and other towns in the upper valley of the Po the native petroleum, which is quite fluid and of a light color, has been burned for years both in street lamps and in dwellings. In the valley of Oil creek, and in the salt region of the lower Allegheny and Kiskiminetas, the petroleum obtained from springs and from the salt-wells was used in a contrivance resembling a tea-kettle, often with two spouts (see Fig. 19), for lighting saw-mills and derricks. For these purposes the amber oils of the lower Allegheny were considered superior to the dark oil of Oil creek.

Since the manufacture of petroleum by distillation was commenced there have been several separate products used for illuminating purposes. Most of the illuminating oils have been called "kerosene", a name which was originally adopted as a trade-mark by some firm engaged in the manufacture of coal-oils, but which soon afterward became a common designation applied to a certain class of oils used in common lamps. This word, however, has not been uniformly applied to a substance of uniform kind and quality, but has been used to designate a class of substances prepared in a similar manner from a common crude material, but which in certain respects present a very wide variation. The varieties known to the trade are "Water White", "Standard," and "Prime", the distinctions on which the classification is based relating chiefly to color. There are, however, wide differences between the oils as manufactured by different methods that exist independently of color. The oils may contain too large a proportion of the volatile products of the petroleum; they may contain too large a proportion of the heavy products; they may contain too large a proportion of cracked material; and yet in either case they may, by judicious manipulation, be made to appear of good color while otherwise of inferior quality—a fact which in this country has been almost overlooked, but which has lately attracted some attention in Germany, and will doubtless be more carefully regarded in future. "Color" and "test" have hitherto determined the quality of competitive illuminating oils, but a more careful regard for the quality of such oils would lead to the determination of the relative proportion of light and heavy constituents and the condition of the oil with reference to the presence and amount of sulphur compounds. The quality of oils with reference to these two particulars is not determined by either the color or the test, but a disregard of them seriously affects the quality of the oil as an illuminator. (*a*) A few years since legislation was obtained in Minnesota which excluded low-test oils from the markets of that state. The following season those markets were stocked with oils, which, to use the English phrase, were mixtures of "tops and bottoms". They were up to the legal test, and were satisfactory in color, but they would become solid at —20° F., and were so heavily charged with sulphur compounds that they blackened at a temperature of 200° F. They were of very inferior quality, and were very successfully used in securing the repeal of the legislation of the preceding winter.

In addition to the ordinary illuminating oils which vary in the manner stated above, the naphthas of different grades have been used in lamps of different kinds. The best lamp in all respects for burning naphtha is that known as the sponge lamp. This lamp is made in a variety of forms, and is filled with sponge, which, on being saturated with the fluid, yields it to the wick and prevents either the spilling of the contents of the lamp or an explosion when the fluid is consumed and air becomes mingled with the vapor. Naphtha is also used in lamps of peculiar construction which have been found especially useful for lighting streets. These lamps are so constructed that the heat of the flame vaporizes the naphtha as it passes through a tube from a reservoir to the burner, where the vapor is burned as if it were a gas jet. This form of lantern is very extensively used, especially in the environs of cities.

Another oil is "mineral sperm", which is distilled from the crude paraffine oils in the preparation of lubricating oils. This oil has a very high boiling point, and flashes at a temperature above 275° F. It is chiefly used in lighting mills, steamboats, and railroad cars, where more easily inflammable oils would be objectionable.

SECTION 2.—SAFE OILS.

While the color of oils is to some extent an indication of their quality, the flash or fire test is the principal guarantee upon which the general public relies for both quality and safety; yet, as has been already stated, the burning qualities are not represented by them. The discussion of the subject of *safe* oils was commenced at a very early date. Among the earliest papers connected with this subject is one published in the *Report of the*

a See *Vohl's Research*, page 181.

Smithsonian Institution for 1862 by the Hon. Zachariah Allen, of Providence, Rhode Island. In this paper Mr. Allen states that the experiments therein described were undertaken at the instance of the Rhode Island Mutual Fire Insurance Company. The experiments were too simple to be deserving of particular notice here, but the discussion of the subject not only exhibits the acuteness with which the author was accustomed to treat technological questions, but also shows how few facts have been added to the sum of human knowledge concerning the products distilled from petroleum during the twenty years that have elapsed since his paper was written. He says:

To ascertain the comparative qualities of the kerosene oil made in different parts of this country samples were procured and tested by the simple process of pouring some of each kind of oil into a cup by itself, and by placing them all afloat together in a basin of water heated by a spirit lamp, and with a thermometer immersed in the water to indicate the temperature while gradually rising from 60° to 212°. During the progress of the increase of temperature blazing matches were passed over the surface of the oil in each cup successively at short intervals of time, until the increased heat caused sufficient gaseous vapors to arise from each to take fire, which they all finally did, at degrees of temperature varying from 80° to 162°, exhibiting faint flames quivering over the surface of the oil, precisely like those hovering over the surface of spirits of wine or alcohol when similarly kindled. The flames are quite as readily extinguished by a blast of the breath, and not the least symptom of any explosive character became manifest when each one took fire. Until the evaporative point of each sample of oil was produced by the increase of heat applied, and until lambent flames were kindled, burning matches were extinguished when plunged into the coal-oil as effectually as if they had been similarly plunged into water. The average heat at which all the samples emitted sufficient vapor to admit of being kindled was about 125° of Fahrenheit's scale. After ascertaining the temperature requisite to kindle the several samples of coal-oil, it next becomes an interesting subject of investigation to ascertain the heat to which coal-oil is ordinarily elevated while burning in lamps. The results of actual experiments showed that in glass lamps the temperature is increased about 6° and in metallic lamps but 10° or 12° above that of the apartment, which, being 67°, produced a heat in the oil of about 71° to 79°, leaving a considerable range of temperature below the average of 125° above stated. Finding by actual observation that only gaseous vapors arising from the heated oil exhibit the phenomenon of flame whilst ascending and combining chemically with the oxygen of the air, it became manifest that no explosive action could be anticipated to take place from any kind of oil or inflammable spirits unless these gaseous vapors were first evolved by a previous increase of temperature, and then brought into contact with the atmospheric air before applying a match thereto. There being no room left for either the gaseous vapor of the oil or for atmospheric air to combine therewith in the chamber of any lamp entirely filled with oil, every attempt to produce explosive action with a full lamp, at all temperatures up to the boiling point of water, utterly failed when lighted matches were applied to the open orifice of the lamp. The only result produced by increasing the heat of the coal-oil was an increase in the evaporation of the gas, and a higher jet of flame steadily rising, as from the jet of a gas burner. So long as lamps are kept FULL of oil, or even of explosive camphene or "burning fluid", there can be no explosive action whatever. *For this special reason it may be adopted as a safe rule to cause all* lamps containing highly inflammable liquids to be kept as full as practicable by being daily replenished.

* * * * * * * * * * *

As the dangerous inflammability of coal-oil appeared to be ascribable to the naphtha not separated therefrom, the following experiments were made to ascertain the extent of the inflammable properties of pure naphtha. Finding that the liquid naphtha evolved sufficient vapors at the ordinary temperature of the atmosphere to become instantaneously kindled into flashing flames, the cup containing it was immersed in a freezing mixture of snow and salt to reduce the temperature to the zero of Fahrenheit's scale. At this low temperature the naphtha appeared to blaze with equal violence. Then a quantity of snow was mixed with the liquid naphtha and thoroughly stirred, for still further reducing the temperature. Even at this extreme degree of cold the naphtha continued to flame so furiously that it was necessarily thrown from the cup upon the ice covering the ground where the experiment was made, in the open air, whilst the thermometer indicated an atmospheric temperature of 19° below the freezing point. The naphtha still continuing to burn upon the surface of the ice, a covering of snow was thrown over it to extinguish the flame. Through this covering of white snow the bright flames still continued to shoot up, presenting to view the extraordinary spectacle of burning snow. On repeating similar experiments on the comparative combustibility of spirits of wine or alcohol, camphene, and burning fluid, they did not emit sufficient gaseous vapors at the freezing point, or 32°, to become kindled into flame when burning matches were plunged therein, but with a little increase of temperature they all became kindled. The preceding experiments seem to exhibit impressively the extraordinary inflammability of naphtha, arising from the facility with which it emits gaseous vapors; the utmost caution is requisite to prevent not only unexpected explosions, but also the almost unextinguishable violence of its conflagration, for practically the application of water does not subdue the conflagration of naphtha in quantity, and only the exclusion of atmospheric air appears to quench the fury of its flames. * * * Petroleum contains a considerable percentage of naphtha, and consequently partakes in a degree of its dangerous properties. * * * In making experiments with the tin vessel of the capacity of a common lamp a single drop of naphtha was found to yield sufficient vapor to produce as much explosive action as could be produced by the most inflammable coal-oil for sale in the market when similarly experimented with; and after every experiment failed to exhibit the slightest explosive tendency of the best kerosene oil, a single drop mingled therewith rarely failed to yield sufficient vapor to manifest its presence by a slight explosive puff when kindled by a lighted match. (*a*)

These experiments, made in 1862, satisfied Mr. Allen, as a representative of very large manufacturing and insurance interests, that "coal-oil" (*i. e.*, mineral illuminating oil), when properly manufactured by responsible parties, was a safe material for use; and they also established these fundamental facts, which have been made the basis of all the action that has since been taken with reference to this question, viz: That the volatile constituents of petroleum are extremely inflammable liquids; that they mingle with the air with great readiness and form mixtures that explode with great violence; that illuminating oil prepared from coal or petroleum, from which these oils, volatile at a low temperature, are carefully excluded, is a safe illuminating material for ordinary use, while the presence of a very small percentage of the naphtha, added to an oil of unquestioned excellence, produces a dangerous mixture, from the use of which explosions and conflagrations are liable to ensue.

The continued agitation of this subject led to legislation by states, cities, and towns, and also to the manufacture of such oils as would satisfy the requirements of the various laws enacted. The result has been the establishment of different tests, that is, different degrees of temperature at which the oils might produce an explosive

a *Rep. Smithsonian Inst.*, 1862, p. 330. The name is here erroneously given T. Allen.

vapor or burst into flame. The tests were therefore classified as flash tests and fire tests, and both classes include a range of temperatures between 75° and 175° F. Both the classes of tests have had their advocates; and to meet the requirements of law with most profit on the one hand, and to protect the public in the use of these oils on the other, a large number of apparatus and a variety of methods for their use have been devised.

The conclusions reached by Mr. Allen, that an oil properly manufactured is safe, while one containing naphtha is dangerous, suggests the further conclusion that there must be two standards: one of relative and the other of absolute safety. The object of establishing any test is *simply to determine at what temperature a given sample of illuminating oil, in quantity sufficient to fill a lamp of ordinary size, gives off enough vapor, which, when mingled with air, can form an explosive mixture.* It therefore becomes a matter of merely secondary importance at what temperature such an oil will take fire, as all experience has shown that an explosion has been followed by fire in so many instances that the question of the temperature at which an explosive oil will take fire becomes eliminated as worthless; because the temperature at which an oil will take fire is acknowledged by all parties at all acquainted with the facts to be no indication whatever of the temperature at which such an oil will flash. It is immediately asked, if such is the case, why is a fire test ever used? It is sufficient to answer, that it is much less difficult to manufacture oils of a uniform *fire* test than of a uniform *flash* test; hence the efforts of some manufacturers have always been used to secure legislation requiring a *fire* test rather than a *flash* test, and legislators have listened to the presentation of practical difficulties rather than to the objections presented by physicists and philanthropists who have urged the claims of the flash test.

As illustrating the inadequacy of the fire test to protect life and property by detecting dangerous oils, of seven hundred and thirty-six samples of oil examined for the New York city health department more than half did not take fire below 110°, while only twenty-three failed to evolve inflammable vapors below 100°.

Returning to the question of absolute safety, we immediately seek to follow Mr. Allen in his inquiries respecting the temperature attained by the oil while burning in lamps under ordinary conditions. The most elaborate research on record is that undertaken by Dr. C. F. Chandler and published in 1871 in his celebrated report on petroleum as an illuminator. (*a*) The following extract from this report gives the conclusion reached:

THE TEMPERATURE OF OIL IN BURNING LAMPS.

FIRST SERIES.—TEMPERATURE OF THE ROOM, 73° TO 74° F.

No.	Kind of lamp.	Capacity of lamp.	Temperature of the oil.				
			After one hour.	After two hours.	After four hours.	After seven hours.	Average for seven hours.
		Ounces.	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
1	Brass hand-lamp	8	85	82	85	86	84.5
2	Brass hand-lamp	24	79	83	84	82	82.0
3	Glass stand-lamp	8	77	78	79	80	78.5
4	Glass stand-lamp	11	77	81	84	82	81.0
5	Glass stand-lamp	20	78	79	79	80	79.0
6	Glass stand-lamp	7	82	80	85	84	82.75
7	Glass stand-lamp	10	84	36	84	82	84.0
8	Glass hand lamp	9	79	78	85	85	81.75
9	Glass hand-lamp	6	81	82	86	86	83.75
10	Glass hand-lamp	7	80	78	....	....	79.0
11	Brass student-lamp	13	82	80	83	84	82.25
12	Glass stand-lamp	10	81	81	79	78	79.75
13	Brass stand-lamp	11	92	89	88	86	88.75
14	Tin lantern	7	89	86	88	87	87.5
15	Glass bracket-lamp	19	82	82	84	83	82.75
16	Glass stand-lamp	29	82	80	80	84	81.5
17	Brass student-lamp	7	80	....	88	....	84.0
18	Brass stand-lamp	14	84	85	87	87	85.75
19	Brass stand-lamp	12	100	100	92	91	95.75
20	Metal stand-lamp	9	82	82	88	87	84.75
21	Brass stand-lamp	12	91	92	88	85	89.0
22	Bronze stand-lamp	16	83	76	79	85	80.75
23	Glass hand-lamp	....	79	80	82	82	80.75

a Am. C., ii, 409, 446; iii, 20, 41; Mon. Sci., 1872, 676, Dingler, ccv, 587; D. Ind. Z., 1872, 376; W. B., 1872, 873.

With the air of the room at from 73° to 74° F. the temperature of the oil in the burning lamps ranged from 76° to 100° F., the highest temperature of 100° having been reached in a metal lamp at the end of one hour. That this was an exceptionally high temperature is shown by the fact that the highest temperature reached in any other lamp was 92° F. The following is a synopsis of the observations:

	In 23 lamps.	In 11 metal lamps.	In 12 glass lamps.
	Deg. F.	*Deg. F.*	*Deg. F.*
Highest temperature reached	100	100	86
Lowest temperature reached	76	76	76
Average temperature	83	86	81

SECOND SERIES.—TEMPERATURE OF THE ROOM, 82° TO 84° F.

No.	Kind of lamp.	Capacity of lamp.	TEMPERATURE OF THE OIL. After one hour.	After two hours.	After three hours.	After four hours.	Average for four hours.
		Ounces.	*Degrees.*	*Degrees.*	*Degrees.*	*Degrees.*	*Degrees.*
	Air of room		82	83	84	83	83
1	Brass hand-lamp	8	92	95	96	95	94. 50
2	Brass hand-lamp	24	88	94	94	93	92. 25
3	Glass stand-lamp	8	84	88	86	84	85. 50
4	Glass stand-lamp	11	84	86	86	84	85. 00
5	Glass stand-lamp	20	85	86	87	86	86. 00
6	Glass stand-lamp	7	86	87	88	88	87. 25
7	Glass stand-lamp	10	88	87	89	88	88. 00
8	Glass hand-lamp	9	87	90	90	90	89. 25
9	Glass hand-lamp	6	87	91	89	87	88. 50
10	Glass hand-lamp	7	84	86	86	84	85. 00
11	Brass student-lamp	13	86	88	88	88	87. 50
12	Glass stand-lamp	10	85	86	86	85	85. 50
13	Brass stand-lamp	11	104	103	101	101	102. 25
14	Tin lantern	7	95	96	94	96	95. 25
15	Glass bracket-lamp	19	84	85	84	84	84. 25
16	Brass stand-lamp	29	84	85	84	84	84. 25
17	Brass student-lamp	7	87	88	86	84	86. 25
18	Brass student-lamp	14	91	93	92	91	91. 75
19	Brass stand-lamp	12	101	100	98	96	98. 75
20	Metal stand-lamp	9	89	92	94	93	92. 00
21	Brass stand-lamp	12	88	98	94	96	94. 00
22	Bronze stand-lamp	16	82	88	88	89	86. 75
23	Glass hand-lamp	6	84	86	85	84	84. 75
24	Brass student-lamp	10	120	120	120	118	119. 50
25	Brass student-lamp	12½	112	115	115	116	115. 00

With the air of the room at from 82° to 84° F, the temperature of the oil in the burning lamps ranged from 82° to 120° F. The temperature 120° was exceptional, being confined to one lamp.

SYNOPSIS OF THE OBSERVATIONS.

	In 26 lamps.	In 13 metal lamps.	In 12 glass lamps.
	Deg. F.	*Deg. F.*	*Deg. F.*
Highest temperature reached	120	120	91
Lowest temperature reached	82	82	84
Average temperature	91½	96½	86

THIRD SERIES.—TEMPERATURE OF ROOM, 90° TO 92° F.

No.	Kind of lamp.	Capacity of lamp.	TEMPERATURE OF THE OIL. After one hour.	After two hours.	After three hours.	After four hours.	Average for four hours.
		Ounces.	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
	Air of room		92	90	92	90	91
1	Brass hand-lamp	8	90	98	100	98	96.50
2	Brass hand-lamp	24	89	98	102	100	97.25
3	Glass stand-lamp	8	88	90	93	94	91.25
4	Glass stand-lamp	11	88	92	94	94	92.00
5	Glass stand-lamp	20	85	92	94	94	91.25
6	Glass stand-lamp	7	90	94	96	93	93.25
7	Glass stand-lamp	10	90	96	96	96	94.50
8	Glass hand-lamp	9	88	95	98	98	94.75
9	Glass hand-lamp	6	89	95	96	97	94.25
10	Glass hand-lamp	7	88	92	93	94	91.75
11	Brass student-lamp	13	89	100	102	102	98.25
12	Glass stand-lamp	10	88	92	93	93	91.50
13	Brass stand-lamp	11	106	114	116	110	111.50
14	Tin lantern	7	99	106	107	105	104.25
15	Glass bracket-lamp	19	85	92	91	91	89.75
16	Glass stand-lamp	29	86	91	92	92	90.25
17	Brass student-lamp	7	92	99	100	100	97.75
18	Brass student-lamp	14	94	100	100	100	98.50
19	Brass stand-lamp	12	108	112	112	107	109.75
20	Metal stand-lamp	9	91	96	100	99	96.50
21	Brass stand-lamp	12	104	110	108	106	107.00
22	Bronze stand-lamp	16	84	90	95	98	91.75
23	Glass hand-lamp	6	90	92	94	94	92.50
24	Brass student lamp	10	124	129	129	128	127.50
25	Brass student-lamp	12½	120	126	127	127	125.00

With the air of the room at from 90° to 92° F. the temperature of the oil in the burning lamps ranged from 84° to 129° F., the highest temperature being exceptional.

SYNOPSIS OF THE OBSERVATIONS.

	In 25 lamps.	In 13 metal lamps.	In 12 glass lamps.
	Deg. F.	*Deg. F.*	*Deg. F.*
Highest temperature observed	129	129	98
Lowest temperature observed	84	84	85
Average temperature observed	98¾	104½	92¼

By these results it appears that the temperature of the oil in lamps often rises much above 100° F., thus reaching a temperature at which oil, *which does not emit a combustible vapor below* 100° *F.*, would be dangerous. It is apparent that 100° F. is too low a standard for safety; 120° F. would not be too high a standard, and its adoption would not add three cents per gallon to the cost of the oil.

An analysis of these tables shows that when the temperature of the room was 73° to 74° (a comfortable temperature) only one lamp in twenty-three reached a temperature of 100°, and no glass lamp reached a temperature of 90°, and that the average temperature of the twenty-three lamps was only 83° F. The average temperature of the eleven metal lamps was 5° higher than that of the twelve glass lamps. When the temperature of the room was 82° to 84° (quite warm for comfort) only one lamp in twenty-five reached a temperature of 120°, and only two glass lamps reached a temperature of 90°, the highest reaching 91°. The average temperature of the twenty-five lamps was 91½° F. The average temperature of the thirteen metal lamps was 10½° higher than that of the twelve glass lamps. When the temperature of the room was 90° to 92° F. (an uncomfortably high temperature) only two lamps out of twenty-five reached a temperature of 120°, and no glass lamp reached a temperature of 100°, and the average temperature of the twenty-five lamps was only 98¾° F. The average temperature of the thirteen metal lamps was 12⅙° higher than that of the twelve glass lamps. Moreover, in the seventy-three lamps tested, but twelve reached a temperature above 100°, and but six above 110°. A series of experiments were described by H. B. Cornwall, (*a*) in 1876, which were made with the design of showing how much naphtha must be removed from a low-test oil to bring it up to safety. His results are tabulated on page 219.

a Am. Chem., vi, 458.

No.	Sp. gr.	Time.	Flashing point.	Time.	Burning point.
	Deg. B.	*Minutes.*	*Deg. F.*	*Minutes.*	*Deg. F.*
1	49.7	21	86	7	107
2	....	25	96	8	112
3	48.7	....	110	....	124
4	47.1	15	80	7	100
5	45.3	23	121	5	138
6	....	12	98	5	113
7	50.4	23	118	6	135
8	45.8	12	104	5	125
9	....	23	104	5	120
10	....	23	81	....	....

No. 1 was an oil flashing at 86° and burning at 107°. He distilled off 4 per cent., and the residue (No. 2) flashed at 96° and burned at 112°. He then distilled off of another portion of the same oil 10.6 per cent., and the residue (No. 3) flashed at 110° and burned at 124°. On mixing the distillate and the residue in proper proportions the mixture flashed at 89° and burned at 107°, almost at the identical temperatures with the original oil No. 1. An oil worse than No. 1 (No. 4) was then distilled until 12.7 per cent. of distillate was secured with 2.7 per cent. of loss. The residue (No. 5), which was very dark, flashed at 121° and burned at 138°. Five per cent. of distillate was removed from another portion of the same sample, and the residue, after treatment with sulphuric acid and soda, gave No. 6, which flashed at 98° and burned at 113°. The following table embraces some experiments made with mixtures of oils and naphtha, and includes some results obtained by Dr. C. B. White, of New Orleans, Louisiana:

Oils.	Flashing point.	Difference.	Burning point.	Difference.
No. 7. Table I:	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
Alone	118	....	135	....
+ 1 per cent. naphtha of 65° B	112	6.0	129	6.0
+ 3 per cent. naphtha of 65° B	103	5.0	123	4.0
+ 5 per cent. naphtha of 65° B	96	4.4	116	3.8
+ 10 per cent. naphtha of 65° B	83	3.5	102	3.3
+ 1 per cent. naphtha of 71.7° B	107	11.0	133	2.0
+ 5 per cent. naphtha of 71.7° B	Below 70	....	105	6.0
No. 8. Table I:				
Alone	104	....	125	....
+ 2 per cent. naphtha of 65° B	96	4.0	120	2.5
+ 10 per cent. naphtha of 65° B	76	2.8	107	1.08
Dr. White's oil:				
Alone	113	....	....	....
+ 1 per cent. naphtha of 65° B	103	10.0	....	....
+ 2 per cent. naphtha of 65° B	92	10.5	....	....
+ 5 per cent. naphtha of 65° B	83	6.9	....	....
+ 10 per cent. naphtha of 65° B	59	5.4	....	....
+ 20 per cent. naphtha of 65° B	....	....	50	....

The naphtha of specific gravity 65° B. is termed *benzine*, the commercial naphtha having a specific gravity of 70° to 76°. The columns marked "Difference" show the average difference for each per cent. of naphtha added. The naphtha used by Dr. White was lighter than 65° B. A series of experiments was undertaken to show the difference in two consecutive tests for flashing point made upon the same sample of oil, after allowing the oil to cool between the tests. The difference was found to be from 3° to 4°.

Probably the greatest danger from kerosene lamps arises from the risk of overturning and breaking the lamp, although undoubtedly explosions sometimes break lamps. A series of experiments were undertaken with a view to ascertaining the action of oils of different quality under conditions similar to those attending a broken lamp.

Thin glass flasks were provided with corks, through which passed tubes holding wicks. The oil in each flask was then heated in a water bath to 95° F., and the wick lighted, after which the flask was dropped on a brick floor near a steam boiler, the bricks having a temperature of about 93° F. The results are given in the following table. No. 8 was a mixture of No. 1 with 5 per cent. of naphtha of 65° B., and No. 9 of No. 1 with 5 per cent. of naphtha of 71.7° B.; the others were bought from dealers.

No.	Flashing point.	Burning point.	Remarks.
	Deg. F.	*Deg. F.*	
1	118	135	The wick continued to burn quietly without igniting the spilled oil.
2	104	120	Like No. 1.
3	100	112	Do.
4	98	110	Part of the oil was slowly ignited.
5	96	111	All of the oil at once took fire.
6	80	100	Like No. 5.
7	80	98	Do.
8	95	116	Do.
9	Below 70	105	Ignited with a flash.

From the above experiments the following conclusions may be drawn, as applying at least to these oils:

1. The naphthas distilled were comparatively heavy, 59° to 64° B., technically known as benzines.

2. The removal of about 10 per cent. of these naphthas from an average unsafe oil raised the flashing point 2.27° and the burning point 1.60° F. for each per cent. removed; the addition of the same proportion of naphtha of equal specific gravity lowered the flashing point in very nearly the same ratio.

3. The second table shows that a paying amount of a light naphtha above 70° B. could not be added to even a very high grade oil without making it conspicuously bad, while as much as 10 per cent. of a heavier naphtha (benzine) of 65° B. could be added to an oil of a little above 100° F. flashing test, and make it no worse than much of the oil now in the market.

4. When a small amount of naphtha of above 70° B. is added to a good oil the flashing point is lowered much more rapidly than the burning point; if the oil is of very high grade and the naphtha moderately heavy, 65° B., the burning point of the oil is lowered almost as rapidly as the flashing point, while the addition of a naphtha of 65° B. to a moderately good oil, flashing at 104° F., lowers the flashing point 35 to 40 per cent. more rapidly than the burning point.

5. The burning point is not a reliable test of the safety of an oil, since oils, when spilled, will ignite instantly on the approach of a flame when heated a degree or two above their flashing point, even although the burning point is 10° or 20° F. higher. (*a*)

6. The first two tables show that an oil flashing at 86° and burning at 107° F. can be made to flash at 100° by removing 6 or 7 per cent. by distillation. This corresponds nearly with the estimate * * * that average petroleum yielding 75 per cent. of 110° F. "fire test" (burning test) oil would probably yield 69 per cent. of 100° "flash oil"; in other words, 8 per cent. of the 110° "fire test" oil would have to be removed to make a 100° "flash" oil. The average flashing point of eight oils given in Dr. Chandler's report as burning at 110° F. was 89°. (*b*)

These conclusions were stated with equal emphasis by Dr. Chandler in his report, from which I have already quoted. He says:

There are two distinct tests for oil: (1) *the flashing test*, (2) *the burning test*, which are often confounded; and when the law or ordinance specifies the *fire test* there is a doubt as to which of the two tests is intended. *The flashing test* determines *the flashing point* of the oil, or the lowest temperature at which it gives off an inflammable vapor. This is by far the most important test, as it is the inflammable vapor, evolved at atmospheric temperatures, that causes most of the accidents. Moreover, an oil having a high flashing test is sure to have a high burning test, while the reverse is not true. *The burning test* fixes the burning point of the oil, or the lowest temperature at which it takes fire. The burning point of an oil is from 10° to 50° F. higher than the flashing point. The two points are quite independent of each other; the flashing point depends upon the amount of the most volatile constituents present, naphtha, etc., while the burning point depends upon the general character of the whole oil. Two per cent. of naphtha will lower the flashing point of an oil 10° without materially affecting the burning test. The burning test does not determine the real safety of the oil; that is, the absence of naphtha. The standard which has been generally adopted as a safe one fixes the flashing point at 100° F. or higher, and the burning point at 110° or higher. In the English act and some of * * * the laws of the states of the American Union the burning test has been very judiciously omitted, as two distinct tests are often confusing, and, moreover, the burning test or point is not an index of the safety of the oil. More than half of all the samples of oil which have been tested for the health department (of New York city) did not take fire below 110° F.; consequently they were safe according to the burning test; but only twenty-eight of seven hundred and thirty-six samples w really safe, all the rest evolving inflammable vapors below 100° F. *The flashing test* should therefore be the only test mentioned in laws framed to prevent the sale of dangerous oils. (*c*)

In 1873 a committee of the Franklin Institute, of Philadelphia, reported "On the causes of conflagrations and the methods of their prevention". This committee reported that in 1872 the number of fires occurring in Philadelphia was 41¼ per cent. greater than in the previous year. Of these fires, 59 (the largest number originating from any one source) were caused by explosions of coal-oil and fluid lamps. The report further states:

The number of deaths in the United States from the explosions of coal-oil and fluid lamps in 1871 was, by the account kept by an insurance paper (the *Chronicle*), 3,500. If the death rate for 1872 kept pace with the increase of conflagrations, which was about 50 per cent., it would give for the past year (1872) 5,250 deaths, and the maiming of probably 20,000 persons within the jurisdiction of the United States.

Statistics of this character could be extended indefinitely.

Regarding the nature of petroleum products, this committee report:

We find by actual experiments that all the light forms of petroleum (products) constantly generate vapor or gas even at the low temperature of 12° above zero. * * * Any oil or burning fluid that evaporates rapidly or generates gas below 100° is exceedingly unsafe. * * * It is not the oil or fluid that explodes, but the vapor mixed with air. * * * When the mixture goes on so that there is one part of gas and four parts of atmospheric air inside the lamp, or when these proportions exist in a room or any other apartment, they form a fearfully explosive mixture. * * * Volatile oils and combination burning fluids generate vapor inside the lamp, hence the less the oil the greater the vacant space filled with vapor and atmospheric air and the greater the danger, and hence it is apparent that to fill a lamp nearly empty while burning is almost certain to result in a terrific explosion.

This report was accompanied by another, in which the subject was discussed by the then secretary of the institute, William H. Wahl, esq. In this report Dr. Wahl reviews the subject in great detail, and reaches the same conclusions as Dr. Chandler, above quoted. (*d*)

I have already referred to the elaborate research of Dr. J. Biel, of Saint Petersburg, upon the comparative value of American and Russian petroleum, published in Dingler in 1879. (*e*) After reviewing the comparative production of America and Russia, in which he shows that the average yearly yield of a Caucasian well is three times as great as that of an American well, he refers to the "special general meeting of the Petroleum Association" held in London on the 14th of January, 1879, at which Mr. F. W. Lockwood, of New York, was present, and the representations there made, that the illuminating oils produced from the petroleum of the Bradford district were not of the same

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a See in this connection Chandler's report, *Am. Chem.*, iii, 42.
b *Am. Chem.*, vi, 458.
c *Am. Chem.*, iii, 42; *Mon. Sci.*, 1872; Dingler, ccv; W. B., 1872.
d *Jour. Frank. Inst.*, xcv, 267.
e Dingler, ccxxxii, 354.

quality as those exported from the United States in previous years and manufactured from the petroleum of the Parker (Butler and Clarion) district. He then goes on to say that the American oils offered for sale were very inflammable and were deficient in illuminating power; that they burned well for a few hours, and that during the succeeding hours, in order to maintain the illumination, it was necessary to raise the wick at short intervals, the result of which was finally the accumulation of carbon upon the wick. In order to determine the cause of this trouble Dr. Biel selected three American kerosenes, Pratt's astral oil, and several specimens of Russian kerosene, and subjected them to fractional distillation in a glass retort with a thermometer immersed in the oil. That portion distilling below 150° C. (302° F.) he called *essence* (essenzen); that portion coming over between 150° and 270° (518° F.) he called *burning oil* (brennöle); and that above 270° he called *heavy oil* (schwere Oele). The three American kerosenes were *Carbon oil* of the Standard Oil company, of Cleveland, Ohio; *Standard oil* of the Imperial Refining Company, of Oil City, Pennsylvania; and *Standard White*, of unknown manufacture. The three oils gave practically the same results, as follows:

1. *Standard oil*, specific gravity 0.795, flash point 26° C. (78° F.), burning point 30° C. (86° F.); concentrated sulphuric acid in equal parts with the oil is colored blackish brown upon being shaken with it. Tension of vapor according to Salleron, 160^{mm} at 35° C. The distilled products were:

Temperature.	Per cent.	Specific gravity.	Burning point.	
Deg. F.		*Deg. B.*	*Deg. C.*	*Deg. F*
(*a*) 125 to 150	14.4	0.741 = 59	16	(162)
(*b*) 150 to 170	9.8	0.760 = 54	29	(85)
(*c*) 170 to 190	8.3	0.770 = 52	43	(110)
(*d*) 190 to 210	6.0	0.778 = 50	59	(140)
(*e*) 210 to 230	5.6	0.786 = 48	75	(167)
(*f*) 230 to 250	8.6	0.796 = 46	100	(212)
(*g*) 250 to 270	7.6	0.808 = 43	112	(233)
(*h*) 270 to 290	5.8	0.818 = 41	....	....
(*i*) Residue	33.9	0.840 = 37½	....	....

I have given the equivalents of the specific gravity and temperatures in degrees of Baumé and Fahrenheit.

The distillation was accompanied with a copious evolution of sulphurous acid and the distilled products that come over between 190° and 230° C. (374° to 536° F.) are also strongly impregnated with it. This is produced by the decomposition of the sulphur compounds in the kerosene, which are produced by the reaction of the crude distillate with the concentrated sulphuric acid, with which the American kerosene is imperfectly purified. He summarizes his results obtained from the three Standard oils as follows:

14.4 per cent. light inflammable essence.
45.9 per cent. really good burning oil.
39.7 per cent. heavy oil.

2. *Astral oil* or so called, "150° fire test," specific gravity 0.783, flashing point 48° C. (118° F.), burning point 51° C. (124° F.). Shaken with an equal quantity of concentrated sulphuric acid it is colored a golden yellow. Tension of vapor after Salleron, 5^{mm} at 35°. The distilled products were:

Temperature.	Per cent.	Specific gravity.	Burning point.	
Deg. F.		*Deg. B.*	*Deg. C.*	*Deg. F.*
(*a*) Under 150	2.2	....	16	(62)
(*b*) 150 to 170	13.5	0.758 = 55½	29	(85)
(*c*) 170 to 190	21.3	0.768 = 52	43	(110)
(*d*) 190 to 210	18.8	0.777 = 50	57	(133)
(*e*) 210 to 230	15.0	0.786 = 48	75	(167)
(*f*) 230 to 250	10.0	0.795 = 46	99	(210)
(*g*) 250 to 270	9.2	0.806 = 44½	111	(231)
(*h*) 270 to 290	4.8	0.813 = 42	....	....
(*i*) Residue...	5.2	0.834 = 38	....	....

The distillation was entirely destitute of any deleterious odor, and the distillate was normal throughout. He summarizes his results as follows:

2.2 per cent. light inflammable essence.
87.8 per cent. good normal burning oil.
10 per cent. heavy oil.

The results that he obtained from the examination of the Imperial oil (Kaiseröl) of Aug. Korff of Bremen, were nearly identical with those obtained from the astral oil, and his examination of the several samples of Russian oil showed them to be of very fair average quality. (*a*)

a See page 180. A better method of conducting a research of this character is to use alembics instead of retorts; 200 cubic centimeters in an 8-ounce alembic will yield 1 per cent. for every 2 cubic centimeters of distillate. If the distillate is received into a narrow measuring jar graduated to one-half cubic centimeters, the measuring can be made to one-fourth per cent. without difficulty.

The point in this discussion emphasized by this research is to be sought in the character of the 14.4 per cent. of distillate obtained from the American kerosenes below 150°, having a specific gravity of 59° B. and burning at 62° F. This naphtha, more dense than average benzine, when mixed with a residue containing oils more dense than those found in the astral oil, produces an oil flashing at 78° and burning at 86°, an extremely dangerous oil if no consideration were made of the large content of sulphur compounds revealed upon distillation. These kerosenes were *cracked oils*, not mixed "tops and bottoms", as the English oil merchants have styled them, but a cracked product that was run for a given specific gravity (0.795, equal to 46° B.) and color, without much regard to test, and none at all for other considerations. While there are, no doubt, occasional instances in which retail dealers have mixed naphtha with good kerosene for purposes of fraudulent adulteration, I do not believe that oils are thus prepared by either wholesale dealers or manufacturers. It is, however, not to be denied that the temptation is very great for manufacturers to allow too large a proportion of benzine for safety to run into an oil designed for a market where there are no laws prohibiting the sale of such substances. It is more probable that these kerosenes were made, as Dr. Biel received them, by cracking the heavy residue from which the normal burning oil had been previously removed, a part of which had been cracked too much and the remainder too little, than that the heavy and light residues, once separated, had been mixed together.

Dr. Chandler is at some pains to show that a cost of a few cents per gallon will remove the naphtha from dangerous kerosene. When kerosene sells at wholesale for less than seven cents a gallon, a few cents a gallon would be a large per cent. of its value. *What per cent.* of the present price of refined petroleum would be required to place all of the oils sold at a flash test of 100° F., and of good quality as regards color and sulphur compounds, I am not able to say. I have not the least doubt, however, that it is quite impossible to convert Bradford oil, with all its paraffine, into illuminating oil of good quality in *all respects* by one distillation and one treatment unless the whole distillate below 60° B. is run into burning oil. I am quite certain that it is impossible to crack the heavy residue from which the normal burning oil that exists in the petroleum has been run off and produce a good oil by one distillation and one treatment, nor do I believe that such an oil can be made safe, that is, with a *flash* test of 100°. The question of how much additional expense would be involved in rendering oils prepared by one distillation safe involves quite a radical change in the manufacture of these oils; a change that would, of necessity, increase the cost of the oils, and would, therefore, have to become universal, but which would not necessarily render the manufacturer's profit less certain. At the same time it would improve the quality of the oils to the manifest advantage of the consumer in respect to safety, health, and economy. That poor oils are not safe has been fully proved; that they are not healthful is as clearly proved by the vapors of sulphurous acid and the products of imperfect combustion from crusted wicks and imperfect flow of the oil. Dr. Beil says, when commenting upon the three samples of American kerosene examined by him:

It is apparent that a kerosene containing such a quantity of heavy oil, and that in addition to this is contaminated by tarry substances containing sulphur, cannot possibly satisfy the demands of the public. While the heavy oils are not in a condition to ascend to the flame in sufficient quantity, the carbonized tarry substances obstruct the wick and prevent the further ascent of the kerosene to the flame. (*a*)

That they are not economical is further shown by the research of Dr. Beil, in which the illuminating power of these common oils is compared with astral oil with the following result:

ILLUMINATING POWER AT A LEVEL DISTANCE OF—

	6cm.	9cm.	12cm.	14cm.
Standard	7	3.35	1.36	0.80
Astral	7	4.50	3.00	1.36
Imperial	7	6.00	3.00	1.36
Russian	(*o*) 7	6.25	4.45	3.70
Russian	(*a*) 7	5.20	4.00	3.00
Russian	(*b*) 7	5.70	3.20	1.65
Russian	(*c*) 7	....	....	....

At 6cm the oils are equal; at 9cm the astral oil is 34 per cent. better than the kerosene; at 12cm the astral is 120 per cent. better than the kerosene; and at 14cm. the astral is 70 per cent. better than the kerosene. The average value of the astral for that distance above that of the kerosene is 27½ per cent. In addition to the inferior illuminating power of these inferior oils we have the fact that they are consumed more rapidly. I am not aware that any exact determinations have been made respecting the comparative rapidity with which equal quantities of these oils are consumed, but it is undoubtedly a fact that oils containing a large proportion of benzine are consumed much more rapidly than those that consist of what Dr. Biel calls "normal burning oils".

I am informed that the demand for "high-test" oils is not equal to the amount that can be made from the petroleum manufactured. Manufacturers the world over can only make what they can sell, and the ignorant and

a Dingler, ccxxxii, 357.

reckless buy the cheapest oil, regardless of all other considerations, encouraging the production of these cheap oils. It is here that intelligent legislation is required, to protect the ignorant purchaser on the one hand, and the honest manufacturer from unprincipled competition on the other, as well as the innocent public, especially prominent as women and children, from the consequences that follow the use of dangerous oils; not safe even with patent "safety lamps". As Dr. Chandler said ten years ago:

It is not possible to make gasoline, naphtha, or benzine safe by any addition that can be made to it. Nor is any oil safe that can be set on fire at the ordinary temperature of the air. * * * Even when the "safety lamp" has an ally in the form of a "safety can", it still fails to make naphtha safe. It is an axiom that *no lamp is safe with dangerous oil, and every lamp is safe with safe oil.* * * * What we want is *safe oil; with it all lamps will be safe.* (*a*)

This axiom expresses a permanent truth. The legitimate use of naphtha for illuminating purposes will be further discussed in Chapter III.

Referring to page 218, it will be observed that Dr. Chandler concludes, from his experiments upon the temperature of the oil in burning lamps, that "it is apparent that 100° F. is too low a standard for safety; 120° F. would not be too high a standard".

While it cannot be denied that these conclusions are correct as indicating a standard of absolute safety, it will be observed that in these experiments the extreme temperature of oil in glass lamps was 98°, being never over 8° above the temperature of the room. The higher temperatures were in metallic lamps, in which the oil reached 27°, and in one instance 39° above the temperature of the room, the exceptional temperature being reached by student-lamp No. 24. Metallic lamps are widely but not generally used, and student-lamps are so constructed as to reduce the danger of explosion to a minimum. It therefore appears to me that if legislation strictly required all oil to be brought to a *flash test* of 100° F. the general public would be fairly protected in the legitimate use of such oils, so far as mere legislation alone can afford protection. Such legislation should rigidly exclude all forms of naphtha from use in households, in lamps or in stoves of any pattern whatever, as always, under all circumstances and under whatever name or guise, more dangerous than gunpowder. An oil that will not take fire when thrown from a lamp broken upon a brick floor heated to a temperature of 93° is a safe oil for legitimate use. Floors are rarely heated to that temperature. A temperature to which oil is heated in lamps of *ordinary* construction in a room the atmosphere of which stands at 93° is a safe temperature. An oil that did not reach 100° under the last conditions stated, and that did not take fire under the first conditions stated, flashed at 100°. I therefore conclude that an oil that flashes at 100° F. is a safe oil, and while oils that flash at a higher temperature, and *that cannot be prepared by cracking petroleum by one distillation*, are more safe, healthful, and economical, legislation can hardly require anything further than a reasonable limit of public safety.

SECTION 3.—METHODS OF TESTING PETROLEUM.

I have not been able to ascertain where, when, and by whom the question of safe oils was first agitated. Early in 1861, when I was engaged in examining petroleum in the laboratory of Brown University, Professor N. P. Hill (now Senator Hill, of Colorado) was interested in this subject, and it was with his assistance, if not at his suggestion, that the experiments described in Mr. Allen's paper, previously quoted, were undertaken. The method of conducting the test, as described by Mr. Allen, was at that time supposed to be sufficient, and it is my belief that when undertaken by a careful manipulator, accustomed to the use of apparatus, it is; but it soon after became apparent that in untrained hands this method of manipulating was in many respects deficient. As a result, a large variety of apparatus and of methods have been contrived for testing oils, both in America and in Europe. The following descriptions of several testers, that represent the classes to which they belong, are taken from an elaborate article in the *Sanitary Engineer*, abridged from the article of Messrs. Engler and Haas in the *Zeitschrift für Analytische Chemie*, 1881: (*b*)

Petroleum testers may be divided into two classes, according to the principle upon which they are constructed. In the first class, the vapor expansion of the petroleum is measured at a stated temperature, and from this its combustibility ascertained; while in the second class the temperature is determined at which the oil evolves inflammable vapor. To the first class belongs the apparatus of Salleron-Urbain, which is the most accurate of its kind, and the only one to be described. Most testers belong to the second class, and are known as "opened" or "closed", the latter because the surface of the oil is more or less protected from the atmosphere.

In some countries two points are determined in testing petroleum: the first is that of the temperature at which the liquid begins to give off an inflammable vapor, and is known as the "flashing point"; while the second, or "burning point", is the temperature at which the liquid continues to burn when ignited. Most forms of apparatus are constructed with reference to the determination of the flashing point only, and, as an oil becomes dangerous at the temperature of its flashing point, there is no necessity for a further test.

The flashing point of a petroleum will be found to vary according as the vessel is partly or entirely filled with petroleum, is open or closed, the petroleum is quiet or agitated, whether the air above it is in a large or small volume in relation to the quantity of oil, whether quiet or in motion, whether charged more or less with the vapor evolved from the petroleum, and, above all, as to the distance of the torch from the surface of the oil. It is also necessary to consider the kind and size of the taper used, the length of time it is allowed to remain near the surface of the oil in applying a test, the dimensions and material of the oil-holder, and the rapidity and uniformity of heating. As these conditions vary in different forms of apparatus, the flashing point will be found higher or lower; and even in the same apparatus this may happen, according to the care given to the manipulation in the above respects.

Salleron-Urbain's apparatus, in which the expansion of the vapor of petroleum is determined, is used principally in France. It consists of a copper vessel, A, Fig. 48, in which is fixed the conical pillar D, and which is covered by the plate *d d* fitting on its upper edge. C is a movable plate turning on the pillar D, and held in place by the screw *n*. In this movable plate is the cylindrical chamber

a *Am. Chem.*, iii, 24.

b *Oil and Drug News*, 1881.

B, closed at the top by the screw-plug *p*, while its lower opening can be placed in communication with the vessel A by means of the opening *o*, or by turning the plate C it can be sealed by the upper surface of *d*. There are also in the plate *d* a thermometer, a graduated tube *m*, 35^{cm} long, and the regulating apparatus *l*, which consists of the screw *r*, so arranged that by raising or lowering it the water level in *m* is made to stand at zero.

Fifty cubic centimeters of water are put in the vessel A, the plate *d d* and the sliding piece C are screwed down tight by *n* and so placed that the chamber B does not communicate with A. B is nearly filled with the petroleum to be tested, the screw *p* replaced, and the whole placed in warm water until the temperature has become constant. The water level in *m* is placed at zero, and then the plate C is moved until the opening of B comes over the opening *o*. The petroleum spreads upon the surface of the water in A, and by the expansion of its vapor causes the water to rise in the tube *m*, when its height is read. By a comparison of this number with the known expansion of the vapor of normal petroleum at a corresponding temperature the combustibility of the oil is determined. For this purpose a table accompanies the apparatus which gives the obtained vapor expansion of normal petroleum in *m* for different temperatures sought.

This method depends upon the supposition that the numbers which express the expansion of the petroleum vapor run parallel with the temperature of the inflammability of all kinds of petroleum. It has been found, however, that this supposition is not correct for all cases, inasmuch as the presence of a small quantity of a very volatile hydrocarbon occasions, by increased temperature, a correspondingly greater pressure in the tube *m*, without its being sufficient to form an explosive mixture with air. Experiments were made on samples of petroleum prepared by mixing in varying proportions oils of low and high boiling points, and from these experiments it is concluded that a small percentage of a volatile constituent, notwithstanding the equal inflammability of the oils, occasions an uncorresponding increase of the vapor expansion. From this it is evident that while this form of apparatus would give accurate results in some cases, it could not be depended upon in others. They have concluded that oils are to be considered safe that exhibit a tension of 64^{mm} of water at 35° C.

The second class of petroleum testers are designed for the determination of the "flashing point", or temperature at which the oil gives off an inflammable vapor. The majority of testers, and those found most reliable, belong to this class.

The older forms consisted of an open vessel partly or entirely filled with petroleum, and heated until inflammable vapors were formed upon the surface of the oil. These have been improved by placing the petroleum in a closed vessel, by which the conditions of the actual use of the oil in lamps is more nearly attained.

Of the open testers the Tagliabue, the Danish, and the Saybolt are the most important.

Tagliabue's open tester, Fig. 49, was employed in the official testing of petroleum in this country until 1879, and even now it is used in Germany with immaterial changes and under various names. It consists of a brass water-bath A upon the stand B, heated by the lamp C. D is the glass petroleum-holder, in which is immersed the thermometer E. The bath is nearly filled with cold water, allowing for the displacement by the oil-holder. D is filled to the top with the petroleum to be tested, care being taken not to wet the rim, the thermometer placed in position, and the lamp lighted. The heating should be gradual, and, if necessary, the lamp be occasionally removed. When the oil has reached the temperature at which you wish to begin the testing, a small flame, either from a wooden splinter or a gas jet, is slowly and carefully passed over the petroleum, about 12^{mm} (nearly half an inch) from its surface. If no flashing takes place, this is repeated as the temperature rises until the flashing point is reached. During testing the apparatus should be protected from draughts of air.

The Danish tester differs from Tagliabue's only in having the petroleum vessel of copper instead of glass, and in being but partly filled with oil.

The Saybolt tester was, in 1879, adopted by the produce exchange of this city in the testing of refined petroleum. It resembles the open tester of Tagliabue, differing only in the use of the electric spark for the burning splinter. It is represented in Fig. 50, and consists of the copper water-bath F, containing the petroleum-holder, which, with the other parts of the apparatus, are placed on the tray C, and for transportation can be inclosed in the box A. D D are the covers of two battery elements. H is a current breaker, E an induction coil, and *e e* the conducting wires for producing the spark over the surface of the petroleum. *a* is the thermometer of the oil-holder, and a^1 that of the water-bath.

In using this apparatus the bath is filled with water and heated to 100° F., after which the lamp is removed. The oil-cup, filled to within 3^{mm} (⅛ of an inch) of the top with the petroleum to be tested, is placed in the bath and the thermometer immersed in the oil until the bulb is just covered. As the temperature of the oil is raised to 90° F., produce a spark by the key H, and after replacing the lamp repeat this operation every two or three degrees until the flashing point is reached.

The apparatus of Abel, represented in Fig. 51, is employed in England in determining the flashing point of petroleum. It consists of the copper cylindrical vessel D, in which is the water-bath, composed of the two copper cylinders B B and C C, the latter resting on the ring *g g* and covered by the plate K K; *f* is a funnel for filling the water-bath, and *e* is the thermometer placed in it.

The brass petroleum-holder A rests in an ebony ring fixed in the plate K, and hangs in the air-filled space H of the water-bath. It is provided with a closely-fitting cover, through which passes the thermometer *b*, and upon which is placed the small oil-lamp *c*, movable upon the horizontal axis. There are also in the cover three rectangular openings, which can be opened and closed by the sliding bar *d*, by the movement of which the lamp is so tipped that its nose comes opposite to the opening in the middle of the cover.

The oil-lamp can be replaced by a gas flame, which is much cleaner, and was used in the experiments with this apparatus.

The water-bath is filled and heated to 54° C. A is then filled to the mark *a* with the petroleum to be tested, covered and placed in the space H. The wick of the lamp is arranged to give a flame 4^{mm} long. When the temperature, by the thermometer *b*, has risen to 19° C., the tests are commenced, and repeated every degree or two until the flashing point is reached. In testing very volatile oils the air-space H should be filled with cold water, and in the testing of oils of high flashing point this water should be heated to about 50° C.

In closed petroleum testers the oil is heated in a closed vessel until inflammable vapors rise from the oil into the empty part of the holder. There are a large number of these testers; among them those of Tagliabue, Abel, Sintenis, Parrish, Bernstein, and others.

The Tagliabue closed tester is represented in Fig. 52, and consists of the water-bath A and the petroleum holder B, both of brass. The latter is provided with a cover, upon which are fixed the hood C, containing a rectangular opening *a*, the sliding bar *b*, for opening or closing the aperture beneath it, and lastly the thermometer D.

There is also an improved form of this tester differing from the first in the arrangement of the cover, which is shown in Fig. 53. In this *a a* is the cover, with openings under the movable bar *b b*, by which they are closed; *f f* are small openings in *b b*, closed by the piece *e*, held up by the spring beneath it. By pressing upon the knob c the apertures *f f* are opened, and the bar *b b* can be moved by the handle *g*.

In using the apparatus, the water-bath and oil-holder are filled and the bath gradually heated by the spirit-lamp. When the thermometer reaches a definite temperature a small flame is introduced through the opening *a* into the hood C; and at the same time the bar *b*, in Fig. 52, is moved to one side, or, as represented in Fig. 53, the knob c is pressed down, in order to establish communication with the air by openings *b* or *f f*. This testing is repeated as the temperature rises until the flashing point is reached.

The next petroleum tester to be noticed is the Parrish naphthometer. It is used chiefly in Holland, and differs from those already described in that the inflammable mixture is carried out of the petroleum holder to a stationary flame. It is represented in Fig. 54, in which A is the tin oil-holder, C the water-bath, D the support, and E the lamp. The holder is provided with a projecting cover, in which is the cylinder *d*, having in its axis a small tube, with a wick running into the petroleum. *e* is a screen, against whose base rests the glass plate *f* for protecting the thermometer from the heat of the wick flame, and lastly B is a chamber communicating with the air, in which are the openings *a* and *b b*, the former for the circulation of the air through the petroleum-holder, and the latter to allow the passage of the oil from B into A. The thermometer c is placed in the vessel B.

The bath is filled with cold water, and the oil-holder with the petroleum to be tested, to a point 1^{cm} below the rim. The heating must be slow and effected by the spirit-lamp, whose flame is only 1 to 1.5^{cm} high. The small wick in *d* is then lighted, care being taken that the flame is not more than 6 to 7^{mm} high. The heat of this flame produces a current of air, which, coming in through the opening *a*, spreads over the surface of the oil and passes out by the tube *d*, taking with it the vapors evolved from the heated oil. When the oil vapors are sufficient in amount to produce an inflammable mixture, they are ignited by the flame in *d*, the flame being extinguished by the sudden motion of the air. At this moment the flashing temperature is read.

The apparatus devised by Engler is of the closed form, to which is added an electric mechanism similar to that of the Saybolt tester. It is shown in Figs. 55 and 56, and consists of the copper water-bath A, heated by the spirit-lamp B. C C is a glass vessel for water, which has a filling mark etched upon it; *m m* is the cover, and *n* the thermometer. In the cover is the glass petroleum vessel D, also provided with a filling mark, and to which is fitted the brass cover *o o*. The latter is shown in Fig. 56, in which will be noticed the following details: *s s* are two movable covers, *t t* the conducting wires, insulated by the ebony rings *u u*, *r* the thermometer, and *q* the handle of the stirrer *p*, seen in Fig. 55. The conducting wires terminate in platinum points in the vessel D, from ½ to $\frac{3}{4}^{cm}$ above the surface of the oil, and at a distance of 1^{mm} from each other. For the production of the electric spark a chromate cell is used, with an induction apparatus which gives a spark at least 2 to 3^{mm} long. The electric apparatus of the Saybolt tester answers very well. In using this tester the baths A and C are filled with water, and D is filled to the mark with the oil to be tested. When the petroleum vessel is in place the water in C should stand 1^{cm} below the rim. The wires are connected with the induction coil and the lamp lighted. As the temperature rises to the testing point the spark is passed every degree, care being taken that the spark continues from one-half to one second. After each passage of the spark the oil is gently agitated by the stirrer. The operation is continued in this way until an explosion occurs, by which the covers *s s* are thrown open.

The difficulties that have been found to attend the construction of an apparatus that in every one's hands should give uniform results have been considerable. In the experiments of Engler and Haas three kinds of petroleum were employed in testing the various forms of apparatus, and at the start the flashing point of each oil was carefully determined in a closed apparatus.

Sample A flashed at	22° C. = 71.6° F.
Sample B flashed at	29° C. = 84.2° F.
Sample C flashed at	40° C. = 104° F.

The following table shows the temperatures at which they flashed in the testers named:

Tester.	A.	B.	C.
	Deg. C.	*Deg. C.*	*Deg. C.*
Tagliabue, open	22.7 to 38.8	32.2 to 48.8	45.5 to 57.2
Danish	19.5 to 21.0	29.0 to 31.0	42.0 to 45.0
Saybolt	30.6 to 31.7	36.1 to 36.6	48.8 to 52.7
Tagliabue, closed	....	24.0 to 39.4	....
Abel	16.0 to 17.1	22.2 to 23.8	32.4 to 33.8
Parrish	20.7 to 23.0	25.5 to 30.7	36.5 to 39.0
Engler	21.0 to 22.5	28.0 to 30.5	39.3 to 39.7

The average of the several tests with the different instruments on the same samples are given in the following table:

Testers.	No. of tests.	Average.	Variation.
		Deg. C.	*Deg. C.*
Tagliabue, open	A 6	30.95	16.1
	B 9	42.00	16.6
	C 6	52.20	13.3
Danish, open	A 5	20.80	3.5
	B 4	30.00	2.0
	C 4	43.25	3.0
Saybolt, open	A 4	31.30	1.1
	B 2	36.35	0.5
	C 2	50.75	3.9
Tagliabue, closed	B 18	31.68	15.4
Abel, closed	A 4	16.60	1.1
	B 7	22.64	1.6
	C 3	32.96	1.8
Parrish, closed	A 5	21.40	2.7
	B 15	27.30	5.2
	C 9	37.70	2.5
Engler, closed	A 4	21.95	1.5
	B 10	29.40	2.5
	C 2	39.50	0.4

The great variation in the results given by Tagliabue's open tester were due to a variation in the height at which the flame was passed above the oil, and the temperatures indicate different heights, from 1mm (0.04 of an inch) to 12mm (0.47 of an inch).

The uniformity of the results furnished by Engler's apparatus upon sample B, where eleven out of nineteen tests were within a variation of 1° C. and sixteen out of nineteen tests were within 1.5° C., is quite remarkable, and shows that this apparatus is greatly superior to most of the others in this respect.

By the use of the double water-bath and the stirrer the heating is slow and regular, and, so far as possible, is independent of the size of the heating flame. Moreover, by the use of the electric spark, the size, intensity, and distance of the igniting agent is always the same, and in consequence of its short duration no vapor formation is noticeable. Finally, the form of this tester is such that the conditions maintained in its use closely resemble those which are found to exist in petroleum lamps. Herr Victor Meyer is of the opinion that, in the use of the ordinary petroleum testers, the true or absolute flashing temperature of the oil is not found, but a temperature higher or lower than the one sought, depending upon the capacity of the various forms of apparatus and the quantity of petroleum employed. The progress recommended consists in putting about 40 cubic centimeters of the petroleum in a glass cylinder of about 200 cubic centimeters capacity, and placing this in a vessel of warm water until the petroleum has reached the testing temperature. The cylinder is then removed, and the oil well shaken; after which a test is made by means of a gas flame, to see if the oil can be lighted. It is clear that in this process we obtain a constant maximum of the saturation of the oil with petroleum vapor corresponding to the prevailing temperature.

In this country the open tester of Tagliabue was at first in general use, and later his closed tester. The New York produce exchange has, within a few years, adopted Saybolt's. In England and Canada Abel's has been adopted; in France both open and closed testers, particularly the tester of M. Granier, has been used, as well as the apparatus of Salleron Urbain; in Holland the naphthometer of Parrish; and in Russia, and also in Germany, some of the open testers have been employed.

It is manifest that the great difference in the results given by these instruments, included between 22.64° C. and 42° C., when made by the same person on the same oil, indicates that a decision should first be had in respect to the instrument used before the temperature should be determined at which an oil is considered safe.

I think that more attention has been paid to this subject in England than in this country, or it would perhaps be more proper to say that in England the subject has received consideration in a manner that has produced more satisfactory results. There legislation has been national; here it has been local. There the subject was placed in the hands of eminent scientific men, and legislation was had in 1868 based upon the results of their labors. This legislation described the instrument and the manner of testing, and fixed the test at a flash at 100° F. After a trial of two years, during which numerous criticisms were found to lie against the provisions of the law, Professor F. Crace Calvert subjected the working of the apparatus under the act to very careful examination, and concluded (*a*) that—

These results show the influence of time in raising six samples of petroleum spirits from 52° F. to their flashing points. Thus, when fifteen or twenty minutes are employed, the whole of the six samples tested could not be called "petroleum", according to the act of 1868; the owner would be liable to a penalty and the loss of the fluids, whilst if the time employed to heat the liquid is half an hour they would all be considered petroleums, their flashing points being above 100° F.

His results are given below:

FLASHING POINT.

No. of sample.	Time, 15 minutes.	Time, 20 minutes.	Time, 30 minutes.
	Deg. F.	*Deg. F.*	*Deg. F.*
1	96	98	102
2	92	99	101
3	90	98	101
4	94	96	104
5	96	98	110
6	95	99	108

He further remarks on this point:

I am therefore of opinion that as the act has been made to protect the public from fire and explosions resulting from the employment of too highly inflammable hydrocarbons, the chemist or person called upon to test liquids of this class should raise the temperature of the fluids as quickly as possible; otherwise they favor the vendor and manufacturer, to the detriment of the consumer.

The next series of experiments was made with a view of corroborating a statement made by Mr. Norman Tate, viz, if two thermometers are placed in the petroleum spirit, one, as indicated in the act, 1½ inches below the surface of the liquid, the other being only one-half inch below the surface, a difference of several degrees will be noticed between them at the time the vapors will flash. * * * The following results confirm Mr. Tate's observations:

	Flashed at—	Flashed at—
No. 4	94° F. 1½ inches.	99° F. ½ inch.
No. 5	94° F. 1½ inches.	98° F. ½ inch.
No. 6	95° F. 1½ inches.	99° F. ½ inch.

This curious and unusual fact is due, in my opinion, to this: that petroleum not being a homogeneous liquid, but a mixture of several hydrocarbons, the highest products being first expelled, the heat rises toward the surface, and in this way the difference in temperature referred to is produced.

a Jour. Soc. Arts, xviii, 290.

After suggesting a remedy for these difficulties Professor Calvert closes his article as follows:

From the above experiments the following conclusions may be drawn, viz, that the petroleum act of 1868 does not give sufficient and precise instruction for testing petroleum spirit; therefore it is to be hoped that government will take the matter in hand and do away with the objections to the present act, substituting more clearly defined rules and instructions, so as to enable the operator to determine the flashing point of petroleum spirit with greater accuracy.

This subject was again very fully discussed by Mr. Boverton Redwood, secretary of the Petroleum Association of London, in 1875, (*a*) in a letter to the *English Mechanic and World of Science*, in which he gives a very excellent popular description of the manner of testing petroleum under the petroleum act then in force.

In July, 1875, the Secretary of State for the Home Department requested Professor F. A. Abel, chemist to the War Department, to report on certain points relating to the method of testing petroleum as prescribed in Schedule 1 of the petroleum act, 1871. In accordance with this request he submitted his report, dated August 12, 1876. Before commencing his investigations he consulted, among others, the late Dr. H. Letheby, Dr. J. Attfield, Dr. B. H. Paul, and Mr. Boverton Redwood, representing with himself an unsurpassed array of talent and experience with reference to this subject. I quote here this report entire as representing the most complete and intelligent discussion of this subject extant, based upon a most exhaustive scientific research, and confirmed by comparative tests in such a manner as to make it a model for a basis of intelligent legislation.

REPORT TO THE SECRETARY OF STATE FOR THE HOME DEPARTMENT ON THE SUBJECT OF THE TESTING OF PETROLEUM.

In compliance with the request of the Secretary of State for the Home Department, as conveyed by Home Office letter, dated July 7, 1875, 1,386, 61 a, Appendix V, that I should report on certain points relating to the method of testing petroleum as prescribed in Schedule I of the Petroleum Act, 1871, I now submit the following statements and the conclusions at which I have arrived respecting the points specially submitted for my consideration in the letter above referred to:

I.

With reference to the merits of the method of testing petroleum at present prescribed.

In the evidence taken before a Select Committee of the House of Lords in 1872, the relative merits of and the relation existing between the open flashing test which is prescribed in the existing petroleum act and a modified flashing test, called the "close test", which it was proposed to substitute for the former, were discussed by a number of witnesses.

The opinions expressed and the experimental data upon which the opinions were based were in several respects very conflicting.

The statements of a great majority of the witnesses were, however, in accord with regard to the unsatisfactory or fallacious nature of the open flashing test as laid down in the existing Petroleum Act.

The important objection raised against the open test is, that it is liable to "manipulation", *i. e.*, that in consequence of certain very readily variable elements in the details of the test (added to the interfering action of even slight currents of air) the flashing point of one and the same sample of oil may be made to differ many degrees in the hands of different operators (or of one and the same operator at different times).

The majority of witnesses also were agreed in the opinion that the proposed "close test" was decidedly more reliable in itself and much less open to manipulation than the open test. The differences of opinion with regard to it were almost entirely confined to the necessity for some modifications in its details and to the relation which the results furnished by it bear to those obtained with the open test, or, in other words, the particular temperature which in dealing with the "close test" should be held to correspond to the standard or "flashing point" (100° Fahrenheit), fixed in the existing act as applied to the open test prescribed. On the latter point a very considerable difference of opinion existed between two sections of witnesses; on the one hand, the results of a number of experiments made by several witnesses with the close and open tests were adduced in support of the conclusion that a flashing point of 85° given by the close test should be accepted as equivalent to 100° by the open test, while on the other hand similarly strong testimony and extensive experiment supported the view that the standard flashing point for the close test (equivalent to 100°) should not be higher than 75°.

These differences of opinion were obviously ascribable, in great measure, to the unreliableness of the present (open) test, and also to certain variable points in the details of the "close test", which tend to allow of the results furnished by this test being also regulated (though not nearly to the same extent as with the open test) by small variations in the *modus operandi* adopted by different experimenters.

The opinion which I myself had formed from the results of practical experience in the employment of the flashing test, as prescribed in the schedule of the existing act, was quite in accordance with the general opinion of the witnesses examined before the House of Lords committee as to its untrustworthiness. Moreover, after careful consideration of the subject, it appeared to me, to say the least, very doubtful whether certain sources of errror could by any modification of the arrangements and directions laid down in the schedule of the existing act be eliminated to such an extent as greatly to reduce the liability of the test to furnish results not fairly comparative with each other, and its susceptibility to "manipulation" or regulation in the hands of different experimenters.

Before proceeding to examine into the merits and defects of the proposed "close test", and to endeavor to supply the want of a generally satisfactory test (either by a modification of one of the known tests or by elaboration of some new method of experimenting), I considered it desirable to ascertain whether the additional experience of the last three years had led some of the principal witnesses and others who had given attention to this subject to modify the views expressed at that time or to form any decided opinion as to the direction in which a satisfactory solution of the difficulties connected with the present system of testing might be sought.

I therefore addressed circular letters (Appendix I) to the following:

Mr. T. W. Keates, consulting chemist of the Metropolitan Board of Works.
The late Dr. H. Letheby.
Dr. J. Attfield.
Mr. Dugald Campbell.
Dr. B. H. Paul.

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a English Mechanic and World of Science, xxii, 355.

The secretary of the Petroleum Association.

The secretary of the Scottish Mineral Oil Association.

The local authorities under the act at Liverpool and Bristol.

As the replies to my communications, which I received from several of the above, embody the present views entertained with regard to the test prescribed by the existing act and the points which require consideration in the attempt to provide a satisfactory test, I consider it advisable to give the following précis of such replies.

Mr. Keates says: "The present test fails by the nature of the test itself; it is not possible to preclude sources of inaccuracy in its use." He proceeds to point out that a considerable difference in results may arise with different operators, working with the utmost honesty of purpose according to the interpretation put upon the directions of the schedule of the act (as to rate of heating, application of test flame, etc.), but that "such differences are trifling as compared with those which can be obtained when there is a desire to get away from the truth", such differences being always in one direction, viz, in postponing the time at which the ignition of the vapor takes place. He proceeds: "I think it is conceded that the present open test is fallacious, and that it can be made to give different results by different operators, according to the wish or intention of such operator." Mr. Keates then dwells upon the merits of the close test, the adaptation of which he had advocated in 1872, and says: "With a proper regulation as to the application of the light to the vapor chamber very close agreement can be obtained, and I do not think the test is capable of manipulation." He expresses his belief that the close test is not objected to *per se*, but that the point upon which great difference of opinion exists is the difference to be made in the parliamentary standard of temperature if the close test be substituted for the open test, which was the main point of dispute in 1872.

The late Dr. Letheby stated that the difficulties in the way of obtaining trustworthy results with the present (open) test, applied "according to the spirit" of the instructions laid down, are manifold, arising in some cases from the faulty construction of the apparatus, in others from the erroneous method of working, and in others from the indefinite nature of the instructions." After discussing the difficulties included under these three heads, and pointing out that the instructions originally laid down by him, Dr. Attfield and myself, in 1869, embody most of the improvements and alterations required to make the present test more certain and satisfactory. Dr. Letheby proceeds to say that, "considering an open test must, under any circumstances, be uncertain, because of the diffusion of the petroleum vapor into the atmosphere," he thinks "a closed test would be more satisfactory", and that the only difficulty is the point at which the legal standard of temperature should be fixed. As regards this standard, he differs considerably from Mr. Keates, and in support of his view refers to experiments made by himself and Mr. Dugald Campbell (and confirmed by Mr. Norman Tate and Dr. Robinson), which were quoted in the evidence given before the House of Lords committee.

Dr. Attfield simply expresses the opinion that nothing short of an original investigation will lead to a satisfactory solution of the difficulties connected with the test.

Mr. Dugald Campbell discusses in detail the defects in the instructions laid down for the use of the present test, and which he regards as giving rise to the discrepancies occurring in the application of the test. He considers, from the results of his own experience, that if certain points, which he details in connection with the application of the open test, be adhered to, "independent experimenters would not *materially* differ in their results." Mr. Campbell's experience with the close test does not lead him to form so favorable an opinion of it as is entertained by Mr. Keates, but he considers that "with strictly defined rules for applying the test", which are carefully carried out, the results furnished by it "are likely, on the whole, to be rather more uniform than with the open test". He considers that some modifications in the construction of and mode of working with the close test as described in 1872 are necessary, and is in accordance with Dr. Letheby regarding the standard temperature which should be adopted with the close test (as equivalent to 100° with the open test).

Mr. B. Redwood, the secretary of the committee of the Petroleum Association, in expressing the views of that committee, considers that the difficulties which have arisen in the application of the present test are due to a "want of detail in the parliamentary directions for applying the test, and to the delicacy of the test or liability to uncertainty in the hands of unskillful operators". The committee consider that if directions with regard to the rate and uniformity of heating the apparatus, and of the size and character of the flame used for testing, had been strictly laid down, "the results of different operators would have *approximated* more closely, and that with *skilled persons* the results would have been *sufficiently uniform* to have given satisfaction. Inasmuch, however, as the inspectors under the act are men whose training has not qualified them to perform operations involving close details of manipulation, the committee are driven to the conclusion that the present test, even with such amended instructions for its use as have been instanced, would be found too delicate."

In discussing the directions which should be taken for providing a better test, stress is laid upon the desirability of adopting a system of testing which would preserve the existing standard of 100°, as the public, having been "educated in the belief that anything over 100° Fahrenheit means safety and below 100° danger, might associate any lowering of the standard with increased risk to themselves even if such lower standard were explained to be equivalent to an equally stringent and more certain test".

Mr. Redwood proceeds to consider the directions in which, failing the possibility of an efficient modification of the existing open test, another test might possibly be sought, and considers, with reference to these, that—

(*a*) The American or fire test (which consists in determining the temperature at which the surface of the heated petroleum takes fire permanently) is as open to discrepancies as the present legal test.

(*b*) The automatic tests which have been proposed (depending for their action upon the vapor traveling to a fixed distance and there becoming ignited) are too complicated for general use, and have not given encouraging results.

(*c*) The close test involves a lowering of the standard flashing point, and is therefore objectionable.

The committee of the Petroleum Association state their opinion through Mr. Redwood, that if it should not be possible to modify the open test so as, while preserving the present standard, to reduce its delicacy sufficiently to allow of its satisfactory employment "by an inspector of average intelligence", "the closed test would appear to be the best substitute, but would, of course, necessitate a reduction of the standard," in consequence of which "the prejudice created in the mind of the public would have to be combated". In the event of my deciding in favor of the close test, the committee refer me to Mr. Redwood's evidence before the House of Lords committee in 1872, in which he agrees with Dr. Letheby and Mr. Dugald Campbell regarding the standard temperature to be adopted in connection with this test as equivalent to the present legal standard of 100°.

In conclusion, the committee request that Mr. Redwood may be allowed to exhibit to me the precise method adopted by the Petroleum Association in testing the petroleum imported into London.

The Liverpool Petroleum Association expresses their concurrence in the statements submitted by Mr. B. Redwood, as secretary of the Petroleum Association.

The Local Government Board of Bristol adopt the views expressed by the representative of the petroleum trade in Bristol, Mr. F. F. Fox, to whom they referred my letter of inquiry, and who suggests that, "following the example" of the Petroleum Association of London, the object aimed at should be "such an improvement of the existing test as shall take away (if possible) its present imperfections, or, failing this, the adoption of the closed vessel, provided an equivalent standard be fixed".

The secretary of the Scottish Mineral Oil Association is desired to state that the directions, as detailed in the existing act, are much too indefinite, and that the test is subject to extraneous influences which produce discrepancies in the results of even conscientious and careful chemists. The association considers it desirable to have a testing apparatus, the range of variations of which cannot, under any circumstances, be more than two or three degrees, and that the close test is the most satisfactory and reliable one that can be adopted. Such an apparatus as was described in the proposed bill of 1872 is believed to meet the views of every one, and is certainly the most accurate test which has had the attention of the association. It should, however, be distinctly stated, with reference to this close-test apparatus, "that the movable cover for the circular opening should be removed only when the light is being applied, and immediately replaced if no flash be produced."

From the foregoing précis will be seen—

(1.) That the authorities quoted are agreed in regard to the unsatisfactory nature of the existing method of testing petroleum, as prescribed in Schedule 1 of the Petroleum Act, 1871.

(2.) That they are also in accord as to the great difficulty, if not impossibility, of modifying the existing "open test" so as to render it capable of uniformly insuring reliable and satisfactory results in the hands of different operators.

(3.) That the close-vessel test, which it was proposed to prescribe in the contemplated act of 1872, is more satisfactory than the present open test; but—

(4.) That differences of opinion exist with regard to the relation which the results furnished by this "close test" bear to the present open test; and—

(5.) That there are evidently some points of uncertainty connected with the proposed "close test" which render it also liable to furnish different results in the hands of different operators.

The results of my own experience with the present legal test, and a careful examination into the various points raised in the foregoing with regard to it, and to the "close test" which it has been proposed to adopt as a more trustworthy test, led me to the following conclusions:

(*a*) That the method of testing petroleum prescribed in Schedule 1 of the Petroleum Act, 1871 (34 and 35 Vict., cap. 105), is not of such a nature as "uniformly to insure reliable and satisfactory results".

(*b*) That the "close test", which it was proposed in 1872 to substitute for the existing "open test", and which was discussed in the evidence taken before a select committee of the House of Lords in session in 1872, though more satisfactory, is open to objection on several grounds, and is liable to furnish different results in the hands of different operators.

II.

With reference to the alterations in method of testing petroleum which should be adopted to secure reliable and satisfactory results.

In addressing myself to the preparation of a reply to the second point submitted for my consideration in the letter addressed to me by the Under Secretary of State for the Home Department, I proceeded, in the first instance, to consider whether it was possible to devise some method of testing differing entirely from either of those which have been referred to, and which would be likely to prove satisfactory, as being sufficiently simple, certain, and free from liability to involuntary or intentional modification in the hands of different operators. My examination into the merits of some automatic tests which have been proposed, and a trial of one or two other plans which suggested themselves, for comparing the volatility of samples of petroleum by operations placed more or less beyond power of control by the manipulator were not attended by promising results.

The possibility of modifying the present legal test (the open test), so as to reduce within satisfactory limits the existing sources of discrepancy, next received a most careful consideration by me; but I came to the conclusion that, supposing directions could be laid down or arrangements contrived for securing uniformity in the rate of heating the oil to be tested, in the temperature at which the operation of testing is commenced, and in the nature and mode of applying the test flame, one great source of uncertainty inherent in the test—namely, the free exposure to the air of the surface of the oil from which the vapor is evolved—would still remain.

At the suggestion of Mr. Boverton Redwood I witnessed some testing operations conducted with the open test, but with the employment, in place of the ordinary thermometer, of an ingenious combination of a thermometer and clockwork, devised by Mr. R. P. Wilson (*a*) (and called by him a chrono-thermometer), the stem of the thermometer being made, with its scale, to form a circular frame, surrounding a dial with clockwork. The object attained by this arrangement is to ascertain readily that the rate of heating is in accordance with any prescribed regulation, the hands of the clock being made to keep time with the rise of the thermometer. The same result is, of course, attainable in ordinary practice by having a timepiece in close proximity to the test apparatus, so that it may be watched at the same time as the thermometer and the rate of rise of the latter regulated accordingly. The employment of Mr. Wilson's arrangement is certainly more convenient than having to watch the thermometer and timepiece separately; but it adds a somewhat expensive item to the apparatus, and, supposing that by its employment uniformity in the rate of heating could be secured, only one element of uncertainty in the existing test would then be avoided.

The general concurrence in the comparatively satisfactory nature of the "close test" led me to consider next whether it might not be possible to remove the points of uncertainty involved in the employment of that test by different operators. The chief variable points connected with it are—

(1.) The rate of heating of the apparatus.

(2.) The nature of the test flame to be used.

(3.) The precise position in which the test flame is to be applied, and the duration and frequency of its application.

Considerable differences of opinion were expressed by experts in their examination before the House of Lords committee as to the rate of heating which should be adopted in the application of the open test, differences of opinion which apply equally to the "close test".

Having carefully considered this point, I have come to the conclusion that it is unimportant whether the rate of heating be 1° or 2° per minute or 20° in fifteen minutes (the three rates insisted upon by different witnesses in the evidence), or whether a decidedly different rate of heating be adopted, provided the source of heat and amount of heat employed, and the mode of applying it, be the same in all cases, such definite rules being laid down with respect to this, and such precautions being taken in the construction of the apparatus, as to render the attainment of uniformity by different operators simple and certain.

The suggestion to apply hot water as the source of heat in connection with a flashing test was made by one of the House of Lords committee in 1872, and Mr. Keates stated that this subject had received consideration, but that decided objections had been advanced against this mode of heating. Being strongly of opinion that hot water presented the only simple means of securing uniformity in the

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a Described in *English Mechanic and World of Science*, xxii, 496.

rate of heating, I made many experiments, with a view of attaining, by simple arrangements, a satisfactory rate of heating by its means, which should be uniform with different apparatus of uniform construction and dimensions. By inclosing the hot-water vessel in an air chamber (or a jacket with intervening air-space), and by interposing an air-space between the hot water and the receptacle for the petroleum, I succeeded, on the one hand, in satisfactorily retarding loss of heat by radiation, and, on the other hand, in securing a sufficiently gradual transmission of heat to the petroleum. The rate of transmission of heat is not uniform throughout all periods of one single operation, but it is uniform at the same periods in different operations, and the average rate of heating is uniform. At the commencement, when the petroleum is cold and the water at its maximum heat, the rate of heating is necessarily most rapid, while as the temperature approaches the flashing point the rise of temperature, which for some time previously has been very uniform, becomes somewhat slower. The comparatively rapid heating at the commencement of the operation is decidedly advantageous, and the diminution toward the close is not sufficiently great to increase the legitimate severity of the test.

The temperature of 130° Fahrenheit has been fixed upon as a convenient one for the water to have at the commencement of the experiment; this temperature gives, with the apparatus of the dimensions adopted, a *mean* rate of heating of about 2° per minute during an experiment. The only operation which is to be performed in preparing for the heating of the petroleum to be tested is, at starting, to fill the heating vessel entirely with water at 130° Fahrenheit. The supply of water of the required temperature may be prepared by adding hot to cold water, or the reverse, in a jug, and watching the thermometer, which is moved about in the water until the desired temperature is indicated. When the heating vessel is filled with the properly warmed water, the petroleum cup being immediately afterward placed in position, the operator has not to concern himself any further with regard to the heating, and has only to attend to the rise of temperature in the cup and to the test flame. When the next test has to be performed, the water in the bath may be again raised to the proper temperature by the application of a spirit-lamp flame, and this is readily accomplished while the test vessel is being emptied and refilled with a fresh sample of the petroleum to be tested.

That the rate of heating must be rendered uniform by this mode of operation when the temperature of different samples of petroleum to be tested does not differ greatly is self-evident, and experiment has shown that, even if considerable differences exist between the temperatures of different specimens, the extra time required to raise the colder oil to the temperature approaching that of the minimum flashing point does not seriously affect the uniformity of the rate of heating at that part of the operation when this uniformity is of importance. There is, however, no difficulty whatever in avoiding any great variations in the temperatures of the samples tested at different times; thus, the warmth of the hand will soon raise a cold oil to a normal temperature, and a warm oil is easily cooled down to such a temperature by immersing the bottle containing it in water. As long as the temperature of the samples at the time of testing ranges between 55° and 65° the uniformity in their rate of heating will not be affected to an extent to influence the results furnished by the test. As illustrating the uniformity in the rate of heating, it may be stated that in two experiments made with one and the same oil, the temperature of which at the time of starting the test was 64° in one experiment and 70.5° in another, the average rate of heating during the rise of temperature from 75° to 85° was almost identical, being, during that portion of the test, 1.04° per minute. The only difference in regard to the heating in the two experiments was that with the oil at the lower temperature a period of six minutes was required to raise the temperature to 75°, while with the warmer oil only four minutes were required to attain the same result. The illustrations of results furnished by the proposed test apparatus given at page 224 show conclusively that they are not affected by differences even greater than the above in the temperatures of the oils at the commencement of the test.

The nature of the test flame to be used, and the mode of using it, were next considered by me, and very much time and labor have been expended upon the endeavor to provide a test flame which, with little care, could be maintained for some time of uniform size, and which might be allowed to remain throughout the testing operation or during the greater part of the time in a fixed position over the vapor chamber of the petroleum cup, my desire being, if possible, to render the actual operation of testing perfectly automatic.

Having satisfied myself that with the petroleum cup filled to a definite height there is no objection to keeping a small aperture in the lid of the cup (similar to that which exists in the lid of the close-test apparatus) constantly open, a very small oil-lamp was contrived, capable of maintaining a flame of the size of the test flames (furnished by a small gas jet or by twine) used in connection with the present test, and the lamp was so attached to the apparatus that when the testing was proceeded with the position occupied by the test flame over the opening in the cup was inevitably the same in all instances.

The variations in the length of time for which the flame was applied, in the rapidity of its movement in and out of the opening and in the frequency of its application, all constituted sources of discrepancy between the results obtained by different operators with the two tests hitherto used, which I proposed to set aside in the manner above indicated, *i. e.*, by keeping the small lamp in a fixed position from the time when the rise of temperature indicated an approach to the lowest attainable flashing point until the completion of the operation. This result was attained after numerous modifications of the small test lamp, and the form of the latter which I eventually adopted permitted of the attainment of uniformity in the size of the test flame by a very simple trimming operation.

The position in which the thermometer was fixed into the lid of the petroleum cup was modified so as to allow of the reading of the temperature simultaneously with the watching of the test flame being much more conveniently performed than in the present apparatus.

Although very satisfactory results were obtained by the arrangements just referred to, some difficulties were experienced in keeping the flame of the test lamp of uniform size throughout a consecutive series of test operations, and slight currents of air were found to affect the results obtained too greatly to render the test thoroughly reliable. After a long series of experiments, carried out with the view of overcoming these difficulties, I was eventually led to return to a method of operation very similar to that adopted in the original "close test", but with this important difference, that uniformity was secured in the nature of the test flame, the mode of applying it, and the position in which it is applied.

The application of the flame is in fact rendered quite automatic in the proposed form of test apparatus, the mode of operation being as follows:

The top of the petroleum cup has an aperture, as in the case of the old close-test apparatus, but in the center of the lid; this aperture is kept closed by means of a metal slide, working in grooves, and having two small uprights. These uprights support the little test lamp, which for this purpose is fitted at the upper part with small trunnions. When the temperature of the petroleum approaches that of the minimum flashing point, the slide is slowly drawn out of the grooves to the full extent permitted by a check; when this point is just reached, a very simple contrivance causes the test lamp to be tilted, so that the flame is always lowered into the opening in exactly the same position. Two seconds of time are allowed for withdrawing the slide, and thus the test flame is applied in all instances for the same period. (*a*) This operation is repeated at the termination of every degree indicated by the thermometer until the flashing point is attained.

a A small weight, suspended in front of the operator from a string 2 feet in length, answers the purpose of regulating the opening and shutting of the aperture. The slide is gradually drawn open during three oscillations of the pendulum, and is then rapidly closed during the fourth.

In this, as in the old close-test apparatus, each time the aperture is reopened and the test flame is applied a small portion of the mixture of air and petroleum vapor necessarily escapes from the chamber, in consequence of the outward current established, and hence the proportion of air in the mixture of vapor and air formed in the chamber must become reduced each time the test is applied, and thus the ready explosiveness of the mixture is liable to some variation. A simple contrivance has been applied in conjunction with what may be called the "testing slide" for remedying this possible source of discrepancy in the test. The opening which the withdrawal of the slide exposes for the application of the test flame is in the center of the upper surface of the chamber. Just before it becomes open to the full extent, and the test flame is lowered into place, two smaller openings, one on either side of it, become also uncovered by the drawing back of the slide and serve to admit air to replace that part of the mixture of air and vapor which is withdrawn from the chamber by the current which sets in the direction of the test flame; as the slide is pushed back again, these two openings are closed the instant before the central opening is closed again.

The description of oil and wick most suitable for the little test lamp are given in Appendix II. When coal-gas is available, it may be substituted for oil in the production of the test flame, as being decidedly more convenient, and for this purpose an arrangement which can be used in place of the lamp, and which admits of a small gas frame being applied automatically in exactly the same manner as the oil flame, has been devised as an alternative adjunct to the apparatus.

Even with a strict adherence to the prescribed method of heating the petroleum to be tested, and with the employment of the automatic test arrangement constructed precisely in accordance with the instructions laid down in the appendix, uniform results would not be obtained in the application of the test unless the petroleum cup be filled in all instances up to to the same height, and, indeed, up to a height which a long series of experiments (varied in many ways) has demonstrated to be the one which best insures the attainment of uniform results. A simple gauge, consisting of a small bracket, terminating in a point, is fixed within the cup, and indicates the precise height up to which this is to be filled with the liquid, which has simply to be poured in gradually until its level just reaches the point of the gauge.

The thermometer which serves to indicate the flashing point is rigidly fixed into the lid of the petroleum cup in a sloping position, so that it enters the liquid at the center of the surface. The length of that part of the thermometer which is inclosed in the cup is so adjusted that when the latter is filled to the prescribed height the surface of the liquid is 0.2 inch above the bulb. The precautions combine to render the readings obtained with the thermometer reliable indications of the actual temperature of the petroleum during the testing operation. The sloping position of the thermometer scale enables readings to be very conveniently taken.

Detailed instructions with regard to the application of the proposed method for testing are given in Appendix II, and Appendix IV gives the details of the proposed test apparatus.

The method of testing, arranged as described, is so simple in its nature that any person of ordinary intelligence, after carefully reading the instructions, or after having been once shown the operation, can carry it out readily, and no experience is required for the attainment of uniform results with it.

The following results, not selected, which have been obtained with the pattern apparatus sent with this report, illustrate the uniformity in the working of the test as now elaborated, and it should be particularly noted with respect to these results that in experiments with one and the same sample considerable variations in the temperature of the oil at the commencement of the experiment did not affect the accuracy of the results obtained:

Sample.	No. of experiment.	Temperature of bath at commencement.	Temperature of oil when placed in bath.	Temperature at which testing was commenced.	Flashing point.	Sample.	No. of experiment.	Temperature of bath at commencement.	Temperature of oil when placed in bath.	Temperature at which testing was commenced.	Flashing point.
		Deg. F.	*Deg. F.*	*Deg. F.*	*Deg. F.*			*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*
A.	1	130	66.0	68	77	K.	2	130	63.0	71	82
	2	130	68.5	70	77		3	130	66.0	69	82
	3	130	69.5	71	77	L.	1	130	54.0	68	75
B.	1	130	70.6	71	80		2	130	53.5	64	75
	2	130	71.0	71	80	M.	1	130	54.0	66	81
C.	1	130	68.0	70	82		2	130	67.0	69	81
	2	130	69.0	70	82	N.	1	130	57.0	63	73
	3	130	70.5	71	81		2	130	59.0	60	72
D.	1	130	59.0	63	75		3	130	57.0	63	73
	2	130	63.5	67	76	O.	1	130	62.0	67	79
	3	130	70.0	71	76		2	130	57.0	63	79
E.	1	130	57.0	65	72	P.	1	130	60.0	65	79
	2	130	59.0	62	71	Q.	1	130	59.0	65	74
	3	130	61.0	62	72		2	130	57.0	67	75
	4	130	68.5	69	72		3	130	67.0	67	75
F.	1	130	63.0	65	78	R.	1	130	66.0	69	78
	2	130	65.0	70	78		2	130	64.0	67	78
	3	130	66.0	67	78	S.	1	130	64.0	65	70
G.	1	130	70.0	70	84		2	130	63.0	64	70
	2	130	74.8	75	84	T.	1	130	63.0	66	80
H.	1	130	74.0	75	80		2	130	64.0	75	70
	2	130	65.0	66	80		3	130	65.5	75	80
I.	1	130	68.0	68	78	U.	1	130	66.0	67	73
	2	130	65.0	67	78		2	130	64.0	69	74
J.	1	130	59.0	68	79		3	130	67.0	68	74
	2	130	58.0	69	79	V.	1	130	67.0	69	80
K.	1	130	57.0	61	81		2	130	70.0	70	80

It will be seen that the foregoing table embraces a considerable range of flashing points; the samples which gave the results there recorded had flashing points ranging from 98° to 126°, as determined by the present legal test. All these were examined with equal facility and with equal accuracy (as shown by the results obtained with one and the same sample), the temperature of the water in the heating vessel having been in all instances 130° at starting. But with oils of much higher flashing points than the highest in the above series the supply of heat furnished by the amount of water contained in the heating vessel, raised to a temperature of 130°, would not be sufficient; and even if in such cases the water in the bath be raised to a much higher temperature, the intervention of the air space between the petroleum cup and the source of heat (which plays an important part in regulating the source of heat in the ordinary use of the test) prevents the very high flashing oil from being raised to its flashing point within any reasonable period. If, therefore, the first experiment made in the ordinary prescribed manner with a sample of oil indicates a very high flashing point (about 100° or upward), the following modified mode of proceeding must be adopted for determining its flashing point. The air chamber which surrounds the cup is filled with cold water to a depth of 1½ inches, and the heating vessel or water-bath is filled as usual, but also with cold water. The lamp is then placed under the apparatus and kept there during the entire operation. (*a*)

With this simple modification of the ordinary mode of working concordant results will be obtained with oils of the highest flashing points. It need hardly be stated that the greater majority of petroleum oils have flashing points within a smaller range than that represented by the annexed tabulated results, and that the application of the mode of proceeding last described will be limited to comparatively heavy paraffine oils, of which it is desired to determine the flashing points.

Having satisfied myself of the satisfactory working of the proposed test apparatus, I invited Mr. Keates, the consulting chemist to the Metropolitan Board of Works, and Mr. B. Redwood, the secretary of the Petroleum Association, to inspect it, and to witness the operation of testing with it. The appended extracts of letters (Appendix III) from those gentlemen show that they concur in considering that the difficulties which existed in connection with the present legal test, and also, though to a less extent, with the close test in the form in which it was proposed by Mr. Keates, are removed by the mode of operating which has been elaborated.

At the instance of Mr. Peter McLagan, M. P., the apparatus was also inspected by a representative of the Scottish Mineral Oil Association, Mr. John Calderwood, whose unqualified approval of it is recorded in the appended extract of a letter from him (Appendix III).

III.

With reference to the "flashing point", which, with the proposed test, should be fixed as equivalent to that of 100° Fahrenheit obtained with the present legal (open) test, and to the question whether the flashing point of 100°, or its equivalent, is "calculated to afford efficient protection to the public without unduly interfering with or restricting the trade".

With the view to establish the relation existing between the results furnished by the proposed test and by the present legal test experiments were made with a series of samples of petroleum, the flashing points of which had been determined by the test as prescribed in the act. Among these samples there was a considerable number for which I am indebted to the kindness of the secretary of the Petroleum Association.

As Mr. Boverton Redwood has had great experience in the testing of petroleum, both by the open test and by the close test, which it was at one time proposed to adopt, I requested him to attend at my office and test a number of the samples with which he was so good as to provide me.

In the first instance, however, I convinced myself that the results which that gentleman obtained by operating according to the directions laid down in the act, and also by applying the original close test, agreed very well with those obtained by Mr. T. W. Keates and by an experienced assistant in my establishment. Mr. Redwood and Mr. Keates were so good as to attend at my department to exhibit to me their ordinary mode of operating in applying the test, and the flashing points ascribed by those gentlemen (operating on different days) to particular samples were sufficiently in accordance to warrant my accepting the numbers obtained by Mr. Redwood in testing the series of samples referred to as representing the flashing points which would generally be obtained by experienced persons operating according to the methods hitherto practiced.

There is no doubt that the flashing points which one and the same operator, of such experience as Mr. Keates and Mr. Redwood, obtains with different samples of oil, using one and the same open test or close test apparatus, bear very generally a correct relation to each other; occasions will, however, unavoidably arise, even under the above very favorable conditions, when the defects inherent in those methods of testing will give rise to irregular and discordant results. Hence it is not to be expected that flashing points furnished by the comparatively accurate method of testing now proposed should present anything approaching absolute uniformity of relation to all those furnished by either of the other tests. Thus, as might have been anticipated, among the samples of oil which have been tested with the new apparatus there are several which, though they gave flashing points identical or nearly so with each other when examined by the present legal test (the open test), were found to differ several degrees from each other as regards their flashing points when examined by means of the new test.

In the examination of a number of samples by the new test and by the proposed close test the relation between the flashing points furnished by the two tests varied somewhat; the "new test" flashing points ranging from two to five degrees lower than the results furnished by the close test. Of 26 samples, ten gave flashing points with the new test 4° lower than the results obtained with the old close test, six gave results 5° lower, five 3° lower, and five 2° lower.

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a With oils of very high flashing points the rate of heating does not affect the accuracy of the results obtained. Therefore, if it is known to the operator that he is dealing with oils of very low volatility, he may save time by starting with the water raised to a temperature of about 120°. The following results are given in illustration of this:

Description of samples.	No. of experiment.	Temperature of bath at commencement.	Temperature of oil when placed in bath.	Flashing point.
		Deg. F.	*Deg. F.*	*Deg. F.*
I.				
Young's patent lubricating oil	1	78	78.0	147
	2	110	74.0	146
	3	120	80.0	147
II.				
Young's patent lubricating oil	1	74	74.0	131
	2	100	68.0	130
	3	100	72.5	131
	4	111	72.0	131

In applying the new test to 29 samples which had been examined by the present legal (open) test the following results were obtained:

Number of sample.	Flashing points by open test.	Flashing points by new test.	Difference.
	Deg. F.	*Deg. F.*	*Deg. F.*
1	98	70	28
2	100	71	29
3	100	72	28
4	100	74	26
5	100	75	25
6	101	73	28
7	101	78	23
8	101	74	27
9	102	75	27
10	103	75	28
11	104	75	29
12	104	76	28
13	104	77	27
14	104	78	26
15	104	78	26
16	105	80	25
17	106	79	27
18	106	80	26
19	106	81	25
20	108	82	26
21	108	83	25
22	108	80	28
23	109	84	25
24	110	83	27
25	110	82	28
26	110	81	29
27	110	81	29
28	113	87	26
29	126	100	26

t will be seen from an examination of these numbers that one among the samples gave a flashing point with the new test only 23° lower than that given by it when examined by the open test, while with four others there was as great a difference as 29° between the flashing points furnished by the new test and the present legal test. Excluding the single sample which showed the comparatively small difference above specified between the two tests the following is a synopsis of the observed differences between the two tests:

Number of samples.	Differences between the flashing points furnished by the two tests.
	Deg. F.
5	25
7	26
5	27
7	28
4	29

It would appear, therefore, from the results of these experiments, that the difference between the flashing points furnished by the present legal test and those obtained with the proposed new test ranges from 25° to 29° inclusive, and it should be borne in mind that the "new test" flashing points which have indicated this range of differences are all the results of two or three concordant experiments.

Taking samples of oil which by the "open test" gave flashing points of 100° and 101° (of which there are seven in the above series), the flashing points of these samples, determined by the "new test", ranged from 71° to 78° inclusive. Again, the flashing points of five samples, which were all shown to be 104° by the open test, ranged with the new test from 75° to 78° inclusive. Three samples, having all a flashing point of 106°, as determined by the open test, gave flashing points ranging from 80° to 82° inclusive by the new test; three, all flashing at 108° (open test), ranged from 80° to 83°, and four, flashing at 110° (open test), ranged from 81° to 83° inclusive. Oils of flashing points between 98° and 106° inclusive (open test) gave flashing points ranging between 70° and 80° by the new test, and those which with the open test ranged from 106° to 110° inclusive gave results with the new test ranging from 80° to 84° inclusive.

While the open test (the present legal test), and even the close test which has been proposed as its substitute, give what may be termed broad results, the new test, which appears to be as nearly absolute as a test of this kind can be made, gives precise results. For this reason, I am of opinion, so far as the results which have hitherto been obtained with the new test warrant my speaking decisively on the subject, that it will be necessary with the new test to adopt a range of 4 or 5 degrees to correspond to what has hitherto been regarded as the minimum flashing point which petroleum oils supplied to the public should have; in other words, I consider that the difference between the results furnished by the new test and the present legal test cannot be expressed by one figure, but must be represented by a range of figures (say, from 25° to 29°).

It need hardly be pointed out that great difficulties have arisen in connection with the present regulations respecting the testing of petroleum oils, consequent upon the legalized acceptance of oils as safe, or their condemnation as dangerous, upon a difference of even one degree in their flashing points, as determined by a test which may give differences of several degrees with one and the same oil in the hands of different operators.

With the adoption of a comparatively precise test, such as there is good reason for believing the proposed one to be, these difficulties should cease to exist, and I consider that a minimum flashing point may be adopted and strictly enforced with the employment of the new test without creating an opening for justifiable differences of opinion, such as have arisen in connection with the present legal test.

Having given my earnest attention to the evidence brought before the House of Lords committee in 1872, and to the questions which have arisen from time to time respecting the occurrence and causes of explosions or other accidents with petroleum, I have come to the following conclusions:

(1.) The present legal "flashing point" of 100° Fahrenheit by no means limits the acceptance of oils of that supposed flashing point to such as have only one particular degree of volatility, but indeed may admit oils as being just within the prescribed limits which really differ decidedly from each other as regards volatility.

(2.) There appear, on the other hand, to be no well-established grounds for considering that "adequate protection to the public" has not been afforded by adopting the flashing point of 100° Fahrenheit as the limit with the present legal test, or that the general results which that test has furnished in its application to determine whether oils imported have flashing points below the prescribed limit have been productive of risk to the safety of the public, even though there may be reason to believe that occasionally oils submitted as just within the limit have had decidedly lower flashing points than those of other oils which have been recorded as identical with them in this respect.

It may therefore be considered that the minimum flashing point to be adopted in connection with the new test may, without danger to the public, be fixed at that point which corresponds to the lowest results (not exceptional) which are furnished by applying the new test to a series of oils having a common flashing point of 100° when examined by the present legal test.

It may also be considered that the fairest course would be to base the equivalent, with the new test for 100° (furnished by the open test), upon the mean of the differences between the two tests applied to a large number of oils (with possibly the exclusion of a completely exceptionally extreme result). The objection would probably be raised against this course by importers of petroleum oils that it would have the effect of excluding from the market some oils which, under the present act, might be admitted as having a flashing point of 100°, and which past experience has failed to prove dangerous. Thus, if the mean difference between the flashing points given by the two tests in the results shown in the foregoing table be accepted as determining the equivalent for the present legal minimum flashing point (100°), then that difference being 27°, the equivalent for 100° would, with the new test, be 73°; but if that be adopted as the minimum legal flashing point with the new test, two out of 28 samples which the present legal test might have admitted would have been excluded from the market if the new test were in force.

Looking to the fact that these two particular samples, though found to have a flashing point of 100°, gave lower results than others of the same flashing point, not only with the new test, but also with the close test, it does appear as if they were oils of just that class which has given rise to occasional disputes, namely, oils which in the hands of some operators would have had flashing points below 100° assigned to them, and which might, therefore, even under the present conditions of testing petroleum, be excluded from the market by the balance of conflicting opinions.

After carefully considering this question, I have come to the conclusion that 27° Fahrenheit might, without injustice to the trade, be accepted as the difference between the results to be furnished by the new test and the present legal test; or, in other words, that 73° might with the new test be accepted as the equivalent for the present legal minimum flashing point of 100°.

It appears to me, however, that it would be much more satisfactory if, before a final decision is arrived at on this point, a very considerably larger number of experimental data than those which I have been enabled to obtain with the means at my command were procured with the new apparatus and by several operators experienced in the employment of the old tests. It would unquestionably much facilitate and expedite further action in the matter of modification of the existing law with reference to the testing of petroleum, etc., if Mr. Keates, of the Metropolitan Board of Works, Mr. Redwood, of the Petroleum Association, and an experienced operator selected by the Scottish Mineral Oil Association were invited to obtain test apparatus made in exact accordance with the pattern apparatus now submitted and to apply it to the testing of a number of samples of petroleum, the flashing points of which had also been determined by the present legal test. If portions of those samples, with the results obtained, were then forwarded to me by those gentlemen, apparent discrepancies could be examined into, and the "equivalent flashing point" of the new test be established upon a large number of results to the satisfaction of all interested in the adoption of a uniform system of testing.

If this suggestion be acted upon, I would recommend that the same person who, under my direction, has constructed the pattern apparatus, should make the apparatus required by those gentlemen, and that those apparatus should, in the first instance, be compared by me with the pattern now submitted.

In the event of the adoption of the new test, the apparatus submitted with this report (and of which photographs, (*a*) measurements, and specification are appended) should be preserved as a standard apparatus and placed in charge of some competent and suitable authority (*e. g.*, under the weights and measures office), who should inspect and test, or have tested, all apparatus which are made for use under act of parliament, for the purpose of ascertaining that they are in accordance with the pattern and specificaton. Such apparatus should then bear some official stamp or mark by which they can be identified as legal apparatus.

Since the attainment of uniform results with the test is dependent upon the uniform construction of the apparatus, it is indispensable that such a course should be pursued, and its adoption could, I apprehend, present no practical difficulties.

In conclusion, I submit, with special reference to the letter of the Secretary of State for the Home Department of July 7, 1875, 1386a 61, Appendix V, the following brief summary of the results and conclusions to which I have been led by the inquiry which forms the subject of this report:

(1.) The method of testing petroleum as prescribed in Schedule I of the Petroleum Act, 1871 (34 and 35 Vict., c. 105), is not "of a nature uniformly to insure reliable and satisfactory results".

(2.) A method of testing petroleum has been elaborated for adoption in place of that prescribed in the petroleum act, 1871, due regard having been had to the fact "that the testing must in many instances be carried out by persons who have had comparatively little experience in conducting delicate experiments". This method, while resembling in its general nature the one hitherto used, is free from the defects inherent in the latter, and is so arranged that it can be carried out, with the certainty of furnishing uniform and precise results, by persons possessing no special knowledge or skill in manipulation. With ordinary attention, in the first instance, to simple instructions, different operators cannot fail to obtain concordant results with it, and it is so nearly automatic in its nature that it is not, like the present method of testing, susceptible of manipulation so as to furnish different results at the will of the operator.

(3.) There are not, in my judgment, any well-established grounds for considering that the present flashing point of 100° Fahrenheit is not "calculated to afford adequate protection to the public".

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a These are necessarily omitted from this reprint.—B. R.

(4.) With the employment of the new test, a minimum flashing point should therefore be adopted which is equivalent, or as nearly as possible so, to the flashing point of 100° Fahrenheit, as furnished by the present test.

(5.) From the uncertain character of the present test, it follows that the "flashing points" furnished by it are not always concordant with oils of the same degree of volatility, and that the same flashing point is sometimes assigned by it to oils of different degrees of volatility. On the other hand, the comparatively very precise test now proposed furnishes, of necessity, concordant results with oils of the same degree of volatility. Hence the differences between the "flashing points" furnished by the present test and those obtained with the new test cannot be strictly represented by one figure, but may be considered as ranging from 25° to 29° Fahrenheit (inclusive).

(6.) The results of a number of thoroughly concordant experiments with the new test, and a comparison of these results with those furnished by the present legal test, and also with those obtained by employment of the close test, which it was proposed to adopt in 1872, indicate that a mean difference of 27° Fahrenheit may be legitimately accepted as the mean difference between the present test and new test, and that therefore a flashing point of 73°, furnished by the new test, may be accepted as equivalent to the minimum flashing point of 100° adopted in connection with the present test.

(7.) Although the conclusions given in the preceding paragraph are based upon the results of a number of carefully conducted and controlled experiments, it appears desirable that the minimum flashing point to be adopted in connection with the new test should be deduced from the results of a much larger number of experiments, and that these should be carried out with the proposed test apparatus by several independent operators of acknowledged experience in the testing of petroleum according to the methods hitherto practiced.

(8.) It is therefore proposed that several test apparatus, precisely similar in construction to that submitted with this report, be prepared, and that, after having been found by me to furnish identical results, they should be employed by the chemist of the Metropolitan Board of Works, the secretary of the Petroleum Association, and a duly qualified representative of the Scottish Mineral Oil Association for the testing of a number of samples of petroleum, the results, together with portions of the samples tested, being forwarded to me, with the view of their forming a basis for final report to the Secretary of State for the Home Department on that particular point.

(9.) In the event of the adoption of the test apparatus submitted with this report, it is important that the standard apparatus, with drawing and specification, should be deposited with some government authority, whose duty it would be to examine and certify to the correctness of all apparatus made for the purpose of testing petroleum under the new legalized regulations.

F. A. ABEL,
Chemist of the War Department.

AUGUST 12, 1876.

Immediately upon receiving this report from Professor Abel, the Secretary of State for the Home Department requested Mr. Boverton Redwood to subject a large number of samples of oil to comparative tests, in order that the relation between the temperatures at which oils flashed when tested under the act of 1871 and when tested by the apparatus contrived by Professor Abel might be accurately determined.

The samples tested numbered 1,000. They represented (excluding the trial samples) 97,766 barrels of oil, and formed a series thoroughly indicating the character of the various shipments which have reached England from the United States during a period of six months. The following is a synopsis of the results, taking the first 968 samples. all of which consisted of the ordinary (refined) petroleum of commerce:

92 samples showed a difference between the two tests of	25°
208 samples showed a difference between the two tests of	26°
225 samples showed a difference between the two tests of	27°
281 samples showed a difference between the two tests of	28°
162 samples showed a difference between the two tests of	29°
968	

Therefore, the whole of these samples afforded results within the range of figures given in Professor Abel's report.

On the other hand, it will be noted that the majority of the last 32 samples gave differences smaller than the minimum figures of Professor Abel's results, the difference being as follows:

9 samples showed a difference between the two tests of	20°
1 sample showed a difference between the two tests of	21°
9 samples showed a difference between the two tests of	22°
1 sample showed a difference between the two tests of	23°
4 samples showed a difference between the two tests of	24°
8 samples showed a difference between the two tests of	25°
32	

These, however, all consisted not of ordinary petroleum oil, but of the special kind which is known in the trade under the name of "water-white" oil, and therefore the exceptional results afforded by them do not affect the question at issue, and are of interest only as showing that samples may be selected or specially prepared having flashing points by the two systems more closely approximating than those of the ordinary petroleum oil of commerce. This water-white oil, as is well understood, possesses the distinctive feature of low specific gravity in addition to that of high flashing point, being, in fact, produced at a considerably enhanced cost, by rejecting, in the process of distilling the crude oil, an unusually large proportion of the heavier as well as of the lighter hydrocarbons; and it is possible that this peculiarity may account for the smaller difference between the two tests, though I can suggest no explanation of its occurrence only with *some* parcels of water-white oil, unless it be that the special mode of manufacture referred to is more carefully carried out in some cases than in others. (*a*)

On the whole, the results which I have obtained afford a complete corroboration of those given in Professor Abel's report. The selection of a mean difference of 27°, or, in other words, of a standard of 73° with the new test, would undoubtedly, as is evidenced by my figures, lead to the condemnation by the committee of the Petroleum Association of a somewhat larger percentage of the oil imported, and would thus place the trade in a more unfavorable position; but, on the other hand, the adoption of a precise method of testing would reduce to a minimum those differences of opinion which, under the present system, may, as Professor Abel points out, lead in certain cases to the legal condemnation of oils which the trade inspection has shown not to come within the provisions of the petroleum act. (*b*)

a These "water-white" oils were not cracked oils.—S. F. P.

b Report of Mr. Boverton Redwood to the English Secretary of State for the Home Department.

It is not my intention in this report to advocate the claims of either the Saybolt, the Abel, or the Engler apparatus for testing oils, which are doubtless superior to all the others, but simply to present the subject as it actually exists, with all the difficulties attending it, and also such attempts as have been made to meet them.

SECTION 4.—PETROLEUM LEGISLATION IN THE UNITED STATES.

In order to secure full information regarding legislation regulating the sale of petroleum products a schedule of questions was prepared and sent to the executive officer of each of the cities and towns having a population of 10,000 and upward, as represented in Census Bulletin No. 45. Some of these schedules were filled with very great care, others were carelessly filled, others were returned with an indorsement of "no legislation" or something equivalent, and in some cases no return was made. The same schedule was also addressed to the secretaries of the different states and the secretaries of the different state boards of health, from nearly all of whom returns were received. I was present in April, 1881, at a meeting of the committee of the New York legislature having in charge the legislation then pending relating to the sale of petroleum products, and was also frequently consulted by committees of the Minnesota legislature during the successive years in which the subject was agitated in that state.

From these several sources of information, of both a negative and a positive character, it appears that at the close of the census year seventeen out of the thirty-eight states of the Union were without other legislation relating to petroleum than that provided by the United States statute of 1867 (*a*) regarding mixing oils and prescribing a test of 110° (not given in the Revised Statutes), and an act regarding dangerous freight or stores on passenger steamers, (*b*) except that within those states there was a large number of cities having ordinances providing some test. Even the District of Columbia, whose laws are directly prescribed by Congress, has no other petroleum laws than the United States laws indicated above. Since the close of the census year a number of these seventeen states have passed laws relating to petroleum.

It was found to be impossible to compile any general statistics as to laws even from the schedules that were most carefully filled; but the returns exhibited the confused condition of legislation regarding petroleum enacted by so many different legislative bodies more or less influenced by a great variety of opinions and interests. On the one hand there are advocates of extremely high test laws who have made their influence dominant in certain localities, and that influence has produced legislation that has either been openly disregarded or strenuously opposed until the repeal of the obnoxious laws had weakened the cause they were intended to strengthen. On the other hand, while there are honorable manufacturers of petroleum who make and sell safe oils and desire to be relieved from competition with the manufacturers of unsafe products, there are others who, without regard for the welfare of the public, desire to be allowed to make what they can sell, leaving the question of responsibility with the purchaser, and who therefore oppose all legislation, using their influence to secure the lowest test possible when legislation is inevitable.

When the United States law of 1867 was passed the proportion of cracked oils in the market was much smaller than at present. That law required a fire test of 110° F. I have been unable to ascertain upon what basis the adoption of this test and the temperature rested. Several years subsequent to the enactment of this law the board of health of the city of New York made the whole question of dangerous petroleum products the subject of a most elaborate research by Dr. C. F. Chandler, and in consequence rejected the "fire test" as worthless and recommended to the city government the enactment of an ordinance that required a "flash test" as the only one of any value. The wisdom of this action has been indorsed by the whole course of English petroleum legislation. Some of the most able scientific men of this generation, after careful investigation of the subject, have shown that

a *And be it further enacted*, That no person shall mix for sale naphtha and illuminating oils, or shall knowingly sell or keep for sale or offer for sale such mixtures, or shall sell or offer for sale oil made from petroleum for illuminating purposes inflammable at less temperature or fire test than one hundred and ten degrees Fahrenheit, and any person so doing shall be held to be guilty of a misdemeanor, and on conviction thereof, by indictment or presentment in any court of the United States having competent jurisdiction, shall be punished by a fine of not less than one hundred dollars, nor more than five hundred dollars, and by imprisonment of not less than six months nor more than three years. (U. S. Stat. at Large, Thirty-ninth Congress, second session, 1867, chap. 169, sec. 29.)

As this section is a part of an act relating to internal revenue, the other sections of which have no relation whatever to petroleum legislation, it is an open question if, in the repeated revisions to which the internal revenue laws have been subjected, section 29 has not been long ago repealed.—S. F. P.

b SEC. 4472. No loose hay, loose cotton, or loose hemp, camphene, nitro-glycerine, naphtha, benzine, benzole, coal-oil, crude or refined petroleum, or other like explosive burning fluids or like dangerous articles, shall be carried as freight or used as stores on any steamer carrying passengers. * * * Refined petroleum which will not ignite at a temperature less than one hundred and ten degrees of Fahrenheit thermometer may be carried on board such steamers upon routes where there is no other practical [practicable] mode of transporting it, and under such regulations as shall be prescribed by the board of supervising inspectors with the approval of the Secretary of the Treasury. * * *

SEC. 4474. The Secretary of the Treasury may grant permission to the owner of any steam vessel to use any invention or process for the utilization of petroleum or other mineral oils or substances in the production of motive power, and may make and enforce regulations concerning the application and use of the same for such purpose. * * *

SEC. 4475 prescribes the packing and marking of such oils, and SEC. 4476 prescribes the penalties for violation of the law. (Revised Statutes, U. S. Ed., 1878.)

a "fire test" is unsatisfactory, and also that a "flash test", at a temperature equivalent to that of 100° F. in an open tester, is a satisfactory test to insure public safety. Oils that will sustain a "fire test" of 110° often flash at 70° to 80°. While the overwhelming mass of evidence goes to show that a flash test of 100° is conclusive as regards public safety, there are large areas of the country with flash tests fluctuating between 120° and 150° as successive legislatures deal with the question, and other large areas where there is no state legislation. Under both these conditions the number of "kerosene accidents" is very large, while that portion of the country over which petroleum legislation is really effective is comparatively small.

The acts that have proved most effective in affording protection to the public have provided that a state inspector, authorized to appoint deputies, shall be chosen by the governor, county judges, or state board of health, who shall inspect oils by testing each for either its flashing or its burning point, or for both, at a specified temperature. Provision is usually made for the payment of the inspector and deputies. In some instances this compensation is made too low to compensate a competent person for doing the work properly. The instrument with which the test shall be made is in many cases carefully described. Then the bonds of the inspector and of the deputies are fixed, and the penalties for violation of the provisions of the law are prescribed.

There are two sources of danger against which legislation should be directed. The first is the *manufacture* of unsafe oils; the second is the preparation of unsafe oils by *mixture*. The machinery of state inspection is cumbersome as related to the manufacturers, and inoperative as regards the dishonest, who will mix safe oils with benzine. The expense of an analysis or inspection of every barrel of oil sold in this country in such a manner as to be of any value is unnecessary, as these oils are transported in tank cars that hold on an average 100 barrels. The inspection of the contents of a car is of just as much value as the inspection of each particular barrel. The idea that one part or stratum of a tank of oil will test differently from another has no foundation in fact. Having conversed with a large number of persons connected with the petroleum trade, I am convinced that legislation embodying the following provisions would reduce the number of petroleum accidents to a minimum, and would meet the approval of all honorable men. To determine, as a first step, what method of testing, what instrument, and what temperature should be adopted as a standard of legislation, the President might be authorized by Congress to appoint a commission, in which the boards of health, scientific experts, and manufacturers of petroleum should be represented equally. It would be well to ask the governments of foreign countries, with which the trade in petroleum is large, to join in the consideration of this question through special commissioners. A small percentage of the losses of the country during a single year would pay all of the expenses of this commission. Upon the report of such a commission, laws could be based making the selling of a dangerous oil a misdemeanor in all cases, and manslaughter when death is occasioned by its use, as already provided when death results from illegal transportation of "nitric oils" and powder, and also providing for the recovery of damages in a civil suit for all losses to either persons or property occasioned by the use of such oil—the retailer to be able to recover from the jobber, the jobber from the manufacturer, etc., until the responsible party is reached. One competent person, who should be authorized to enter premises and demand samples of oil for inspection, could do all of the necessary work for a large state, and he should be paid an adequate salary, not paid by fees. The examination of oils should not be confined to the flashing point alone, but should regard the percentage of sulphur, of benzine, and of heavy oil as well. This suggestion has met the approval of persons representing the producing, the manufacturing, and the selling interests as one which would make the manufacture of unsafe oils unprofitable, and, in addition, would prescribe penalties for the man who would willfully mix benzine with a good oil, tending to stamp out that nefarious business. In addition to a standard of testing for ordinary illuminating oils, another and much higher standard should be determined for oils to be used on steamboats and railroad cars in interstate commerce. Under present legislation, a car running over a thousand miles of road may start in a state in which a 110° oil is legal, and, passing through another in which a 300° oil is required, finish the run in a third state in which there has been no state legislation. As a further illustration of the results of such variable legislation, I may state that while engaged in collecting the statistics for this report I saw in the testing room of a large refinery a large table, on which were no less than seven different instruments that were in daily use for testing oils to fill orders from different localities. These instruments included Abel's for the Canada market, Saybolt's for the New York city export market, the Ohio tester for the Ohio market, and a number of others. I doubt if the legislative regulation of any other substance presents such anomalous and contradictory characteristics.

There is but one temperature at which illuminating oils manufactured from petroleum can, when properly tested, give off an amount of vapor sufficient to produce an explosive mixture within the limits of public safety. That temperature alone should be made the subject of legislation, and the testing should be made with whatever instrument gives results that may be repeated with the greatest accuracy. The question of absolute safety has already been discussed; that of comparative economy is outside the domain of legislation.

SECTION 5.—BURNERS.

One other subject deserves consideration in this connection. It is frequently maintained that with proper burners oils are safe that under other conditions are unsafe. While it cannot be denied that some burners are to be preferred to others, it is my belief *that all burners are safe with safe oil.* There is no doubt, however, that very considerable differences obtain between different burners in point of illuminating power, and hence of economy. This was made a subject of research by Mr. C. J. H. Woodbury in 1873. (*a*) In his report he says:

The comparative worthlessness of the lighter product of petroleum tempts the unprincipled manufacturer to add them to kerosene, making a product which, on account of its extreme volatility, is *cleaner* than pure kerosene; the flame is of greater brilliancy, and, on these grounds, it recommends itself over the pure oil to those who have not been able to give attention to this subject. Many of these compounds are quite as dangerous as gunpowder. As kerosene has been in use only a few years, a sufficient interval has not elapsed to enable us to burn it with the greatest possible economy. * * * The writer, in the following series of experiments upon various kerosene burners, has endeavored to ascertain the most favorable forms of burner for an economical expenditure of oil compared to the light given. The results given for each lamp are the mean of from 150 to 250 observations.

FLAT WICKS.

No.	Chimney.	Wick.	Candle power.	Hours required to consume 1 gallon.	Candle power to gallon.
		Inch.			
1	Bulge	$\frac{5}{8}$	8.469	99.06	594
2	Bulge	$\frac{5}{8}$	6.426	127.53	815
3	Bulge	$\frac{5}{8}$	6.587	125.35	823
4	Sun	$\frac{5}{8}$	5.138	163.93	829
5	Sun	$\frac{5}{8}$	4.829	171.89	830
6	Sun	$\frac{1}{2}$	4.810	174.87	835
7	Bulge	$\frac{5}{8}$	7.398	115.23	887
8	Sun	$\frac{5}{8}$	7,371	131.19	964
9	Sun	$\frac{5}{8}$	5.997	188.57	1,110
10	Bulge	1	10.754	113.17	1,209
11	Bulge	$\frac{7}{8}$	*19.480		
12	Bulge	$\frac{1}{2}$	*10.030		

* As these lamps were made to burn mineral sperm oil, we do not give the results.

CIRCULAR WICKS.

No.	Chimney.	Wicks.	Candle power.	Hours required to consume 1 gallon.	Candle power to 1 gallon.
13	Circular	Circular	8.387	101.20	833
14	Circular	Circular	8.824	103.68	911
15	Circular	Circular	10.905	123.68	1,347

The list could have been made much longer, but it would serve our purpose no better.

The oil used was Downer's kerosene, specific gravity 0.801. One gallon, at 62° F., weighing 3,025.3 grams. The first column of results shows the candle power given by the lamp when burning with a full flame, but below the smoking point. The second gives the number of hours required to consume 1 gallon of oil. The object of the third column is to give the economy of the lamp, by a unit, which is the candle power given by an ideal lamp, exactly similar to the one under observation, with the exception that it shall consume precisely 1 gallon an hour. This result is constant for all except extremely high or low flames. Such a unit is very empirical, but no more so than the modulus of elasticity, or absolute zero. * * *

A simple inspection of the above lamps shows their economical results to be in the direct ratio to the facilities afforded the air for approaching the base of the flame. Where the air cannot enter freely, much of the oil seems to be volatilized without combustion. The best example is given by cases 5, 8, 9, and 10. The lamps are all similar, except in the difference noted below, and are of the pattern generally known as "sun-burners". In the first example, the air must pass through two horizontal brass diaphragms at the base of the chimney; one is pierced with holes $\frac{3}{8}$ inch in diameter, the other about $\frac{1}{16}$ inch; case 8, one fine diaphragm at base of chimney; cases 9 and 10, the base of the chimney is open; a diaphragm is near the base of the flame. Although the two lamps are different in size, they are identical in principle, the following being the cause of difference in the result: a certain portion of the light is shaded by the top of the burner. This conceals an equal amount (not proportion) of the flame, whether it is high or low. Also, a large flame makes a much more powerful draft than a smaller one. If we have two similar lamps, the larger one will give the best results.

In the four lamps just cited, if we remove the coarse diaphragm from the first lamp we increase its efficiency 16 per cent.; in addition, taking away the fine one, we increase it 18 per cent. more; make the draft more powerful by a bulge chimney, we have a further increase of 12 per cent. Lamps like 9 and 10, from their open construction, are extremely sensitive to currents of air. Lamp No. 3 is a metallic lamp, and very thoroughly constructed. The air is supplied from the base of the lamp, the burner being closed; it is not sensitive to currents of air, and gives the most steady and agreeable flame of any that have come under observation. If the entrance to the air passage was made larger, and the diaphragms in the burner were pierced with larger holes, the efficiency of the burner would be increased greatly, while it would probably retain its steadiness of flame. In lamp No. 15 the air is introduced into the center of the flame with less obstruction than in the two previous cases, and this lamp gave the most economical results.

a Jour. Frank. Institute, xcvi, 115. The names of the burners and their manufacturers are given in the original memoir.

The results here given show that in the question of the economical combustion of illuminating mineral oils much depends upon the burner. At the special general meeting of the London Petroleum Association, held on January 14, 1879, it was generally admitted that not only the burner, but the wick, played an important part in the successful combustion of petroleum oils. It was also shown on that occasion that a loosely woven wick was preferable to a more solid one, but that with any form of wick or burner oils of inferior quality produced a crusted wick with a smoky flame and heated burner. Judging from the discussion that took place on that occasion, together with my own experience, I conclude that oils that are prepared from petroleum without destructive distillation may be burned with a very slow consumption of the wick, but that the wick used with these oils, in time, through some physical or chemical action which has not yet been investigated, suffers impaired capillarity and becomes unfit for use, although it may still be of sufficient length to reach the oil. Such wicks should be discarded as soon as they give trouble. Burners also should be discarded as soon as they become worn and do not act satisfactorily. The primary question, however, rests with the oil. Cracked oils containing much heavy oil and a comparatively large content of sulphur very soon convert a wick into a charred mass saturated with a gummy substance that partially destroys its capillarity and produces an imperfect combustion and inferior flame. To secure the best results the best oil should be burned in lamps supplied with fresh burners and wicks carefully trimmed.

The fact has been established beyond all controversy *that no combination of lamp, burner, and wick that has ever been invented or can be invented will make an inferior or unsafe oil either satisfactory, economical, or safe.*

Dr. Thomas Cattell writes as follows to an English journal:

It is two years since the first intimation of danger from sophisticated candle-wick was forced on my attention. The candle, a thick dipped one, was placed lighted upon a table, and after a period of about twenty minutes it guttered so violently that the tallow flowed down on to the table around the bottom of the candle-stick, followed in a few seconds by a collapse of the wick, bared of tallow, on to the table, setting fire to the melted tallow. If I had not been present serious consequences would have ensued. When this incident occurred I had not thought the fault lay primarily with the candle-wick; I held the tallow to blame. A recent accident, however, with a large paraffine lamp has brought to light the fact that the medium or wick through which the tallow and the oil are used as sources of light is unsuitable for its object, as well as fraught with considerable danger. Experience has taught that cotton is the one peculiar and valuable medium for supplying the sources of light here referred to. Spurious cotton-wick I believe to be a mixture of cotton and flax waste, or a combination of jute, hemp waste, and cotton. Such wick, or at least the alien portion of it, becomes quickly carbonized both in candles and lamps. With the first, the carbonized particles as they form dart out with a flash or drop on the melted tallow undergoing absorption by the wick, giving rise to guttering and a great waste of tallow. In the other, the ignited portion soon carbonizes, which more and more increases in depth, until a point is reached when further capillarity in the direction of the flame ceases and ignition of the lower part of the wick takes place, followed by that of the oil in the receiver, with explosion or other mishap. I believe it will be found that the danger to which I here allude will afford an explanation of many fires and accidents that, but for these observations, had ever remained involved in mystery. Pure cotton-wick is slow to carbonize, and its consumption is uniform, unaccompanied by sudden little ejections and explosions, as occur in the burning of spurious cotton-wicks previously alluded to. If ordinary paraffine oil be not of the required combustion standard, such wick would greatly increase its danger. Microscopically, flax fiber consists of jointed cylindrical tubes. Cotton consists of flattened twisted tubes without joints. Chemical analysis would give us more or less of the nitrates, nitrites, and binitrites of cellulose. (*a*)

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a Oil and Drug News, January 31, 1882.

CHAPTER III.—NATURAL GAS AND THE CARBURETING OF GAS AND AIR.

SECTION 1.—OCCURRENCE AND COMPOSITION OF NATURAL GAS.

The occurrence of springs of water accompanied with gas have been noted from a very early period. The number of localities named "burning springs" in different parts of the country attest the wide distribution of this phenomenon. It is, however, very erroneously supposed by some writers that these burning springs are immediately related to volcanoes. Dr. Ansted appears to think that they are closely related to mud volcanoes; but in the United States, east of the Mississippi river, where mud volcanoes are unknown, it appears that gas springs are the product of the same kind of action that has produced petroleum, and they often accompany petroleum. Wall observed in his researches upon Trinidad that—

The phenomena of salses or mud volcanoes, consisting of the solution of inflammable gas, accompanied by the discharge of a muddy fluid and asphaltic oil, is, perhaps, closely related to the activity just described, as carbureted hydrogen may be disengaged in the direct formation of asphalt.

Several of them occur in Trinidad, also in the "Newer Parian". They were likewise observed in the province of Maturin, presenting similar characters. At Turbaco, near Carthagena, precisely the same action is manifested, but on a much larger scale. This is further confirmatory of a great extension of the above formation to the westward. The thermal waters of Trincheras, near Valencia, issuing from mica-schist, contain merely traces of silica, sulphureted hydrogen, and nitrogen, and possess a variable temperature, as shown by the following determinations:

Humboldt, in 1800	194°
Boussingault, in 1823	206°
The author, in 1859	198°

The hot springs of Chaquaranal, near Pilar, in a limestone of the "Older Parian", present the rare phenomena of water discharged at and even above the boiling point. Sometimes the fluid is delivered under pressure, rising in a jet, continuing in a state of ebullition for several feet from the point of discharge, accompanied by a forcible evolution of steam, and depositing abundance of calcareous matter.

The fissures of the adjacent rock are lined with spathose crystallizations and the acicular forms of sulphur. The vapors escaping from these fissures consist principally of steam. (*a*)

Professor Ansted observed copious discharges of gas, petroleum, and mud from the mud volcanoes of the valley of Pescara, in Italy, and also in the Crimea. I do not, however, interpret these phenomena as volcanic, or as in any manner an association of cause and effect, but rather as associated incidents of the dying out of the metamorphic action which has in most cases by invasion of strata containing organic matter distilled all of the forms of bitumen, including inflammable gas. The observations of Wall confirm this hypothesis in the most striking manner.

In the great petroleum region of the Appalachian system the accumulations of gas are often found upon the anticlinals in the pebble conglomerates and sandstones that hold the petroleum, while at a still lower level in the troughs of the synclinals salt water occurs. In a general manner, with the sea-level as a datum line, the Venango and Bradford oil-sands lie sloping at a gentle inclination, the southwestern edges submerged in salt water, and the northeastern edge saturated with gas under an enormous pressure. Not the slightest evidence that volcanic action ever has obtained in that region has been observed; but all the geological features, which have already been so fully discussed on previous pages of this report, lead to the conclusion that petroleum and natural gas have been produced by the same cause. That volcanic action is not that cause is further shown by a comparison of the analyses that have been made of natural gases from various localities.

In 1876 Professor S. P. Sadtler, of the University of Pennsylvania, examined with great care the gas from four different wells in northwestern Pennsylvania, which was used in all cases for technological purposes. I quote from his paper read before the American Philosophical Society, February 18, 1876, as follows:

Having had occasion lately to analyze some of the gases issuing from wells in western Pennsylvania, I have obtained some results which are given as a contribution to our knowledge of these important natural products. There have been almost no analyses whatever made of these gases. In 1866 a French geologist, M. Foucou, visited a number of these gas-wells and collected specimens of the gases. These were afterward analyzed by M. Fouqué, and the results published in *Comptes Rendus*, lxvii, p. 1045. The localities were Pioneer run, Venango county, Pennsylvania; Fredonia, New York; Roger's gulch, Wirt county, West Virginia; Burning Springs, on the Niagara river below the cataract; and Petrolia, Enniskillen district, Canada West. These points are certainly widely enough removed to make the series comprehensive from a geological standpoint. The analyses do not appear to have been complete ones, as M. Fowqué determined the exact amounts of only a few of the constituents. In general, the gases were composed of the marsh-gas series of hydrocarbons. Thus the gas from Pioneer run he found to have essentially the composition of propyl hydride (C_3H_8), with small quantities of carbonic acid and of nitrogen; the Fredonia gas appeared to be a mixture of marsh-gas (CH_4), and ethyl hydride (C_2H_6), with a small quantity of carbonic acid and 1.55 per cent. of nitrogen; the Roger's gulch gas was CH_4 almost exclusively, with 15.86 per cent. of carbonic acid and a small quantity of nitrogen; the Burning Springs gas almost pure CH_4 with a little CO_2; the Petrolia gas a mixture of marsh-gas

a Q. J. G. S., xvi, 467.

(CH_4) and ethyl hydride (C_2H_6), with a small amount of carbonic acid. However, the composition as given was only apparent, as in the case of the Pioneer run gas, for on passing the gas through alcohol a part was absorbed, which was afterward shown to be butyl hydride (C_4H_{10}), while the part unabsorbed showed nearly the composition of marsh-gas (CH_4). It was evident, therefore, that what appeared to be propyl hydride (C_3H_8) was in reality a mixture of marsh-gas (CH_4) and butyl hydride (C_4H_{10}).

In 1870 Professor Henry Wurtz made an analysis of the gas from a well 500 feet deep in West Bloomfield, Ontario county, New York. He found:

	Per cent.
Marsh-gas CH_4	82.41
Carbonic acid CO_2	10.11
Nitrogen N	4.31
Oxygen O	0.23
Illuminating hydrocarbons	2.94
	100.00
The specific gravity of the gas was	0.693

Professor S. A. Lattimore, of Rochester University, New York, examined this gas in 1871, and estimated its flow to be 800,000 cubic feet in twenty-four hours of 14.42 candle power.

The gases which I collected and analyzed were: First, the gas of the Burns well, in Butler county; secondly, that of the Harvey well, in the same county; thirdly, that from the Leechburg well, across the Kiskeminitis river from Leechburg, in Westmoreland county; and fourthly, the gas bubbling from a spring at Cherry Tree, in Indiana county.

He obtained the following results: (*a*)

COMPOSITION OF THE GAS OF CERTAIN WELLS.

Name of well.	Carbonic acid.	Carbonic oxide.	Illuminating hydrocarbons (C_nH_{2n+2}).				Oxygen.	Nitrogen.	Specific gravity.	Heating power.	Pyrometric heating power.
			Hydrogen.	Marsh-gas.	Ethyl hydride.	Propyl hydride.					
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Deg.*
Burns' gas-well	0.34	Trace.	6.10	75.44	18.12	Trace.	....	....	0.6148	14,214	2,745
Leechburg gas-well	0.35	0.26	0.56	89.65	4.39	Trace.	....	....	0.5580	14,105	2,746
Harvey gas-well	0.66	Trace.	13.50	80.11	5.72	Trace.	....	....	0.5119	15,597	2,763
Cherry Tree gas-spring	2.28	....	22.50	60.27	6.80	....	0.83	7.32	....	....	....

The following results were obtained from the analysis of the gas escaping from a well in Belfast, Ireland. It passed through 33 feet of silt and 7 feet of gravel containing organic *débris*. The gas escaped from the gravel. Its density was 0.661, air = 1, inodorous, and contained no compounds of carbon and hydrogen, except CH_4. Its composition was found to be—

	Per cent.
CH_4	83.75
CO_2	2.44
O	1.06
N	*b* 12.75

An analysis is here given of the gas of the Burning Spring of Saint Barthélemy (Isère): (*c*)

	Per cent.
CH_4	98.81
CO_2	0.58
N	0.48
O	0.10
Loss	0.03
	100.00

The results of several analyses of the gases escaping from the solfataras and fumaroles, given below, will be found to exhibit a strikingly different composition. The first is an analysis of the gases rising through the Lago di Naftia in the Val del Bove of Etna:

	I. Per cent.	II. Per cent.
CO_2	94.23	84.58
H_2S	.....	6.17
CH_4	1.82	2.42
O	0.28	4.52
N	3.79	1.89

Neither acetylene nor olefines were present. (*d*) The next is an analysis of the gases evolved from fumaroles on the island of Saint Paul. The temperature was 78°–80°: (*e*)

	Per cent.
CO_{21}	14.24
O_1	17.01
N_1	68.75

a *American Chemist*, vii, 97; W. B., 1876, p. 1134.
b C. N., xxx, 136; J. C. Soc., xxviii, 242.
c *Mont. Sci.*, 1870, p. 550; W. B., 1870, p. 704.
d *Gaz. Chim. Ital.*, ix, 404; J. C. S., xxxviii, 345.
e *C. Rendus*, 1875, No. 7.

The gas from Campi Flegrei, Vesuvius, is not constant in composition, but is mainly CO. H_2S is about 5 per cent., O less than 1 per cent., N 5 to 10 per cent., sometimes as high as 50 to 60 per cent., with occasionally a small quantity of CH_4. The Grotto del Cane yields pure CO. (*a*) No combustible gases are evolved by the Caldeira de Fumas, San Miguel, Azores, differing in this respect from the geysers of Iceland and the Suffoni of Tuscany, both of which invariably contain H and CH_4. (*b*) The gases from Santorin, after the eruption of 1866, contained CO_2, O and N in constantly varying proportions, with traces of H, H_2S, and CH_4. In 1870 HCL and SO_2 were present. (*c*) The gases evolved from solfataras contain CO_2, H_2S, O, and N. Two of them yielded wholly CO_2. The Great Solfatara yields steam, H_2S, CO_2, O, and N. (*d*)

A comparison of these results of analysis shows the great difference between the constituents of the gases from these two sources. In the gases from Burning Springs CH_4 predominates, accompanied by other products of *distillation;* in the gases from solfataras CO_2 predominates, accompanied by other products of the *combustion* of carbon. The distillation of strata rich in organic remains, when invaded by metamorphic action, has doubtless produced the inflammable gases of burning springs and gas-wells in a manner analogous to and often simultaneous with the production of petroleum.

In the United States the phenomena of burning springs were observed by the earliest settlers west of the Alleghanies. Dr. Hildreth described these springs as they occur in the valleys of the Little and the Great Kanawha, in West Virginia, in 1833, and later in the valley of the Big Sandy, in Kentucky. The volume of gas escaping from these springs is often remarkable, but no attempt was ever made, so far as I can learn, in any manner to utilize this material. The boring of wells for salt and petroleum led to the frequent penetration of strata heavily charged with gas that was destitute of petroleum. This was most frequently the case on the borders of petroleum fields in rocks that were, relative to the sea-level, higher than those yielding oil. The localities that have been and are most noted for their gas-wells are: Fredonia, Chautauqua county, New York; Wilcox, Elk county, Pennsylvania; Rochester, Beaver county, Pennsylvania; Burns well and Harvey well, Butler county, Pennsylvania; Leechburg, Westmoreland county, Pennsylvania; Sheffield, Warren county, Pennsylvania; Allegheny county, Pennsylvania; Erie, Erie county, Pennsylvania; Painesville, Lake county, Ohio; East Liverpool, Columbiana county, Ohio; Gambier, Knox county, Ohio; New Cumberland, Hancock county, West Virginia; Burning Springs, Wirt county, West Virginia.

The gas from wells at several of these localities has been made very valuable for technological purposes:

The use of natural gas at Fredonia was begun in 1821, and was introduced into a few public places, among which a hotel was illuminated when General Lafayette passed through the village. The gas from this well, which was sufficient for about thirty burners, was used alone until about 1858, when another well was drilled, which supplied some two hundred burners. Another well was drilled in 1871 with better success. The average monthly supply of the three combined is about 110,000 cubic feet, of which an average of 80,000 cubic feet per month is consumed for lights. Seven other wells, varying from 50 to 800 feet deep, have been made without success. The area covered by these wells is about one mile in length by one-half mile in width. The supply has not perceptibly diminished since the opening of the wells. (*e*)

At Erie, Pennsylvania, gas-wells have been bored along Mill creek. Some of the deepest of these wells have yielded a dense oil. The Demming well struck gas at about 440 feet under such a pressure that it blew oil to the top of the derrick for twenty-four hours. Many gas-wells have been drilled for private dwellings and manufacturing establishments. For the latter purpose, where large quantities are used, the yield of the wells runs down in a few years. At Painesville, Ohio, gas-wells are bored for private dwellings, and the gas is used often for heating as well as for illuminating purposes. At Rochester, Pennsylvania, and East Liverpool, Ohio, the gas is burned in enormous quantities in glass houses. At Gambier, Ohio, and New Cumberland, West Virginia, the gas is burned in a manner to produce lampblack. The gas of the Burns, Harvey, and Leechburg wells is or has been used in puddling iron. The latter was found particularly valuable in the preparation of the quality of pure rolled iron used for tin plate. The Sheffield well was bored for oil, but instead of oil it has discharged a jet of gas that has burned continuously for five years. In the oil regions the gas from these wells is frequently burned in the open air for no other purpose than to prevent the formation of dangerous explosive mixtures of gas and air.

Bradford and other towns in the oil regions are mainly heated and lighted with natural gas from the oil-wells, and in some instances from wells drilled on purpose to obtain gas. If no oil accompanies the gas, the flame is clear and white, but if oil is present it is red and smoky. Benzine often condenses in the pipes from natural gas, and it is not unreasonable to suppose that, at the enormous pressure under which this gas is held in the oil-sand, the gas is condensed to a liquid. In the Bradford region especially this pressure is much too great to be ascertained by pressure gauges, and has often been made a subject of conjecture, rather than of estimate, as equaling from 2,000 to 4,000 pounds per square inch. Any attempt to ascertain the pressure would be attended with the risk of having the casing and tubing thrown out of the well. The evaporation due to the removal of this pressure produces an extraordinary reduction of temperature. At Sheffield the temperature fell so low that ice formed in the well pipe and finally closed it. The ice was then drilled through 100 feet in depth. When it was pierced, the pressure threw

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a *C. Rend.*, lxxv, 154; J. C. Soc., xxv, 884.
b *Ibid.*, lxxv, 115; *Ibid.*, xxv, 885.
c *Ibid.*, lxxv, 270; *Ibid.*, xxv, 885.
d *Ann. de Ch. et de Phys.* (4), xxv, 559; J. C. Soc., xxv, 469.
e Letter of E. J. Crissey, secretary of the Fredonia Natural Gas-light Company, to S. F. P.

the tools and well casing out of the top of the derrick. When a stratum yielding gas is struck in boring, the force of the escaping gas prevents water from reaching the bottom of the well if poured down the side, or even, in some cases, if introduced from a tank through a pipe reaching to the bottom. In most cases by this latter arrangement (which gives the weight of a column of water several hundred feet in height) the gas is "stopped off". The gas has been used in several instances to work an engine for pumping without water or heat by introducing it into the cylinder, precisely like high-pressure steam. In drilling the Roy well, near Kane, Pennsylvania, the gas from a well more than one-fourth of a mile distant was used in this manner. It is very frequently used as a fuel for making steam, and, when there is a surplus, that is burned at the end of a pipe to prevent explosions. The greatest gas-well on record in the oil regions is the Newton well on the Nelson farm, 6 miles north of Titusville. There the gas raised a column of water 100 feet high with a noise that could be heard 2 miles, and when the column burst it threw the water 15 rods each way.

The Bradford Gas-light and Heating Company receive gas into a gasometer from wells near the city. Two sets of pipes pass through the city. One set passes from the wells to the gasometer, and has the same pressure as that on the wells; the other set passes from the gasometer, and delivers the gas under a pressure of about 6 inches of water. Gas is delivered from both sets of pipe; from the high pressure for boilers, etc., and from the other set for use in dwellings. The mains attached to the wells will deliver through the same orifice about ten times the amount delivered from ordinary street mains. The wells are so deep that the friction on the escaping gas is very great, and retards the motion and lowers the pressure as it escapes. The pressure at the wells gradually diminishes. In one case it ran down from an estimated pressure of 1,000 pounds to 6 pounds in five years. When first struck the gas would easily have lifted the casing out of the well, requiring a force of at least 500 pounds per square inch. It was estimated that during the month of January, 1881, 7,500,000 cubic feet of gas reduced to ordinary pressure were delivered in Bradford, where it is almost universally used for heating as well as for illumination. The burning of the superfluous gas at nearly all the wells forms at night great flaming torches, that glare in the darkness from the surrounding hillsides.

Mr. Charles A. Ashburner, of Philadelphia, has described a well which has received the name of the "Kane geyser well". It is situated 4 miles southeast of Kane, on the Philadelphia and Erie railroad. While drilling—

Fresh "water-veins" were encountered down to a depth of 364 feet, which was the limit of the casing. At a depth of 1,415 feet a very heavy "gas vein" was struck. This gas was permitted a free escape during the time the drilling was continued to 2,000 feet. When the well was abandoned, from failure to find oil, and the casing drawn, the fresh water flowed in, and the conflict between the water and the gas commenced, rendering the well an object of great interest. The water flows into the well on top of the gas until the pressure of the confined gas becomes greater than the weight of the superincumbent water, when an explosion takes place and a column of water and gas is thrown to a great height. This occurs at present at regular intervals of thirteen minutes, and the spouting continues for one and a half minutes. On July 31 (1879) Mr. Sheafer measured two columns, which went to a height respectively of 120 feet and 128 feet. On the evening of August 2 I measured four columns in succession, and the water was thrown to the following heights: 108 feet, 132 feet, 120 feet, and 138 feet. The columns are composed of mingled water and gas, the latter being readily ignited. After nightfall the spectacle is grand. The antagonistic elements of fire and water are so promiscuously blended that each seems to be fighting for the mastery. At one moment the flame is almost entirely extinguished, only to burst forth at the next instant with increased energy and greater brilliancy. During sunshine the sprays form an artificial rainbow, and in winter the columns become encased in huge transparent ice chimneys. A number of wells in the oil regions have thrown water geysers similar to the Kane well, but none have attracted such attention. (*a*)

Some of the most remarkable gas-wells that have ever been drilled outside the oil region are the Neff gas-wells near Gambier, Knox county, Ohio. These wells are located on the Kokosing river, a tributary of the Walhonding river, which empties into the Muskingum above Zanesville.

No. 1 well is sunk not far from the line of Knox and Coshocton counties. Such a powerful vein of rich illuminating gas was struck as to cause suspension of all work. From this well immense floods of water, in paroxysms of about one minute interval, are thrown up to a height of 80 to 100 feet. The vein of water was struck, fortunately, at a depth of only about 66 feet, where a large stream was tapped, producing no inconvenience in boring until the gas was struck, when suddenly it was all discharged at regular intervals of not more than one minute. The boring throughout its whole length of 600 feet is filled and discharged, making a most magnificent hydraulic display. It is, however, at night that the grand phenomena of this well are best exhibited. The enormous amount of water, perhaps 10,000 barrels per day, keep the derrick and floor so wetted that the gas can be fired with safety. When this is done, at the instant of paroxysm a sudden roar is heard, and at night the flame is seen shooting up 15 to 20 feet above the derrick, which is 53 feet high. It is a grand sight to see the flame leaping fiercely amid the rushing waters, darting out its fiery tongues on every side; now rolling above the most powerful part of the jet like balls dancing on a fountain, and now, with an intensely bright flame, leaping suddenly down the column and running along the floor, and illuminating, as with burning liquid naphtha, which is undoubtedly thrown out with the water, the whole forest scenery around as a magnificent spectacle. When the derrick was covered with ice the gas escaping from the well was frequently ignited, and the effect, especially at night, of this fountain of mingled fire and water shooting up to the height of 120 feet through a great transparent and illuminated chimney is said to have been indescribably magnificent. (*b*)

A phenomenon (called a gas volcano) that has been observed in the valley of the Cumberland, in southern Kentucky, near Burkesville, is thus described. In a private communication Dr. J. S. Newberry writes:

This name is given to explosions of gas accumulated under the flaggy rocks of the Hudson River group in the valley of the Cumberland and its tributaries. I have visited localities where explosions have occurred, but have never witnessed one myself. They result from the confinement of gas generated below under impervious strata of rock, the pressure ultimately becoming sufficient to throw off the superincumbent mass of rock, earth, water, etc. These explosions are not very uncommon in the valley of the Cumberland, and they are well known to the inhabitants.

a *Jour. Frank. Inst.*, cviii, 347.

b Prospectus of the Neff Petroleum Company, 1866.

SECTION 2.—USE OF NATURAL GAS IN THE MANUFACTURE OF LAMPBLACK, ETC.

The gas of the Neff and other wells is largely utilized for the production of lampblack. This black is of very superior quality, and when first produced and thrown upon the market commanded as high a price as 75 cents per pound, but the production was very soon increased so largely in comparison with the demand that the price is now only about 15 to 20 cents per pound. Concerning the production of lampblack from natural carbureted hydrogen, a writer in Dingler observes as follows : (*a*)

It is known that gases escaping from the soil of some of the oil districts of Pennsylvania (compare 1878, 228, 534) is prepared for illumination and heating purposes (1877, 224, 552). P. Neff now produces from the same by imperfect combustion an excellent lampblack, which he brings into market under the name of "*diamond black*". This gas flows from two wells which are bored at Gambier (Knox county, Ohio), in the vicinity of the mouth of the Kokosing. According to J. R. Santos (*Chemical News*, 38, 94, 1878), it has the following composition :

	Per cent.
Marsh-gas	81.4
Ethylene	12.2
Nitrogen	4.8
Oxygen	0.8
CO	0.5
CO_2	0.3
	100.0

Neff burns daily with 1,800 burners of peculiar construction almost 8,000 cubic meters of gas and obtains from it 16 per cent. of lampblack. The specific gravity of this lampblack is, according to Santos, 1,729 at 17° C. Dried at 200° an elementary analysis gives:

	I. Per cent.	II. Per cent.
C	96.041	96.011
H	0.736	0.747

By means of Sprengel's air-pump the gas is pumped out, having the following composition :

CO	1.387
CO_2	1.386
N	0.776
H_2O	0.682

Besides, 0.024 per cent. of a bright yellow hydrocarbon soluble in alcohol, and which boils at from 215° to 225°, is obtained, which is probably impure naphthaline. The small quantity of ashes consisting of the oxides of iron and copper comes from the burners. The united composition of diamond black is accordingly as follows:

	Per cent.
C	95.057
H	0.665
N	0.776
CO	1.378
CO_2	1.386
H_2O	0.682
Ashes	0.056
	100.000

The black is consequently very pure, and in any case is well adapted for fine printers' ink and the like. It is also used in the preparation of lithographic ink.

At New Cumberland, Hancock county, West Virginia, Messrs. Smith, Porter & Co. use natural gas for burning fire-brick. The gas from one well furnishes fuel for nine brick kilns, three engines, and ten furnaces in the drying house, with fuel and lights for several dwellings, besides a large excess that is burned at the end of an escape pipe. They produce 55,000 brick daily.

SECTION 3.—GAS FROM CRUDE PETROLEUM, PARAFFINE OIL, AND RESIDUUM.

A large number of patents have been taken out for processes and apparatus for the manufacture of illuminating gas from crude petroleum and the dense products of its manufacture. The general principle upon which all of these processes depend for operation consists in a distillation of the materials at a temperature sufficiently elevated to crack the petroleum compounds into gaseous products. The "gas oil", which is petroleum deprived of its naphtha, is conducted into a retort previously heated to a red heat. The method of heating the retort, the manner of distributing the fluids, and the purification of the gas from the undecomposed petroleum and tarry matters, are all subject in the different patents to differences of arrangement, but the underlying principle of destructive distillation is fundamental in all of them. This method of preparing illuminating gas is quite extensively used for lighting large manufactories and villages and small towns. It is especially valuable for these purposes on account of the comparative simplicity of the apparatus and process of manufacture and the purity of the product. The gas prepared by this method is particularly free from the ammonia and sulphur compounds that contaminate gas prepared from coal.

a Dingler, ccxxxi, 177.

SECTION 4.—GAS FROM NAPHTHA.

Gas is also prepared by the destructive distillation of petroleum naphthas and benzine. One of the methods of operating this process is thus described: A still holding 40 barrels of naphtha contains a coil of 2-inch pipe; steam passes through the coil, volatilizing the naphtha, the pressure carried on the still being on an average about one-half inch. The vapor passes to three benches, of three retorts each, by a 3-inch pipe; 1½-inch branches to each retort are tapped into the side of this mouth-piece, connecting with a 6-inch cast-iron pipe, which lies inside of the retort to within 1 foot of the back, and is open at the back end, but plugged in front with a clayed stopper. The vapors circulate through the 6-inch pipe to the back end of the retort and return forward and up the stand-pipes, which are 6 inches in diameter. These retorts are heated to dull redness. During this transit the vapors of naphtha are converted into gas and pass through a submerged U-shaped condenser, 18 inches in diameter, lying in a tank with sufficient inclination for a drip. An air-pump is used to preserve an exhaust of about 3 inches, from which the gas passes to a station meter and "mixer". At every revolution of the station meter 42 per cent. of air is drawn in by a reverse drum on the same spindle, and is mixed with the gas, which thence passes to the holder. The introduction of air is not necessary, as the gas can be burned with a suitable burner; but the gas thus prepared is very rich, and the air is introduced to reduce its quality to the average standard of 15 or 20 candle-power. It will be observed that all apparatus for purifying the gas is dispensed with, the gas being entirely free from all deleterious sulphur and ammonia compounds. The only residue in this process is a small quantity of heavy oil, apparently a residue from the cracking of the benzine.

SECTION 5.—CARBURETORS.

The idea of saturating illuminating gas with the vapors of volatile hydrocarbons for the purpose of increasing its illuminating power was entertained long before the discovery of petroleum in commercial quantities.

Lowe patented a process in 1841, and alluded to it in a general way in a previous patent of 1832, the claim in which is so comprehensive that, if valid, it would render doubtful all subsequent patents. (*a*) Mansfield also claimed the application of atmospheric air as a vehicle for the vapor of very volatile hydrocarbons in such a manner that the "vaporized air" might be burnt like ordinary coal-gas. (*b*)

As early as 1856 Longbottom attempted to prepare illuminating gas by passing air through benzole, ether, or oil of turpentine. (*c*) These appear to be the earliest attempts at carburation. These machines were never made a practical success, however, until the distillation of petroleum furnished volatile hydrocarbons in commercial quantities. The low price at which these products could be obtained after petroleum became extensively produced led to the invention of a large number of machines in a great variety of form and principle of construction. The number patented in England, France, Germany, and the United States prior to 1880 must be in the neighborhood of 1,000. The first patents that were issued were for inventions that produced a partial or a complete saturation of the gas or air without in any manner controlling the evaporation or the temperature. The result of the operation of these machines was invariably an overcharging with vapor in warm weather or when the apparatus was first put in action, causing subsequent condensation of the vapor, followed by undercharging as the naphtha was distilled and the residue became less volatile, and as it also was rendered more dense in consequence of the reduction of temperature resulting from the evaporation. Evaporation was induced and rendered more constant and rapid by the construction of a sort of labyrinth through which the gas or air was forced. The tank containing the naphtha was made shallow and of large diameter, and curtains of flannel were so arranged that the upper border of the curtain was securely fastened to the under surface of the cover of the tank and allowed to hang freely, dipping into the naphtha below. As a result, the gas was forced to pass through the spaces between these curtains, and a great evaporation and absorption of the naphtha vapor by the gas followed. This method of carburation, while very effectual, was still open to the objections above made, and did not furnish uniform results; but the difficulty was removed by an invention by which the tank in which the naphtha was being distilled was submerged in a wooden tank of water. The great latent heat of water caused it to give out heat, equalizing the temperature, producing a uniform distillation, and consequently a uniform partial saturation of the gas or air. This contrivance may be said to have rendered the carbureting of air a success, and a large number of machines have been constructed upon this principle. The general arrangement of the apparatus has been a wooden tank, sunk in the ground outside the building and below the frost. In this tank the receptacle for the gasoline is placed, and the intervening space is nearly filled with water. At this depth the water preserves nearly a uniform temperature at all seasons, and from its large volume it compensates the gasoline for its loss of heat due to evaporation, and keeps both the temperature and the distillation uniform; consequently the amount of combustible material supplied the current of air is uniform. This current is forced through the labyrinth by an air-pump worked by a heavy weight, and placed in the basement of the building to be lighted. This form of carburetor is entirely free from the grave defect of starting at the beginning of the evening with an excessive evaporation and ending at 10 or 12 o'clock with an insufficient evaporation. The distillation proceeds uniformly, and changes in quantity gradually, the difference being perceptible only after the machine has been in operation several weeks or months. The gradual fractional distillation results in the accumulation of a residue in the labyrinth too dense for evaporation with

a *Jour. Soc. Arts*, ii, 503. *b* *Ibid.*, 520. *c* Jahresbericht, 1856, p. 422.

sufficient rapidity to properly carburet the air, and is, consequently, attended with diminished illumination. Many attempts have been made to remedy this defect, in which great success has been attained by a remarkable invention of very recent date. This machine is called the metrical carburetor, and is used for carbureting either gas or air. The name designates a peculiar feature of the instrument—that it *measures* the amount of carbureting fluid to either the gas or the air; hence there is never an excess of carburation, no fractional evaporation, and no condensation of liquid in pipes. One and one-half to 2 gallons of light naphtha are measured to 1,000 cubic feet of ordinary street gas, or 3 to 6 gallons of gasoline to 1,000 cubic feet of air, according to the purpose for which the gas is to be used.

The carburation of gas and air has been made the subject of many elaborate researches. Prominent among those who have conducted them is the late Dr. Henry Letheby, medical officer of health to the city of London, who, as early as 1861, reported that—

With regard to the carbureting process we are of opinion, from the data obtained by the laboratory experiments quoted in the report to the commission of the 30th of July last and the experiments made on the public lamps in Moorgate street during the months of June and July last, that the process of carburation appears to be capable of economizing the use of gas in the public lamps to the extent of from 40 to 50 per cent. This conclusion is founded on the assumption that the best quality of naphtha is to be used, namely, a naphtha which will give to the gas continuously a proportion of about 10 grains of volatile hydrocarbon to each cubic foot of gas, these being the average results of the laboratory experiments. (*a*)

The following comparative tests were published in 1879 in *Engineering*, but the author is not mentioned:

PRACTICAL TEST.—Barometer, 29.8; temperature, 56°; the weight of gasoline, 655 grains to water 1,000 grains; therefore one gallon of gasoline = 45.850 grains. The air was simply aspirated at the rate of 6 cubic feet per hour through an ordinary chemist's wash-bottle, and each cubic foot took up 735 grains, illuminating gas of 17.10 candles taking 585 grains.

$$\frac{\text{1,000 cubic feet of air} = \text{735.000 grains}}{\text{1 gallon of gasoline} = \text{45.850}} = \text{16.0 gallons of gasoline per 1,000 cubic feet of air.}$$

$$\frac{\text{1,000 cubic feet, 17.10 gas} = 585.000}{\text{1 gallon of gasoline} = 45.850} = \text{12.7 gallons of gasoline per 1,000 cubic feet of gas.}$$

One thousand cubic feet of air, after being carbureted, = 1,320 cubic feet; and 1,000 cubic feet of 17.10 gas, after being carbureted, = 1,270 cubic feet.

SPECIFIC GRAVITY TEST.—The time required to pass equal volumes of air, gas, carbureted gas, and carbureted air, under equal pressure, through the same aperture (Shilling's test), was: air, 88 seconds; gas, 58 seconds; carbureted gas, 90 seconds; carbureted air, 104 seconds.

$$\text{Gas, } \frac{58^2}{88^2} = \text{434 to air 1,000.}$$

$$\text{Carbureted gas, } \frac{90^2}{88} = \text{1,045 to air 1,000.}$$

$$\text{Carbureted air, } \frac{10}{88^2} = \text{1,396 to air 1,000.}$$

PHOTOMETRIC TEST.—Test on Hartley's improved photometer, 15-hole argand burner (old standard), 7-inch by 2-inch chimney, consuming 2.4 cubic feet per hour of carbureted gas, = 14.59 standard candles; reduced to the standard of 5 cubic feet, = 37.78 standard candles.

Also, with No. 1 steatite bat-wing, consuming 2.40 cubic feet per hour, = 18.63 standard candles; reduced to the standard of 5 cubic feet, = 38.83 standard candles; 3.48 cubic feet per hour of carbureted air consumed through argand burner = 16.52 candles; reduced to the standard of 5 cubic feet, = 23.70 candles.

DURABILITY TEST.—The durability of 1.10 cubic feet 4-inch flame:

	Min.	Sec.
Gas	5	45
Carbureted gas	16	38
Carbureted air	11	24

Various forms of machines were experimented on, viz, cylinders containing lamp cotton, sponge, felt, and wood carbon. They are all useless and obstructive, nor do they yield so high or regular a light as air aspirated or exhausted through gasoline and charged into a gas-holder, from which it is supplied ready for use at the burner when required.

Upon this the editor of the *Journal of the Franklin Institute* comments as follows:

Two great objections still exist to the use of these machines, viz, the impossibility of storing large quantities of gasoline without the risk from fire to property in the neighborhood; and, secondly, that if the pressure becomes excessive the flame from the burner will be blown out, and terrible explosions, resulting in loss of life, have followed in consequence. The increase in the illuminating property of coal-gas as ordinarily furnished, when passed through these machines, is very great, and the flame, also, is not liable to be blown out with increased pressure; and a wide field seems to be open in this direction if all danger from fire in the carbureting of the gas could be done away with. (*b*)

The value of the metrical carburetor will be appreciated when it is understood that it gives a degree of carburation perfectly satisfactory for gas with 1½ to 2 gallons of light naphtha to 1,000 cubic feet of gas, and for air with 3 to 6 gallons of *gasoline* to 1,000 cubic feet of air. Moreover, this quantity is *measured* to the gas or air with great accuracy, is all immediately absorbed, and, as no supersaturation ever occurs, no condensation ever takes place in the pipes, and no "running down of the light" is ever due to cold nights or distillation of the gasoline. In regard to economy, safety, and perfect operation this metrical carburetor far excels all others hitherto invented.

a Jour. Soc. Arts, x, 87.

b Jour. Franklin Institute, cvii, 404, 1879.

CHAPTER IV.—THE USE OF PETROLEUM AND ITS PRODUCTS AS FUEL.

SECTION 1.—THEORETICAL CONSIDERATIONS.

The excessive production of petroleum in some localities, and the scarcity of coal and wood in others where petroleum abounds, has led to a large number of experiments in the use of petroleum as fuel. The theoretical consideration of its value as fuel was made the subject of elaborate investigations at an early date. In 1864 R. Mallett stated that—

The theoretical evaporating power of American petroleum may be ascertained as follows:

$$\frac{\begin{matrix} C\ 86 \\ H\ 14 \end{matrix}}{100} = 18.06 \text{ kilograms.}$$

For—

$$\begin{aligned} C\ 0.86 \times 8.080 &= 6948 \\ H\ 0.14 \times 34.462 &= 4824 \\ &\overline{11772} \text{ heat units.} \end{aligned} \qquad \frac{11772}{652} = 18.06$$

Regnault's formula is 65.2 heat units for the evaporation of 1 kilogram of water at 0° to steam at 150°. (*a*)

In 1869 Henri St. Claire De Ville conducted an elaborate research upon the calorific power and physical peculiarities of petroleum. His results are given in the following table:

Locality of the oils.	Specific gravity.	Calorific power.
1. Heavy oil from White Oak, West Virginia; well, 135 meters deep; lubricating oil.	0.873	10.180
2. Light oil, from Burning Springs, West Virginia; well, 220 meters deep; illuminating oil.	0.8412	10.223
3. Light oil, from Oil creek, Pennsylvania; well, 200 meters deep; illuminating oil.	0.816	9.963
4. Heavy oil, from Ohio	0.887	10.399
5. Heavy oil, from the Plummer farm, Franklin, Pennsylvania; well, 200 meters deep; lubricating oil.	0.886	10.672
6. American petroleum, as offered for sale in Paris, probably from Pennsylvania.	0.820	8.771
7. Heavy coal-oil, from the Paris Gas Association	1.044	8.916
8. Petroleum from Parma, near Salo	0.786	10.121
9. Oil from Java, commune Daudang-Llo, district Tima-acon, residency Pembang.	0 923	10.831
10. Oil from Java, commune Tjibodas-Fanggah, district Madja, residency Cheribon.	0.823	9.593
11. Oil from Java, commune Gogor, district Kendeng, residency Karabaya.	0.972	10.183
12. Oil from Bechelbronn, upper Rhine, distilled	0.912	9.708
13. Oil from Bechelbronn, raw	0.892	10.020
14. Oil from Schwabweiller, lower Rhine	0.861	10.458
15. Oil from east Galicia	0.870	10.005
16. Oil from west Galicia	0.885	10.231
17. Raw schist oil, from Vagnas, Ardèche	0.911	9.046
18. Raw schist oil, from Antun, manufactured by Champeaux, Bazm & Radary.	0.870	9.950
19. Heavy *Kiefernharz* oil, from Mount de Marzan	0.985	*10.081

* *C. Rendus*, lxvi, 442; lxviii, 349; C. N., 1869, 237.

In 1871 he examined the petroleums of the Russian empire from the neighborhood of Baku, on the Caspian sea, and obtained the following results: No. 1 was crude naphtha from the Balchany wells, specific gravity at 0°, 0.882; No. 2 was residuum from the Baku stills, specific gravity 0.928; No. 3 was black oil from the Weyser refinery at Baku, specific gravity 0.897; No. 4 was light oil of Baku, specific gravity 0.884; No. 5 was heavy oil of Baku, specific gravity 0.938. On distillation they afforded:

Temperature.	1.	2.	3.	4.	5.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Volatile at 100° C	1.0				
Volatile at 140° C				2.7	
Volatile at 160° C	5.0			7.0	
Volatile at 180° C	9.3			13.3	
Volatile at 200° C	14.0		2.3		1.0
Volatile at 220° C	15.3			19.0	1.3
Volatile at 240° C		1.0	8.0	23.3	1.7
Volatile at 260° C	29.0	2.3	14.0	29.3	3.0
Volatile at 280° C	37.0	4.3	22.3	36.7	6.0
Volatile at 300° C	41.3	7.7	33.7	73.3	9.7

COMPOSITION AS GIVEN BY ANALYSIS.

Hydrogen	12.5	11.7	12.0	13.6	12.3
Carbon	87.4	87.1	86.5	86.3	86.6
Oxygen	0.1	1.2	1.5	0.1	1.1
	100.0	100.0	100.0	100.0	100.0

a Pract. Mech. Jour., March, 1864, p. 314; Dingler, clxxii, 71.

From these data their calorific power was calculated and compared with that obtained by experiment in the petroleums marked 4 and 5. The results are thus given in calorics:

	1.	2.	3.	4.	5.
Calorific power, calculated	11.370	11.000	11.060	11.660	11.200
Calorific power, observed	(11.070)	(10.700)	(10.760)	11.460	10.800

Numbers 1, 2, and 3 were calculated from the results in 4 and 5. These results show the Baku oils to be superior to those of America and Europe for heating purposes. (*a*)

In 1877 K. Lissenko stated that—

Some forms of petroleum that yield a less amount of heat on combustion than that calculated are regarded as containing hydrocarbons of the series C_nH_{2n+2}, accompanied by small quantities of non-saturated hydrocarbons. (*b*)

Later, M. Berthelot has shown in a research upon the gaseous hydrocarbons that the heat of combustion of an hydrocarbon is not always equal to that of its elements. The variation is least in the case of the saturated hydrocarbons C_nH_{2n+2}. (*c*)

As no two petroleums from different localities are alike in composition, these researches indicate that considerable variation exists in the heating power of different petroleums, and that practically their heating power is considerably less than would be calculated from their elementary composition.

Section 2.—PETROLEUM AS A STEAM FUEL.

The employment of petroleum as a steam fuel has been the subject of many experiments and much controversy. From a careful survey of the subject I conclude that no important practical difficulty has been anywhere encountered where for any reason petroleum has been a more desirable fuel than other material. Petroleum has always been burned for steam fuel more or less in the oil regions of Pennsylvauia. All sorts of experiments have been made there to burn the crude oil, both pure and mixed, with steam. Mr. D. A. Wray, on Oil creek, filled with crude oil, at 50 cents per barrel, an 8-horse boiler, with safety-valve attached. He fired up under it as if it was filled with water, and burned the vapor as if it were gas. The arrangement worked well until the spaces between the boiler tubes became choked with coke. This deposit of coke from distillation of the oil has been found to be the chief practical difficulty, and has usually been avoided by injecting steam through the escaping oil in such a manner as to completely volatilize it. Another practical difficulty observed by Mr. Wray was explained by him as in accord with an observation of Tyndall that the flame of a Bunsen lamp is intensely hot to objects immersed in it, but that it radiates comparatively little heat. Mr. Wray has observed that all successful contrivances for burning petroleum must distribute the flame *upon* the surface to be heated, and not beneath it. Inattention to this condition is the cause of many unsuccessful attempts to generate steam by the use of crude petroleum. It is impossible that I should attempt to describe the great number of apparatus devised for burning the crude oil, many of which are entirely adequate. The successful use of the oil for years in stationary engine boilers has demonstrated the absence of all serious practical difficulties. The questions of economy and safety appear to have determined that for *general* use it is not a desirable fuel, while in special cases its use has been attended with complete satisfaction.

Mr. William T. Scheide has communicated to me the following results obtained by the United Pipe-lines:

The oil was burned with a steam jet under four stationary boilers (60-inch shells 14 feet long, with 83 3-inch tubes), and the steam furnished a Worthington compound duplex pump doing an *actual* work of about 200 horse-power. (The indicated horse-power would probably be about 225 to 250 horse-power.) These boilers and this pump use as nearly as possible 4.54 pounds of bituminous coal per horse-power of *work done* per hour. Using this average, which is pretty well determined, as a basis, 1 ton of 2,000 pounds of this coal is equal as fuel to either 3.94 or 4.13 barrels of 42 gallons each of oil. The experiment was not conducted as it should have been, and there is a qnestion as to the pressure against which the pump worked, which accounts for the difference in the estimate. I think it may be stated, however, that 4 barrels of oil would be required to furnish the equivalent of a ton of good bituminous coal if the oil is burned with a steam jet. With an air jet I look for better results.

It has also been very thoroughly tested for use on steam vessels. In 1868 the then Secretary of the Navy reported that the appropriation of $5,000 for testing petroleum as a fuel on steam vessels had been expended on a series of elaborate experiments at the New York and Boston navy-yards.

The conclusion arrived at is, that convenience, comfort, health, and safety are against the use of petroleum in steam vessels, and that the only advantage thus far shown is a not very important reduction in bulk and weight of fuel carried.

At Woolwich experiments were made with naphthaline, creosote, residuum, tar, and grease, but nothing proved satisfactory except pure American petroleum and "clear British shale oil". Comparative tests showed the—

	Per cent.
Highest evaporation of water per pound of coal	7.33
Lowest evaporation of petroleum	12.02
Highest evaporation of petroleum	13.00

On July 31, 1869, a train arrived safely in Katschujan, 81 versts from Charkoff, whose engine was heated with raw naphtha (petroleum) instead of coals. The honor of the invention is ascribed to the mining engineer, Portski.

a *C. Rendus*, lxxii, 191; lxxiii, 491.
b Russian Chem. Soc., June, 1877; C. N., xxxv, 180; J. C. S., xxiv, 453.
c *C. Rendus*, xc, 1240; J. C. S., xxxviii, 786.

Two engines on the Strasbourg line, fitted in 1870 with M. Deville's furnaces, burn from 3½ to 5 kilograms of oil to every kilometer traversed, or say 8—12 pounds to two-thirds of a mile. The oil is completely burned, and no sulphur is observed in the atmosphere of the tunnels.

Petroleum has also been used with entire success upon steamers and locomotives in the United States. While all of these experiments and practical tests show that petroleum can be used on locomotives without difficulty, and perhaps with some elements of superiority over other kinds of fuel, it cannot be affirmed that it is as yet so economical as to lead to its use in the face of the very grave and unquestioned elements of danger attending it. Coal in the United States is cheap, plentiful, and safe, but on the Caspian sea it is rare and costly. This fact constitutes a sufficient reason why persistent and successful efforts to burn petroleum and residuum on the steam vessels that traverse that sea should have led to its almost exclusive use for steam purposes. The following concise statement explains the method of its use:

An apparatus has been devised for the utilization of petroleum as fuel in steam navigation, and its application for this purpose in central Asia has, it is reported, been attended with results that are considered very satisfactory, such fuel also occupying much less space than the amount of coal necessary to produce a similar effect.

With the old-fashioned boilers in use—with a central opening running longitudinally—no modification, it is stated, is necessary for the employment of the fuel in question. A reservoir containing some hundred pounds' weight of the refuse, "astalki," is furnished with a small tube, bearing another at its extremity, a few inches long and at right angles with the conduit. From this latter it trickles slowly. Close by is the mouth of another tube connected with the boiler. A pan containing tow or wood saturated with astalki is first introduced to heat the water, and on the slightest steam pressure being produced a jet of vapor is thrown upon the dropping bituminous fluid, which is thus converted into spray; a light is applied, and then a roaring deluge of fire inundates the central opening of the boiler. It is a kind of self-acting blow-pipe.

The volume of fire can, it is stated, be controlled by one man, by means of the two stop-cocks, as easily as the flame of an ordinary gas jet. Mention is made of a steamer of 450 tons and 120 horse-power on this principle, 30 pood per hour of astalki being burned to obtain a speed of 13 nautical miles in that time; and as 1 pood is about 33 pounds, and costs on an average about 10 to 12 cents, or about $60 for a twenty hours voyage at full speed.

The use of petroleum in Russia for steam fuel on both locomotives and steam vessels has been very fully discussed by T. Gulichambaroff in the *Gornii Journal* for 1880. He says that—

In the Caucasus the refuse of the distilleries is used as fuel, which in 1874 could be had for nothing. In 1875 the price was 3*d.* per barrel of 20 poods (720 pounds); in 1876 it rose to 1*s.*, and 1877 to 2*s.*; in 1879 the price had reached 5*s.* 3*d.*, while raw petroleum at the same time was 10*s.* Attention is now being directed to the use of raw petroleum, against which there is a standing prejudice on account of the possibility of explosions. Any liability to explosion is easily removed by exposure to the air for a few days. On the Balachauskoi railroad the locomotives are fired with raw petroleum, which is poured into the tender direct from the springs; yet there has never been an accident. The author has seen burning logs quenched with petroleum without setting it on fire, and spontaneous combustion is impossible, as the oils do not absorb oxygen. At present all the steamers on the Caspian sea use liquid fuel, 4.5 to 4.9 pounds per horse-power; 1,080 pounds of naphtha (petroleum) is found to be equal to 343 cubic feet of oak wood. The use of petroleum by injectors and its freedom from sulphur present great advantages over any other form of fuel. (*a*)

The action of hydrocarbons at a red heat with steam has been investigated by M. Coquillion. He shows that steam assists the dissociation of the hydrocarbons, producing at the same time a fall of temperature which is added to that produced by the reduction of CO_2 to CO. (*b*)

As already stated, the use of petroleum for steam fuel is determined by its cost relative to other kinds of fuel. With the low price of petroleum at Baku and the absence of wood and coal on the steppes of Russia and the shores of the Caspian sea, there can be no question that petroleum is the cheapest and best steam fuel to be had in that region. But in the United States the question lies between petroleum and anthracite coal for ocean steamers and bituminous coal on the western rivers. I think no one would now question the ease and efficiency with which petroleum can be burned in several forms of apparatus lately invented, nor can it be denied that it is less bulky than coal and more conveniently handled; but that it is a safe material to use on ocean passenger steamers as compared with coal cannot be maintained. Moreover, the claim that is made that much less stowage is required is not found to hold to any extent against anthracite coal. A ton of anthracite requires 48 cubic feet and a ton of petroleum requires 44 cubic feet. The difference is inconsiderable. As the question is at present stated, I do not look for any considerable increase in the use of petroleum for steam purposes in the United States.

SECTION 3.—PETROLEUM AND ITS PRODUCTS IN THE MANUFACTURE OF IRON.

The natural gas of the oil-wells has been successfully used in the manufacture of iron in the vicinity of Pittsburgh, Pennsylvania. Messrs. Spang, Chalfant & Co., whose works are at Sharpsburg, brought the gas in a 6-inch pipe to their works from wells near Saxonburg, Butler county, a distance of 17 miles. They use it for puddling and heating and for making steam. Messrs. Rogers & Burchfield placed their works at the wells on the Kiskimenitas, a tributary of the Allegheny river. They use it in an ordinary reverberatory furnace by bricking up the bridge and introducing the gas in pipes with a blast. It has been remarked that the quality of the iron is something wonderful; with ordinary gray coke pig-iron sheets for tin-plate equal to those from the best charcoal iron are made at a cost of $50 per ton less.

a Proc. London Inst. Civil Engineers, lxiii, 408. *b* C. *Rendus*, No. 19, 1878; C. N., xxxvii. 262.

A large number of processes have been invented and patented for using raw petroleum in the manufacture of iron. Of these the Eames process appears to have been the most successful, and to have had the most satisfactory trial.

At the Laclede iron works, in Saint Louis, experiments have been instituted under what was known as the "Whipple and Dickerson", or "Ambler process". These experiments were unsatisfactory, but in what respect I have not been able to ascertain. Experiments were also made at the Chatham dockyard, in England, which were in many respects highly successful, particularly with reference to the fine quality of iron produced.

The Eames process has been put into practical operation both in Titusville, Pennsylvania, and in Jersey City, opposite New York. Why it has not proven a commercial success I have not been able to learn. Competent judges having an interest in the success of the establishment at Titusville bear testimony to the extraordinarily fine quality of the iron produced from scrap and refuse of the most forbidding character. The process has been made the subject of a most careful and exhaustive examination by Professor Henry Wurtz, of New York, and Professor R. H. Thurston, of the Stevens Institute of Technology, Hoboken, New Jersey. The cut, Fig. 57, represents the apparatus in section. It consists of an ordinary reheating furnace with the "generator" and steam-boiler attached. The generator, which is the peculiar feature of the apparatus, is shown at A. It consist of a cast-iron vessel, from the sides of which shelves project alternately. The oil, entering from a reservoir at D, trickles over these shelves, from which it is swept by a jet of steam superheated to incandescence, entering the generator at E from the coil B. The amount of oil required for this furnace, which is capable of working charges of 3,000 pounds and making steam for the rollers besides, is a maximum of 30 gallons or 200 pounds per hour. The trickling oil is met by the jet of steam moving in the opposite direction, and is at once completely vaporized under a pressure of about 10 pounds and is carried into the furnace C. Air enters at F, and, mingling with the mingled vapor and steam, passes through the former bridge at H, and burns within the furnace in a long solid sweep of flame, which escapes from the furnace at I, and returns, after passing beneath the boiler, through the boiler flue to the stack. The old bridge of the furnace is completely bricked up excepting at H, where a space extends across the furnace, closed only by fire-bricks placed on end, and it is found that if this "combustion chamber" has a horizontal thickness of more than 18 inches the fire-bricks are *fused*.

I quote the language of Professor Wurtz's memoir respecting the working of the apparatus described:

It is quite easy to determine with precision with the arrangements at Jersey City the relations of consumption of oil to iron produced, and time, labor, and material occupied in any special case. The oil was fed from a tank, sunk in the ground, which had a horizontal section throughout of 4 feet square. Each inch in depth, therefore, corresponded to 2,304 cubic inches, or closely enough to 10 United States gallons of 231 cubic inches. By gauging with a graduated rod each hour, therefore, the hourly consumption of oil was readily followed up. It was thus determined by me that, starting with a cold furnace and boiler full of cold water, 45 minutes was a maximum time, with oil fed at the rate of 30 gallons per hour, or 22.5 gallons in this time, to bring the whole fire space to a dazzling white heat. Six piles of boiler scrap, averaging 500 pounds, or 3,000 pounds in all, being then introduced, 35 minutes more at the same rate of consumption not only brought the piles to a high welding heat, but raised the steam in the boiler to 90 pounds pressure, being that required to operate the rolls. The time required after the furnace was heated and steam up for each charge of 3,000 pounds averaged at most 80 minutes, and as the brick-work became heated throughout it was apparent that the feed of oil might be somewhat diminished. Thus in a working day of ten hours just seven such charges could be worked off, averaging 2,500 pounds of rolled iron each; total, 8 tons per day of boiler-sheet from one such furnace, with an average consumption, as a maximum, of 30 gallons (200 pounds) of oil per hour, or 300 gallons (2,000 pounds) in all. To this must be added, however, the fuel used under the generator and small supplementary boiler, which together was 500 pounds per day. It is admissible that one generator and one small boiler will operate several furnaces, the inventor says 5; if we say 4, it will diminish the small addendum of cost.

As to working this furnace with coal, it was ascertained from the testimony of the operators that, by keeping up the fire all night, so that a heat could be had at a reasonable time in the morning, the maximum product of finished sheet might be, with superior work, allowing 90 minutes for each heat, 6 tons, with a consumption of at least $5\frac{1}{2}$ tons of coal = 12,320 pounds, or 2,053 pounds of coal per ton. (*a*)

I have omitted Professor Wurtz's estimates of comparative cost, as any one interested can readily make them to suit the prices of coal and crude oil in his own locality.

SECTION 4.—STOVES.

During the last few years stoves in great variety have been contrived in which some of the products of petroleum are consumed as fuel. Practically they may be divided into naphtha and kerosene stoves. In reference to the use of the naphtha stoves I have nothing to say, excepting that their manufacture, sale, and use ought to be prohibited by law. I need not repeat here the facts and arguments already brought forward to show why they are dangerous to persons who use them and to the communities in which those persons live. In spite of all that has been written and spoken on this subject, a vast number of them is sold every year. The apparent apathy of the public in reference to this matter is shown by the fact that after the terrible fire in the New York tenement houses in January, 1881, caused by the careless use of gasoline in some sort of plumbers' apparatus, Commissioner Gorman said to a *New York Herald* reporter—

That he had examined the law regarding the use of gasoline, and he found no statute that could prevent its being used as a heating and illuminating agent. Section I, chapter 584, of the laws of 1871 provided that "no refined petroleum, kerosene or other burning fluid shall be used for heating or illuminating purposes in any dwelling, house, store, shop, restaurant, car, coach or other vehicle, which

a *Am. Chem.*, vi, 94.

shall evolve combustible vapor at a temperature below 100° Fahrenheit". Now, had the law not been repealed, it would have prevented plumbers using gasoline for heating purposes. The law, as I have read it to you, was, however, repealed by section 4, chapter 742, of the laws of 1871, which reads "that no refined petroleum, kerosene, coal or similar oil, or product thereof, shall be used for illuminating or heating purposes which shall emit an inflammable vapor at a temperature below 100° F., or shall be kept for sale or stored within the corporate limits of the city of New York". (*a*)

On the 1st of June following 27 barrels of gasoline lying on the platform of the Consolidated Railroad freight-house in Springfield, Massachusetts, took fire from some accidental cause, and after a part of them were supposed to be extinguished several of the remainder exploded and injured about 40 persons more or less seriously. December 27 following the steamer West Point exploded and burned at West Point, Virginia. Nineteen persons were killed and a number badly injured. Her "cargo was made up of miscellaneous freight, among which were several hundred barrels of oil, sixty of which were *gasoline*". These are some of the gasoline accidents for one year, and yet there is no general legislation to prevent gasoline from being used in lamps and stoves and from being carried as common freight except section 4472 of the Revised Statutes of the United States, quoted on page 236.

The kerosene stoves are being brought to a great degree of perfection, and are found to be very useful. Of the several different manufacturers who are seeking the patronage of the public I am not disposed to select any as making in all respects an article superior to all others. These stoves act best with high-test oil, and are therefore safe. Their healthfulness depends upon the manner in which they are used. It is claimed that one of these stoves with two burners discharges an amount of carbonic acid into the atmosphere of a room equal to the respiration of 2½ persons. I have not examined the merits of this statement; but, assuming the statement to be correct, it is a sufficient reason why the most thorough ventilation should be urged upon those using these stoves. Very few are used under circumstances that admit of the removal of the products of combustion from the apartment, and when one is used in a small room occupied by two persons the contamination of the air amounts to that caused by the constant occupation of the room by from four to five persons. When to this unavoidable source of impure air is added the sulphurous acid and half-burned products of the combustion of poor and cheap oil, the use of petroleum stoves cannot be recommended as conducive to health. Yet they are cheap and convenient, are used by tens of thousands, and their use is increasing.

SECTION 5.—MISCELLANEOUS APPLICATIONS OF PETROLEUM PRODUCTS FOR HEATING PURPOSES.

Petroleum and nearly all of its products and natural gas are used in glass houses for producing high temperatures and flames free from soot and other materials that would injure the glass. At Wheeling, West Virginia, one of the largest glass houses uses benzine for producing the intense heat of the "glory holes", and other houses use natural gas for the same purpose. Throughout the oil regions natural gas is largely consumed in the towns for heating dwellings and culinary purposes. It is used with a large Bunsen burner, from which the flame is projected into an ordinary stove. Another method, and much the best, is to introduce the Bunsen flame into the back of an ordinary portable grate. The grate is filled with fragments of fire-brick, which become bright red in the gas-flame, and radiate as much heat as glowing anthracite, which, in fact, they much resemble.

A novel application of petroleum to the production of motive power has been made successful in Hock's petroleum motor, in which vapor of petroleum is exploded behind the piston of an engine and the expansive force made available as a motor. It claims to possess the following advantages over other similar engines:

1. Perfect safety; neither incompetence nor malice can produce a destructive explosion.
2. No particular attention needs to be given it.
3. The facility with which the engine can be started and stopped, no complex preparations being necessary.
4. Its almost noiseless operation. (*b*)

At Mosul, Persia, in the valley of the Euphrates, the crude petroleum and maltha from the springs of Hit is used for burning lime, and proves an invaluable fuel in a country nearly destitute of wood.

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a *New York Herald*, January 6, 1881; *Ibid.*, June 1, 1881.

b *Jour. Frank. Inst.* (3), lxviii, 87.

CHAPTER V.—THE USES OF PETROLEUM IN MEDICINE.

SECTION 1.—THE PHYSIOLOGICAL EFFECTS OF PETROLEUM AND ITS PRODUCTS.

Although crude petroleum has been used as a remedial agent from the earliest times, both in the Old World and in the New, I have not met with any recorded attempt at a careful study of its physiological effects. The few notes that I have made in reference to this subject are therefore fragmentary and inconclusive. While in the oil regions I was told several stories relating to the experiences of persons who had breathed natural gas or the vapors of the very volatile fluids that escape from the oil as it flows from the wells. From these several experiences I conclude that the natural gas from the wells intoxicates like laughing gas. Persons leaning over the edge of a well tank experience at first an agreeable sensation, which is followed by unconsciousness. On recovering consciousness the person is very talkative, exceedingly witty, with a vivid imagination. These effects do not disappear for several days, and are described as resembling somewhat those of a prolonged spree. Death results from the prolonged action of the gas. In March, 1880, a man was found dead at the top of a ladder at the man-hole of a tank. He was supposed to have become asphyxiated while watching the flow of oil into the tank, from breathing the gas which was escaping into the air through the man-hole.

Rhigolene, which is the most volatile fluid ever condensed from petroleum, and the lightest liquid known, is an effective anæsthetic agent, and has been used as a substitute for ether in a few instances. Professor Simpson used naphtha (specific gravity not stated) as an anæsthetic during the extraction of necrosed bones. The insensibility was deep and tranquil, and the breathing was less stertorous than when chloroform is used. Its effect on the heart's action, however, was much greater, the pulse becoming more rapid and fluttering. (*a*) Dr. French, of the Liverpool, England, board of health, investigated the subject on a memorial of citizens, and reported that petroleum had an offensive odor, but was not injurious to health. (*b*) Landerer relates a case, but does not say whether the petroleum was crude or refined. It is presumed the material was illuminating oil. A quantity was swallowed, the greater part of which was vomited. It produced a strong, burning sensation in the tongue and throat, both of which became reddened and swollen. The stomach and bowels were also affected with strong symptoms of gastro-enteritis. Both the urine and the sweat smelled strongly of the oil for several days, and the odor was especially strong under the armpits. The patient became very weak, but recovered.

In 1864 M. E. Georges published a memoir upon the physiological effects of petroleum ether, of which the following is a summary:

1. The essence of petroleum acts in a peculiar manner upon the creative faculties (sens génesique), and also under peculiar circumstances upon the temperament.
2. It occasions violent headache with nervous persons.
3. That action appears to be due to a peculiar principle, which may be separated from it, and which acts principally upon the brain and upon the heart.
4. The ether of petroleum can be employed with advantage to produce cold upon the exterior in operations, because it does not produce pain upon the parts where the blood flows. (*c*) The term petroleum ether evidently designates a substance similar to rhigolene.

The neutral paraffine oils and paraffine itself appear to be without action upon the human system. The extensive use of paraffine for chewing-gum shows it to be without deleterious effects.

Petroleum is generally destructive of animal life, and particularly of insect life. Hildebrant, an African traveler, advises smearing the face and hands with petroleum to protect them from mosquitoes. He also advises the use of petroleum upon horses and cattle as a protection against the deadly Dondorobo gad-fly. By its use natural history collections are also preserved from the invasion of moths and ants in the tropics. (*d*) Petroleum has been used in France to destroy insects on plants and walls, also on dogs. In the latter case it is applied either before or with soap. An agriculturist of Aube is reported to have said that rats and mice left his cellar when petroleum was stored there, and slugs left a garden that had been watered with the rinsings of petroleum casks. Its use has been recommended upon plants to kill lice, and also to kill mange and scab on dogs and sheep, for which purpose 10 parts of benzine, 5 parts of soap, and 85 parts of water are recommended. It must be used with great caution upon animals. Those who have used it recommend that it be diluted with benzine. The use of crude petroleum and maltha for ridding vines of parasites has already been mentioned, the product of the Albanian springs having been sent to Smyrna and the Levant for that purpose. Moths are destroyed in furniture and garments by immersing them in baths of benzine. One great obstacle, however, to the frequent use of petroleum products is their disagreeable odor, which to many people is particularly offensive.

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a *An. Sci. Dis.*, 1850. *b* *Ibid.*, 1864. *c* *Ann. du Genie Civil*, 1864, p. 525. *d* *Nature*, xviii, 373.

SECTION 2.—PETROLEUM AND ITS PRODUCTS AS THERAPEUTICS.

Crude petroleum has been used as a remedial agent in both external and internal administration. Its use as a liniment dates from a very remote antiquity. In 1839 M. Fournel addressed a letter to the French Academy, in which he discussed the employment of petroleum by the ancients in the treatment of itch. (*a*) He says:

> Pliny (Nat. Hist., Book XXXV, chap. 15), speaking of the petroleum of Agrigentum, that was called Sicilian oil, says: "They make use of it for lamps instead of oil; also for the scab in draught cattle." Before him Vitruvius (Ten Books of Architecture, Book VIII, chap. 3) had mentioned the custom among the Africans of plunging their beasts into the waters of a bituminous spring near Carthage; and after him Solinus (Poly. Hist., chap. II), speaking still of the springs of Agrigentum, says: "It [the oil] is used as a medical ointment in the diseases of draught cattle."

All the authors of the fifteenth, sixteenth, and seventeenth centuries have indicated the same remedy, notably among them François Arioste, who cured men and animals afflicted with itch with the petroleum which he had discovered in 1460 on Mount Libio, in the duchy of Modena. Among many others Agricola also may be cited, who said, in the middle of the sixteenth century, "Cattle and beasts of burden, when smeared with it, are healed of the scab." If I pass to petroleum obtained by distillation, I find that in 1721 Eyrinis obtained from the asphaltic stone of the Val-de-Travers, in the canton of Neuchatel, in Switzerland, an oil, of the efficacy of which for the cure of itch he boasted much, affirming that he had cured more than 30 persons by means of it. (*Dissertation upon asphalt or natural cement*, etc., pamphlet in 12mo; Paris, 1721.)

In America crude petroleum has always maintained a high reputation as an external application for rheumatism. The Indians living in the neighborhood of oil-springs used it for that purpose, and the early voyagers learned of them its value. Seneca oil and Barbadoes tar were offered for sale in the United States and Europe many years before petroleum in its present use became an article of commerce. In 1822 the editor of the *American Journal of Science* acknowledges the receipt from James R. Sample, of Barbadoes, of specimens of *Barbadoes green tar*, a petroleum of excellent quality, and indurated bitumen or "munjack", and says:

> The tar is found very useful in preventing lockjaw, when the first symptoms are attended to, by rubbing the spinal bone from end to end and the muscles of the thigh and arms. When taken internally it is also a powerful sudorific. (*b*)

Again, in 1833, when writing of the petroleum spring at Cuba, New York, Professor Silliman, sr., says the oil was used by people about that place for sprains and rheumatism, rubbed on. (*c*)

In recent years refined petroleum has borne a valuable reputation as a hair renewer. It is said to promote the growth and luxuriance of human hair and to stimulate the growth of hair on bald scalps to a wonderful degree. Marvellous as are the tales that are circulated by the press, I know of no authentic case, nor have I observed any notices of such cures in reputable scientific journals.

Throughout the oil regions of Pennsylvania petroleum bears a high reputation as an internal remedy in cases of consumption. The oil of the old American well, under the name of American oil, was sold in Pittsburgh for that purpose at the time when Kier was making his first experiment at distilling petroleum. While in the oil regions I met several persons who testified to having witnessed its beneficial effects either upon their own persons or upon those of near relatives. A Mr. S. stated that his brother-in-law was seriously ill with phthisis, when he commenced taking crude petroleum in teaspoonful doses, which he increased in a year to a tablespoonful. His case experienced a marked improvement, and the tubercles were said by the attending physician to have been healed.

During 1879 the French *Bulletin de Therapeutic* contained an article in which it was stated that petroleum had been proved very beneficial in chronic bronchitis, and was thought to be so in phthisis. Administered in teaspoonful doses before each meal, the nausea that was first experienced soon disappeared. For administration it had been put up by a Paris pharmacist in capsules containing 25 centigrams of the oil under the name of "huile de Gabion", after an ancient petroleum spring.

Notwithstanding these well-attested facts concerning the therapeutic action of petroleum, it cannot be said to have a recognized status in American pharmacy.

SECTION 3.—PHARMACEUTICAL PREPARATIONS OF PETROLEUM.

Petroleum has been deodorized and purified for administration by filtering. Within a few years a series of compounds has been prepared for homeopathic practice called myro-petroleum compounds. They are prepared by causing to react upon each other fixed oil of mustard, an alkali, and petroleum. The myronic acid of the oil of mustard forms a salt or soap with the alkali in which the petroleum is dissolved. There are four primary preparations, viz:

1. Myro-petroleum—album.
   - Refined petroleum.
   - Mustard oil.
   - Alkali.

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a *C. Rendus*, ix, 217. *b* *Am. Jour. Sci.* (1), v, 406. *c* *Ibid.* (1), xxiii, 99.

2. Myro-petroleum—nigrum.
   Crude petroleum.
   Mustard oil.
   Alkali.
3. Myro-petroleum soap.
   A mustard-oil soap containing paraffine. The claim is made that paraffine is saponified.
4. Glycero-petroleum.
   Which it is claimed is a petroleum *glycerine.*

The first three preparations are, no doubt, produced as claimed, and their merits as therapeutic agents rest on careful tests, not upon opinion. The claims that are set up, however, for these preparations—that paraffine is saponified and that glycerine is prepared from petroleum—show that the persons making such claims have no clear idea of the chemical constitution of either petroleum or the saponifiable fats. Paraffine was so named from being found destitute of affinity, and acids and alkalies have no more action upon pure paraffine than upon a piece of India rubber, and no substance resembling glycerine has thus far been obtained from petroleum or any of its products. They are all, however, including paraffine, soluble in soaps; hence soaps may be produced containing paraffine or petroleum, but glycerine cannot be obtained from petroleum. About 15 per cent. of paraffine can be incorporated with soap. These soaps are found very valuable in hospital practice for washing malignant ulcers and inflamed mucus surfaces. It is, however, as a material forming the basis of ointments that the preparations of petroleum have obtained their strong hold upon the medical profession. The preparations cosmoline, vaseline, petrolina, etc., which are all essentially the same thing, have now a permanent place in the materia medica.

As early as 1861 C. T. Carney, of Boston, substituted paraffine for wax, spermaceti, and almond oil in cerates, and exhibited specimens at the meeting of the Pharmaceutical Association that year. He remarked:

> An ointment made in this way would, in my judgment, be very permanent and keep a long time without becoming rancid or ropy.

White wax in small amount rendered the ointment more tenacious. (*a*) It was not until the discovery and preparation of so-called amorphous paraffine that a material was furnished to pharmaceutists that was destined to supplant the old preparations. I have made no attempt to adjust the conflicting claims of those who manufacture this preparation under different names. I prefer to leave that to the subtle administration of patent law. It is sufficient for my purpose that somebody discovered that when a petroleum residue obtained by evaporating the oil *in vacuo*, or by any other means that will prevent its destructive distillation, is filtered through animal charcoal, an amber-colored, nearly odorless material is obtained of the consistence of paste at ordinary temperatures. One man called it cosmoline, another vaseline, and others have given it other names. Whatever named, amorphous paraffine is rapidly becoming the ointment of the world. It is prepared by the manufacturers either plain or scented with rose or some other perfume for the retail trade, and is also prepared in bulk for the apothecaries.

At the meeting of pharmacists, held in 1880, for the revision of the United States Pharmacopœia, the superior claims of this material over all other preparations as a basis for ointments were acknowledged, and the necessity for its recognition as an officinal preparation of the pharmacopœia was conceded. Some difficulty was experienced in preparing a formula for a substance the origin of which was hidden behind the mysterious veil of conflicting patent rights. On the other hand, the profession was justly cautious in recognizing a name that might designate one thing to-day and another to-morrow. Finally *Unguentum Paraffini* obtained a name and place in the Pharmacopœia. Some difficulty has been experienced in establishing a proper melting point for the preparation. The merits of this question are fully set forth in the following paper, prepared by Dr. Charles Rice, of the Bellevue hospital, New York, and read at the last (1881) meeting of the American Pharmaceutical Association:

> "What melting point is most desirable for petroleum ointment?" * * * Our present as well as former pharmacopœias contain two principal classes of unctuous substances intended for external application; one of these of the class of cerates, and the other that of ointments. These have generally been understood to have two entirely different functions, at least in the majority of cases, and for this reason they have been carefully kept apart, although they overlap each other in a few instances. A cerate, as the name already implies, is a "waxy" ointment, that is, an ointment stiffened with wax, for the purpose of raising its melting point. An ointment is intended chiefly for "inunction", and for this reason should possess a melting point but little above that of the temperature of the body. A cerate, on the other hand, is rather intended as a dressing, to be spread on lint, linen, or muslin, and to be applied to the injured surface.
>
> These well-known distinctions furnish the clue to the solution of the question, at least from the standpoint of theory, and also from the standpoint of the physician. The writer has had an opportunity during the past year of learning the views and opinions of a considerable number of practitioners on this subject, and he only regrets that he cannot quote their statements and reports, which were made for another purpose than the drafting of the present paper in full, and with their names attached; but he is at liberty to state that most of them, and among them the foremost dumatologists, pronounce the melting points of several of the commercial petroleum ointments to be altogether too low.
>
> During the heat of summer particularly, and in the warmer sections of our country even in other seasons of the year, an ointment should not have a melting point below about 40° C. or 104° F., and as it is easier to soften an ointment by heat than to stiffen it by cold, it appears preferable to select a uniform melting point for the year round, based on the requirements of the average summer temperature.

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a Am. Jour. Phar. (3), ix, 72.

Petroleum ointment is principally desired by practitioners as a perfectly *bland*, *neutral*, and *inactive* base for suspending therein various topical remedies. Naturally, this very property of blandness and neutrality will in many cases alone produce curative effects, because it will permit the natural healing process to proceed normally and uninterruptedly, provided the injured part is thoroughly covered so as to exclude the air.

From the opinion of most of the practitioners whose views have been solicited or tendered two petroleum ointments of different melting points are chiefly desirable. One of these, which could take the place of lard or ointment or other low-melting unctuous compound, should have a melting point of 40° C. or 104° F. And the other, which could take the place of cerate or of corresponding compound of higher melting point, should have a temperature of about 46° C. or 115° F.

The preceding would be an answer to the query from the standpoint of the physicians. But there is another feature connected with the query which cannot well be separated from it, though it is not expressed in words. In fact, the question might as well have been formulated thus:

What is the most desirable melting point to be recognized by the next pharmacopœia for petroleum ointment?

While the pharmacist acknowledges the correctness of the distinction between ointment and cerates, and will doubtless agree with the opinion of the physician that there should be both a soft and a firm petroleum ointment, according to the purpose for which it is to be used, he will, on the other hand, most probably deprecate the introduction of more than *one* kind of simple petroleum ointment into the pharmacopœia, because a multiplicity of them will surely result in confusion, both on the part of prescribers and dispensers, and besides, because the likelihood of the pharmacopœial requirements being observed, will diminish in proportion to the number of grades recognized, since it is out of question for the retail pharmacist to prepare the article himself. Hence, from the standpoint of the pharmacist, it will be safest, at least with our present knowledge and experience, to recommend the official recognition of that petroleum ointment only which has the *lowest* melting point declared suitable by competent medical authority. And this melting point is 40° C. or 104° F. Any higher melting point can be easily obtained by incorporating with the petroleum ointment more or less *yellow wax*, and the exact consistence and melting point of the product will, therefore, be more easily within the personal control of the pharmacist than if he were compelled to rely upon the alleged melting point of a manufactured product.

The addition of *yellow wax* to petroleum ointment has long been known to yield a perfectly homogeneous and satisfactory product. Nor does it introduce into the mixture any source of deterioration, at least for any reasonable period of time, since it has been shown that the mixture remains a long while free from all trace of rancidity, particularly if the petroleum ointment itself was sweet and fresh.

It has been said above that pharmacists, as a rule, will probably prefer only *one* officinal petroleum ointment, and this supposition will probably be confirmed should any discussion of this paper take place after being read. But it is also approved by quite a number of physicians with whom the subject has been discussed, and to whom the difficulties attending the recognition of several grades have been pointed out. But, so far as the writer is aware, those who advocate the introduction of only one petroleum ointment, whether pharmacists or physicians, do not deny the correctness of the statement of the other side, that several grades of petroleum ointment of different melting points are very desirable. They only wish to point out that the *official* recognition of more than *one* kind would, by no means, be a guarantee that the other products could even be at all times procured in the market when required, or would be furnished if ordered. And as it is certain that the pharmacist can furnish to the physician equally satisfactory products of *controllable* and *known* melting points, if such are required, by the method above indicated, it is hoped that the two professions will come to the harmonious conclusion to recognize, in the forthcoming new pharmacopœia, only *one* petroleum ointment having a melting point 40° C. or 104° F. (*a*)

The merits of these preparations have met with a very cordial recognition in Europe, and frequent mention is made of them in foreign journals under the names of either cosmoline or vaseline. The following notice from an English journal presents many facts of general interest in relation to the substance and the varied uses to which the apothecary can apply it. It is presented in preference to others for the sole reason that it was convenient of access, and well represents the appreciative consideration which has been extended to "petroleum ointment" on the other side of the Atlantic:

AN ENGLISH VIEW OF VASELINE. (*b*)

BY W. H. SYMONS, F. R. M. S., F. C. S.

Although petroleum in some form or other has been in use for two thousand years (Herodotus, born B. C. 484, is the first writer who distinctly refers to it), petroleum jelly or vaseline has only been known during the last few years, and is said to have been discovered by Mr. R. A. Cheesebrough, of the Cheesebrough Manufacturing Company. I have been unable to find any authentic account of the manufacturing process, but according to the pamphlet which I have on the table, and which most of you have doubtless read, it is the residue from the distillation of petroleum purified by an elaborate system of filtration, known only to the company, or at least so says the pamphlet. This secrecy of its manufacture is one of the greatest drawbacks to its usefulness and official recognition.

Vaseline was the subject of an original paper read by Mr. J. Moss at the meeting of the Pharmaceutical Society, on February 2, 1876. He describes it as a pale yellow, translucent, slightly fluorescent, semi-solid, melting at 37° C. and having a specific gravity of 840 at 54° C. It is insoluble in water, slightly soluble in alcohol, freely so in ether, and miscible in all proportions with fixed and volatile oils. It is not acted upon by hydrochloric acid or solution of potash, and has all the other characteristics of a mixture of paraffines; an ultimate organic analysis made by him gave 97.54 per cent. of hydrocarbons.

Under the microscope, vaseline, in common with most other fats, is found to contain numerous small acicular crystals, doubtless consisting of a paraffine of higher melting point than the mass, but these do not in any way interfere with its usefulness, because of their extreme minuteness and easy fusibility.

Vaseline may be kept indefinitely without becoming rancid; this is its chief characteristic, and together with its indifference to chemicals and its readiness to take any perfume is sufficient to recommend it for pharmaceutical and toilet purposes in place of the fats generally used. (*c*)

If vaseline be considered too thin it may be thickened to any extent with paraffine wax. I have found one to seven a good basis for general use, or one in ten would answer for most purposes; but to obtain anything like smoothness in the mixture it must be thoroughly

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a *Proc. Am. Pharm. Ass.*, 1881; *Oil and Drug News*, September 6, 1881.

b A paper read before the School of Pharmacy Student Association, London.

c One improvement seems to me to be possible, and that is the isolation of single paraffines, of various melting points, one suitable as a basis for liniments, another for ointments, in place of the mixture of paraffines sold as vaseline. (The objections to this multiplicity of preparations have been presented by Dr. Rice.—S. F. P.)

beaten while cooling. Vaseline alone being used for making such ointments as that of ammoniated mercury, or for diluting mercurial or the nitrate of mercury ointments, a partial separation takes place on keeping; but if a mixture of paraffine wax and vaseline be used no such separation occurs.

With regard to the preparations of the pharmacopœia, in which vaseline has been suggested as a substitute for the basis in present use, first and foremost I must mention the nitrate of mercury ointment. Squire states that this can be prepared from white vaseline by substituting it for the lard and oil in the official formula. I tried the experiment on half a pound of white vaseline, using the B. P. quantities of nitric acid and mercury and a temperature rising to 214° F., but it was a decided failure. I could obtain nothing but a mechanical mixture, the vaseline being changed in color from white to pale yellow and the acid solution continually weeping out, and nearly all of it could be separated by pressure. It may be that failure arose from lack of manipulative skill on my part, but I have generally been able to get fair results with the B. P. process. I have on the table a specimen of citrine ointment, prepared from a mixture of white wax and vaseline and about the same quantity of mercury, but rather less nitric acid; this specimen is about eighteen months old, and is as good as when first made. As far as my experience goes, vaseline is not suitable for making citrine ointment of full strength, but it certainly is useful for its dilution. Here is some fresh official ointment, and also some recently diluted with vaseline. I likewise have a specimen which I prepared two years ago; its color is still good. I found that the vaseline had partly separated from it, and in future shall make it with one-eighth paraffine wax.

The next troublesome ointment, I think, is that of red oxide of mercury. I have here a sample of the official ointment, which has been kept for over two years, and is now certainly an unsighly preparation; also some made with prepared lard, quite as bad. Benzoated lard seems to have answered very much better, but still more successful is the mixture of castor oil and beeswax, suggested some years ago in the *Pharmaceutical Journal*. Vaseline, however, will take the palm for more elegant appearance, and it will keep any length of time unaltered.

Compound lead ointment has been spoken of as very liable to change. I have some here made from the official formula which has been kept over a year, and also some made with vaseline eighteen months ago; likewise a sample of zinc ointment. The official ointments, although only a few months old, are quite rancid; but the samples made with vaseline show no alteration after being kept eighteen months.

Mercurial ointment is also very advantageously made with vaseline and wax, instead of with rancid fat, as is usually the case. Under the microscope, samples of both ointments exhibit globules of mercury of about equal size.

Iodine is soluble in about twenty times its weight of vaseline; therefore vaseline is very suitable as a basis for iodine ointment. I am not aware of any action occurring between iodine and the paraffines, although action does take place with chlorine and bromine under favorable circumstances. I prepared some a few days ago of B. P. strength, but without any iodide of potassium.

The crowning success for vaseline is in the preparation of cold cream, and if this were the only compound in which it could be used with advantage its mission would, I think, be fully accomplished. I have made my cold cream for some time with white vaseline, and have found a very marked increase in my sale for that article. I have kept a sample freely exposed to air in a warm place for some months without any alteration, except loss of water. I make it by dissolving ℥ ij. of white wax in 1 pound of white vaseline by heat, adding ʒ iss. of borax dissolved in ℥ ix. of water, and perfume with ʒ ss. of oils, stirring until nearly cold and then pouring into pots.

Vaseline, with or without paraffine wax, is undoubtedly the best basis for pomades, and only requires one-half the quantity of perfume common fats do.

Vaseline has been suggested for internal administration, but it is not the province of the pharmacist to discuss the relative merits or demerits of any therapeutic agent; it behooves him, however, to study the best method of exhibiting it, and to bring it to the notice of the physician.

The Cheesebrough Company prepare vaseline in the form of pastilles, which they say contain 33 per cent. of vaseline, with a like quantity of sugar and gum; these they flavor with wintergreen oil, which is very much appreciated by our cousins across the Atlantic, but not so much so on this side.

Vaseline can be emulsified with the usual agents. The emulsion made with gum acacia is tolerably permanent, also that with yolk of egg. If for external application the vaseline can be mixed with one-eighth its weight of white wax and then emulsified with borax or any alkali. The sample on the table was prepared by triturating ʒ ij. of white vaseline and gr. xv. of white wax with ʒ xiv. of water containing gr. xv. of borax in solution.

I do not look upon vaseline as a nostrum, or I certainly should not have brought it before your notice. It is true we have not yet been let into all of the details of its manufacture, but it may be that such disclosure is not far distant. Because the manufacture of Duncan's chloroform is kept a profound secret among the partners of the firm, has that prevented the medical profession from insisting upon that particular preparation as an anæsthetic? If medical men do not hesitate, when it falls in with the interest of the profession and the public, to recommend a particular preparation of a particular firm to the exclusion of all others, I do not see why chemists should consider it *infra dig.* to recommend and use such an elegant and useful article as vaseline. One trouble looms in the far distance—will the supply of vaseline last as long as the demand for it? Coal may be replaced, and heat and light obtained from electricity by unknown means; but how shall we find a substitute for vaseline, unless, indeed, we be able to make it from its so-called elements? The supply of petroleum does not, however, seem to show any signs of decrease at present. Sources known two thousand years ago still yield bountifully, and if the American supplies prove as permanently productive as those of the Old World we may leave this question for the present. (*a*)

Benzine has been used as a solvent for certain oleo-resins. (*b*) It has been used successfully in the preparation of atropine, santonine, veratrine, delphine, strychnine, brucine, cantharadine, quinine, cinchonine, narcotine, aconitine, and coumarine.

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a London Pharmaceutical Journal, 1881. *b Proc. Am. Pharm. Ass.*, 1873, p. 592.

CHAPTER VI.—MISCELLANEOUS USES OF PETROLEUM AND ITS PRODUCTS.

Petroleum and its products are used for a great variety of purposes that do not fall under the classes previously considered. Commencing with the lightest products, a liquid called cymogene, nearly if not identical with rhigolene, but said to be condensed by pressure, is used in ice-machines with complete success. Gasoline has been proposed as a suitable substance to be used in cleansing raw wool. The following discussion of the use of naphtha (gasoline) for this purpose is introduced here from a circular issued by the Boston Manufacturers' Mutual Fire Insurance Company, with some statements regarding the use of mineral oils for use on wool as the latest information on the subject:

WOOL OILS.

The quality and kind of oil used for preparing wool is a matter of the utmost importance to the underwriter, as it is spontaneous combustion that has caused the record of losses on woolen-mills to be heavier than that on cotton-mills: but in touching upon the subject of wool oils we approach a very "touchy" subject. Many of the methods of treating wool are jealously guarded as trade secrets; the composition of several of the mixtures used on wool has been communicated to us confidentially, and only in order that we may be assured of their safety.

In respect to testimony, we could summon witnesses to prove conclusively that each oil or mixture now used is the very best for its purpose; and conversely that not one of them is really suitable, some difficulty being found either in respect to safety, to the effect on the fiber, or in the removal of every oil used.

All, or nearly all, appear to require a hot solution for their removal, by which the elasticity or luster of the fibers cannot fail to be injured in some degree.

It would appear, according to the evidence and also according to the practice of many of the best manufacturers, that mineral or paraffine oils may be safely and economically used upon wool, either pure or mixed; on other equally competent evidence, that they are utterly unfit to be used and cannot be scoured out, and that nothing but olive, lard, or red oil can be tolerated. The "red oil", so called, is in fact oleic acid, and is subject to impurity if the sulphuric acid used in the process of candle-making (of which "red oil" is a subsidiary product) is not sufficiently removed. When thus impure, we understand it to be peculiarly liable to spontaneous combustion.

The mixed oils, sold under fancy names, of necessity consist of combinations of some of the oils above named, to which the natural yolk or grease of sheep's wool is sometimes added, the latter substance being imported from abroad under the name of "de gras", mostly for the use of curriers.

From the standpoint of the underwriter, the use of mineral oil, mixed to the extent of at least 40 per cent. with animal or olive oil, is to be desired; because in such proportion it abates all danger of spontaneous combustion, and does not in that proportion seriously increase the danger if fire occurs from other causes.

If consideration be given to the work done by the oil, the chief reason why olive, lard, or red oil is preferred, aside from the question of economy, may be that they are a little more viscous than the mineral oils. This may be a point worthy of investigation. If the slight viscosity of fatty oil is desirable, it may be obtained in a mineral oil as well. The substance to be desired is, therefore, one that is not liable to spontaneous combustion; that is not readily ignited by contact with fire; that is readily saponified or reduced to an emulsion, and readily removed from the fiber without the use of any high degree of heat; and that does hold the fibers together in the process of manufacture.

Since none of the oils, greases, or compounds now in use fully meet all these conditions, and since the adverse testimony against them all is stronger than that in favor of any one kind, it follows that both the common practice in scouring all washed or unwashed wool, and the common practice in preparing the wool for carding and spinning, are in some degree bad; that they are not consistent with true economy; that they enhance the difficulties in manufacturing and dyeing, and that if there has been any improvement indicated as being possible by experiments made in a laboratory, from which it is fair to infer that great gain would follow if the theory of the laboratory can be reduced to practice, such experiments deserve the closest attention of all parties in interest.

We therefore beg leave to submit, as the result of our investigation of wool oil, certain propositions. These propositions are submitted only for what they may prove to be worth, and with some hesitation, because none of the officers of the company have ever had any practical experience in the treatment of wool.

Proposition 1. The wool now used in this country will yield 45,000,000 pounds of grease that is now worse than wasted, because it, together with all the alkalies used in the present imperfect method of extracting it, is discharged into ponds and streams, polluting them in a manner most dangerous to health.

2. All this grease can be extracted more perfectly by the use of naphtha than it can be by the use of alkalies, because this grease or yolk does not saponify or yield readily to alkaline treatment until it is in some degree oxidized by age; for which reason the best foreign woolen fabrics are made from wool a year or more old. On the other hand, the newer the clip the more readily the grease is removed by naphtha.

3. The grease and fertilizing material that may be all saved by the naphtha process will more than pay the cost of scouring.

4. This process does not require any heat in the application of the naphtha, and only tepid water for scouring, with a little ammonia in it, it being possible to cleanse a single fleece, by careful manipulation, without disturbing the position of the various portions, thus leaving every fiber in a perfect condition.

5. A portion of the oil thus extracted from the wool itself, after being in some degree refined and mixed with a small portion of mineral oil, makes a viscous emulsion, absolutely free from tendency to spontaneous combustion and in very slight degree inflammable, meeting all the conditions that are required for preparing the wool for carding and spinning.

6. The fiber wool thus cleansed is in much better condition for spinning than when it has been heated and scoured with alkali. Wool and cloth thus treated are in much better condition for the reception of dyes than is possible under any other treatment.

7. This process may be conducted safely in buildings constructed outside mill-yards, at a fair distance away, but not beyond the distance to which the small amount of heat needed may be carried from the main boilers in underground steam-pipes.

In witness of these allegations, we present the report of Mrs. Richards, which was first printed in the *Bulletin of the National Association of Wool Manufacturers*, vol. ix, No. 2.

MRS. RICHARDS' REPORT.

During the progress of the investigation of oil instituted by the Boston Manufacturers' Mutual Fire Insurance Company, for the purpose of abating the danger of fire from spontaneous combustion and other causes, it became expedient to study the natural oil or grease of sheep's wool, which is now saved to a considerable extent in Europe and imported into this country under the name of "de gras", for the use of curriers and for other purposes.

The results of our study of this substance, although not immediately bearing upon the purpose of the inquiry, yet may have an interest to the members of the company, especially those engaged in the manufacture of wool, and are therefore submitted.

The preparation of the raw material is a question of the first importance in any manufacture, and anything which promises to improve the quality of the product, to lessen the labor and cost of preparation, or to lead to the utilization of a hitherto waste product, deserves at least a careful hearing. One of these possibilities seems to be foreshadowed in the wool manufacture.

As is well known, wool, as it is cut from the unwashed sheep, yields from 40 to 75 per cent. of extraneous matter. All this is waste product, and is washed away down our streams to their great damage. Of this large waste, from 12 to 40 per cent., according to the kind of wool, is a grease or oil with valuable properties, and the remainder is largely made up of nitrogenous matters, potash, and phosphates in a very suitable condition to be returned to the soil from whence they were primarily derived. Of course some wools contain sand and mineral dust to the amount of 10 or 20 per cent.

The total amount of washed and unwashed wool used in this country has been estimated at 250,000,000 pounds per year. This will yield approximately 112,000,000 or 115,000,000 pounds of scoured wool, or 45 per cent.: 45,000,000 pounds of grease (18 per cent.); 30,000,000 pounds of fertilizer (12 per cent).

The recovery of a portion of the valuable material has been attempted in France in two ways:

First, by the treatment of the wash-water for the recovery of the grease in a form for gas manufacture, or for the recovery of the potash by the incineration of the evaporated residue, which yields also a very finely divided charcoal, used instead of lampblack. Prussiate of potash has also been manufactured from these residues. By this method, which is an inconvenient one, requiring large tanks and numerous operations, only a portion—about one-third—of the total greasy matter is saved, and none of the nitrogenous matter.

The second method used was the extraction of the grease by means of bisulphide of carbon. The dried wool was then sent to the picking and beating machines before washing, and the wool dust thus obtained was sold for fertilizing purposes. The danger in this process is twofold: the yellowing of the wool by the bisulphide of carbon, and the heat necessary to volatilize the last traces of the solvent (150°–170° F.).

This method, theoretically good, has never been practicable in this country by reason of the cost of bisulphide of carbon. But we have a solvent for grease, in many respects superior to this, which has never yet been applied in this country on a large scale for this purpose, and we have no evidence that, before the present year, any accurate experiments have been made with the best form of this solvent. We have been told of several patent processes for the use of "benzine" for the extraction of the grease; but from the statements as to the results, as well as from a knowledge of the articles sold under the name of "benzine" a few years since, we have no hesitation in saying that the material used was not of proper quality for the purpose or was not carefully applied.

A certain amount of moisture seems necessary to the suppleness of the wool, and any degree of dry heat which takes away this needful moisture renders the wool brittle and harsh. This drying of the fiber is probably the cause of injury in the processes hitherto used.

Our experiments have been made with a quality of naphtha called "gasoline", of about 86°. We have packed the wool in a closed vessel and allowed the naphtha to remain in contact with it for about twenty minutes without any application of heat. The liquid was then drawn off and fresh naphtha run in, the process being repeated three or four times, according to the amount of grease in the wool. "Gasoline" of this quality boils at 90° to 100° F., and air of 50° or 60° F. completely removes it. The naphtha has no affinity for water, and does not, in this cold liquid form, carry away any moisture; very little will be taken out by air at 60° F. before the naphtha is all gone.

In the large way a current of warm air would now be passed through to carry off the absorbed liquid; in our experiments we simply exposed the drained wool to the outdoor air for a few hours. The wool is picked and beaten (the dust being saved), then put into warm water and washed without the aid of any other substance than the soap of potash, which is left on the fiber, untouched, by the naphtha.

The wool thus obtained is very white and soft, and has a "crinkly" appearance.

The objections which have been made to a process of this kind, whether benzine, fusel-oil, or bisulphide of carbon is used, are:

1. That the grease is too completely removed, part being needed to work the fiber.
2. That the grease is also removed from the inner tube of the fiber.
3. That the potash is left in a caustic condition, and hence certain to injure the wool.

In regard to the first objection, Grothe, (*a*) the great German authority, says that the office of the natural grease is so distinct from that of the oil added to facilitate manufacture that this cannot be held valid. The natural grease envelops the fiber as it comes from the hair sack in the skin, making a somewhat stiff coating over it, and only after the removal of this is the wool in the best condition for completely good carding, and also for fulling.

The second objection, that the grease is removed from the tube of the fiber, seems to be founded on earlier ideas. Grothe does not mention this as an objection, and, in the description of the hair, (*b*) says: "In the axis of the hair-shaft is found the pith. This pith is not evident in all wools. In some sorts, viz, Vicuna, it is much developed. The pith-cells contain either liquid or air."

Kölliker (*c*) says that the pith is wanting in colored head-hairs and in most wools: "On treating white hair with caustic soda we get the pith-cells, which do not contain, as was formerly supposed, fat or pigment, but air-bubbles."

It has been stated that washed wool after a time becomes greasy, and it has been supposed that the additional grease came from the pith of the fiber. It is suggested that, as soap can never be entirely washed out of any material, this grease may be derived from the soap used in washing, which is partially decomposed by the cold rinsing-water.

The third objection, that the naphtha or other solvent takes the grease away from the potash on the wool, and thus allows the latter to attack the fiber, seems also derived from a former idea of the nature of the substances under consideration—an idea which is not correct, but which still prevails. The following quotation from an address made in 1872 to a wool manufacturers' association seems to give the prevalent opinion: "In its natural state, as taken from the sheep's back, the whole fleece is filled with a yellowish matter, called by novices grease, but known among dealers as yolk. It is not grease, but a partial soap, being largely composed of alkali, and becoming, if suffered to lie until the volatile oil has dried out, almost a pure soap of itself; hence, as all manufacturers know, old wool scours by ordinary processes much easier than new wool just shorn."

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a Grothe, Wolle, i, 70. Berlin, 1876. *b Ibid.*, i, 18. *c* Kölliker, Gewebelehre.

Hartmann, in 1868, showed that this "yolk" is a true grease, containing cholesterine in place of glycerine. (*a*)

Schultze, (*b*) of Zurich, in 1873 and 1874, carried on the research on certain kinds of wool, and it is to his investigation and that of his associates that we owe nearly all of our present knowledge of the composition of the "Wollfett", or grease. He has not only proved the presence of cholesterine, but of isocholesterine and another analogous alcohol. We now know that these substances are in the place of glycerine; hence the far more difficult saponification of this grease than of lard and tallow, which are compounds of glycerine with the fatty acids. Also, the indications are that the wool-fat in the different races of sheep is composed of varying quantities of these cholesterines.

The presence of cholesterine in wool-fat is a very curious fact. Hitherto cholesterine proper has been known chiefly as a product of excretion from the brain, eliminated by the liver; hence its presence in bile. Gautier (c) says: "Cholesterine is to the brain what urea is to the blood and other organs."

Why we should find this same substance on the wool of sheep is an unexplained mystery.

The grease is dissolved out by naphtha in the same condition as it is in the wool; a potash soap remains behind untouched.

The proof that the potash is not left caustic is that the concentrated wash-water shows but a very faint alkaline reaction. Only on subjecting it to a high temperature does the reaction become strongly alkaline, showing that a decomposition has taken place.

It may be supposed that because carbonate of potash is made from wool-washings, therefore it exists as such in the wool. It is also obtained from wood ashes, but in neither case does it exist as carbonate before incineration.

The advantages claimed for the naphtha process are the more perfect cleansing of the wool, the better condition of the fiber for taking dyes, etc., the ready recovery of the waste products, hence a prevention of further pollution of streams from wool-washing establishments.

The disadvantage allowed is the inflammable character of the naphtha, rendering a separate building necessary. This is not an insurmountable obstacle, as the use of the substance for several industries has been perfectly successful.

The ultimate cost of the process will depend largely upon the value of the recovered products. This subject has as yet only been touched upon, but we have ascertained that the recovered oil is "equal to the best" for currying leather. It is not liable to spontaneous combustion.

The accompanying table will show the great variation in the wools already tested, the small amount of potash to be obtained, and the necessity of a large number of tests:

	Weight taken in grams.	Per cent. taken out by naphtha.	Per cent. lost on picking.	Per cent. lost on washing in warm water.	Total per cent. lost in cleaning.	Yield of clean wool, per cent.	Carbonate of potash in crude wool.	Per cent. of organic matter, dust picking.	Ash of the grease in per cent. of the grease.	Composition of the residue from evaporating the wash-water. Per cent. of carbonate of potash.	Iron oxide and phosphate of lime.	Lime carbonate and magnesium carbonate.	Sand, etc.	Total volatile organic matter.
No. 1. Victoria. Not liable to moths...	70	21.43	2.0	21.57	45.0	55.0	3.3	....	0.38	15.4	3.6	(*)	25.8	55.2
No. 2. Cape of Good Hope, Natal. Full of moths.	76	21.70	22 0	15.10	58.8	41.2	1.1	41.45	1.72	7.3	2.7	Like No. 1....	35.3	54.7
No. 3. Buenos Ayres. Full of moths...	70	13.57	15.3	36.13	65.0	35.0	3.1	....	3.50	10.7	1.5	0.6	34.8	52.4
No. 4. Adelaide. Many moths.........	70	22.86	18.0	19.14	60.0	40.0	1.4	18.00	5.00	7.6	4.3	1.6	40.4	46.1
No. 5. Victoria. Not much injured by moths.	70	18.57	6.7	24.63	49.9	50.1	3.0	....	1.40	11.7	1.3	0.5	39.0	47.5
No. 6. Cape of Good Hope. Liable to moths.	70	13.57	4.5	38.33	56.4	43.6	4.4	....	3.80	11.5	3.3	0.8	36.3	48.1
No. 7. Uruguay. Many moths.........	70	12.87	8.0	39.43	60.3	39.7	2.5	....	3.20	6.5	0.9	0.3 magnesium. Trace only.	46.7	45.9
Vermont wool. Very greasy............	71	38.50	....	....	76.7	23.3	....	....	....	....	....	....	....	....
West Virgina wool. Very fine..........	1,088	....	....	21.60	....	....	4.2	....	....	19.5	....	....	....	....
Mixed wool............................	33,770	25.00	....	....	....	....	....	....	0.80	....	....	....	....	....
Mixed wool............................	7,400	....	....	9.00	....	....	2.5	....	....	27.3	....	....	....	....

* Very little calcium; trace of magnesium.

Naphtha dissolved the grease of all but Nos. 9 and 10 with the greatest facility. These two samples seemed to be older wool, and to have free cholesterine, which was more difficult of solution.

All the samples of wool noticed in the table, except No. 10, were kindly furnished by Mr. George William Bond, to whom we are under great obligation for his interest and co-operation.

No. 10 was furnished by the agent of the Washington mills.

The table will show the small amount of potash which can be obtained, reckoned as percentage on the raw wool. We were surprised at this result, as we had been led to suppose, from various statements, that there was a larger per cent.

The small quantity of ash left by incinerating the grease shows also that it is not a soap of either lime or potash; a portion of this ash was carbon, which is very difficult to burn entirely when derived from cholesterine. It must be remembered also that this was crude grease, which doubtless mechanically carried down some of the other substances.

ELLEN H. S. RICHARDS.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
Boston, May 5, 1879.

We may also cite, in confirmation of these laboratory experiments, the commercial success of the Adamson process of extracting oil by means of naphtha from bone, dead meat, and even in paying quantities from the meat scraps previously treated in the most powerful presses.

a Inaugural Dissertation. Göttingen, 1868. *b Journal für Praktische Chemie.* *c Chimie appliquée à la Physiologie*, ii, 216.

This process is also now being applied commercially to linseed and cottonseed, and, in witness of the great affinity of naphtha for oily matter, it may be stated that Mrs. Richards has lately treated some of the hardest and driest cottonseed-cake from the most powerful steam-press now in use for the extraction of the oil; and we find that, after the utmost quantity of oil had been removed by the press, there still remained a quantity equal to $15\frac{77}{100}$ths per cent. of the weight of the cake.

While the direct result of our investigation of wool oil has therefore only given us the data by which to cause one or two mixtures to be avoided that apparently contained volatile mineral oil, we may yet hope that the final result may be a substantial improvement in the method of scouring wool and woolen fabrics and the saving of a waste substance of great value not only to the woolen manufacturer, but also to the leather-dresser, for whose use large quantities of "de gras" are now imported of a much less pure quality than can be obtained by the naphtha process.

Since naphtha itself is almost a waste product in this country, and is somewhat difficult to obtain in large quantities abroad, owing to the cost and danger attending its transportation, its application to the treatment of wool can be made in this country at much less cost than elsewhere.

The cost of the apparatus would be small, and the waste of material very little, as it can be saved by condensation with very little loss in each treatment.

I am told that the oils that are especially prepared and sold under the name of "wool oils" at the present time are supposed to be in general mixtures of not more than 50 per cent. of mineral oil with either lard, olive, or red oil; and even these mixtures that do not contain more than 50 per cent. of mineral oil are limited in their use to coarse work, it being understood that for fine work the smaller the percentage of mineral oil used the better.

Benzine is equally as useful as benzole for dissolving grease, but it will not dissolve aniline. It is not only used to dissolve grease from cloths, but from animal matter and waste products of any sort from which a refuse fat can be removed. Naphtha of a specific gravity of 62° to 70° B. is used in the manufacture of varnishes, lacquers, and floor-cloths. Rectified anhydrous petroleum spirit (naphtha) of a specific gravity of 0.725 is used to dissolve anhydrous caoutchouc, by which the India-rubber is vulcanized on the addition of chloride of sulphur. (*a*) Naphtha has also been used in air thermometers and for cleaning guns.

Paraffine oil (kerosene) has been recommended to protect seeds from mice, and is said to promote rather than injure vegetation. It has also been successfully used to protect pease from birds, slugs, and caterpillars. Large seeds are soaked in the oil, but it is recommended to sow the ground liberally with sawdust soaked in the oil when smaller seeds are planted. Paraffine oil (lubricating) has been used for saturating gypsum figures and for oiling clocks. Solid paraffine is largely used for stuffing leather, for glazing frescoes and paper, for preserving flowers and wood, and for protecting labels and stoppers of bottles from corrosive liquids.

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a Le Technologiste, xxvi, 126, 312; xxx, 308.

CHAPTER VII.—THE INFLUENCE OF PETROLEUM UPON CIVILIZATION.

In an introductory discourse, delivered before the Literary and Philosophical Society of New York, May 4, 1814, De Witt Clinton remarks:

> There is a bituminous spring in Allegany county whence the famous Seneca oil is obtained. * * * At Amiano, in Italy, the petroleum of a spring discovered within a few years is also employed to light their cities. * * * It might be of considerable consequence to discover whether the petroleum of our spring might not be used for like beneficial purposes.

It is, however, only during the last twenty years, and through the production of petroleum in the United States, that this substance has exerted a marked influence on civilization; for while petroleum has been produced and used in Burmah, Japan, the Caucasus, Galicia, and Italy for many centuries, it cannot be claimed that its use was more than local, or that such use exerted any extended influence upon the world. Indeed, for the most part it was confined to such rude mechanisms that, as an illuminating agent in those regions, it was much inferior to the materials employed twenty years ago among highly civilized peoples. The earthen lamps of Burmah, the pastils of dried camels' dung used in Persia, and the rude lamps of Galicia were all of them little better than faggots or pitch knots. It is the advent of refined petroleum at comparatively low prices that has practically lengthened the duration of human life and has added vastly to the social enjoyment of mankind, not only among highly civilized peoples, but among the semi-civilized and barbarous nations; in fact, wherever the white wings of commerce can transport it there it has gone, and, more, its light has penetrated even the solitudes of the eastern deserts and the forests of both hemispheres.

Speaking of the rise and progress of the trade in petroleum, Mr. E. W. Binney remarks that it is "the most remarkable rise and progress in a trade in modern times. In 1861 the exports from the United States were 1,194,682 gallons; in 1869 it was 99,148,947 gallons". (*a*)

In considering this influence it may be regarded either as of the past or of the future. Dr. Draper, of New York, writing of the influence of petroleum in America, said, in 1864:

> The effect that this illuminating agent has produced throughout the country is very striking. It has entirely displaced all other means of lighting except gas, and is used even in cities by many who desire an absolutely steady light. The great desideratum is a perfect chimneyless burner. The petroleum requires a large amount of air for complete combustion of its carbon, and by no other means than a tube 6 or 8 inches long has the supply been rendered sufficient. Although by the substituting of mica for glass the difficulty of breakage has to a certain extent been overcome, there is still great room for improvement. Kerosene has, in one sense, increased the length of life among the agricultural population. Those who, on account of the dearness or inefficiency of whale oil, were accustomed to go to bed soon after sunset and spend almost half their time in sleep, now occupy a portion of the night in reading and other amusements; and this is more particularly true of the winter season. (*b*)

Notwithstanding the desirability of a chimneyless burner which was thus early felt and clearly stated, that want is yet to be supplied, as all attempts to supply such a burner have thus far been only partially successful. In eastern countries, where the compensation of labor is so small, the cost of chimneys, enhanced by long transportation and breakage, is said to seriously interfere with the extended use of kerosene among the poorer classes. Yet the use of refined petroleum in the East has steadily increased, until petroleum is no longer produced in Japan, and the production has little energy in Burmah.

In 1869 M. Félix Foucou published an article in the *Revue des Deux Mondes* that is especially interesting in this connection. He says:

> In the domain of the useful arts each age reveals characteristic tendencies. In the last century mankind had need to clothe itself cheaply. It was this that made the fortune of Arkwright and the machine spinners, the sudden prosperity of Manchester and the continental cities which imported the new method of labor. The nineteenth century has wished for light, both in the birch-bark wigwam of the Indian and in the mud cabin of the poor Ruthenian of Galicia. The introduction of the most modest lamp gives activity to family life in prolonging the evening's labors. France has largely contributed to this result. The invention of Argand, which was the first progressive step in advance of the smoky candle-wick of ancient times, arose painfully at the eve of the French revolution; the Carcel lamp and gas are of yesterday. A crowd of obscure inventors have, with unremitting labor, perfected the mechanism of lamps in order to escape the costly necessity of burning vegetable oils. These experiments, many of which were undertaken under the monarchy, prepared the way for the success of petroleum; unfortunately they came at a moment when it was premature to dream that illumination by mineral oil should become universal. The material was at first wanting; chemistry had not furnished a method of extracting those precious substances from the schists with which they were found associated at many points; and science had not yet shown the part that liquid petroleum was destined to play, of which a great many springs were then known. It is to the Americans that the merit belongs of having given this last right of citizenship among the industries. The native talent that led them to regard the useful aspect of everything, above all the feverish but patient activity, seconded so well by a happy temperament, has served them marvelously on this occasion. The French chemist Selligue gave them the first experiments in the basin of Autun, about the year 1832, by distilling on an industrial scale the schists that abound in that part of France. Mr. James Young, of Glasgow, perfected the process, and established in 1847, in Derbyshire, a vast manufactory for treating the English minerals, incomparably richer than those of France, and known under the names of bog-head and cannel coal. In a few years this establishment took on an extraordinary development, and yielded its

a Proc. Lit. and Phil. Soc. of Manchester, viii, 135.

b Chem. News, x, 204.

projectors several hundred thousand francs of revenue. The prospect of such profits so soon realized placed this manufacture in a reputable position. It extended to the United States in 1854, where it was employed upon the Scotch bog-head as well as several other indigenous schists. In 1860 there were in North America 64 manufactories of schist oil. The discovery of abundant reservoirs of petroleum suddenly arrested this growing industry, ruined a large number of manufactories, and led their projectors to change them into refineries of petroleum, that substance being much richer in illuminating material than bog-head or cannel coal. (*a*)

This graphic statement of the manner in which the requirements of the age have been met, and how fully they have been met, is well supplemented and illustrated by chart No. III, page 148, in connection with the statistical statement on page 149 *et seq.* The statement shows that in twenty-two years preceding December 31, 1880, there had been produced 156,890,331 barrels of petroleum, of which amount about 16,000,000 barrels were stored above ground, leaving, in round numbers, 140,000,000 from the Pennsylvania oil regions alone for consumption during twenty-two years, an average of 6,363,636 barrels per year. But the production increased from 500,000 barrels in 1860 to 26,032,421 barrels in 1880. The stocks held in the producing regions did not accumulate in excess of the demand until 1875, when they amounted to 4,250,000 barrels; but the demands of the next two years reduced those stocks, and the price advanced to above $2 50 per barrel. Since February, 1878, stocks in the producing region have constantly accumulated, with a constantly increasing demand, and a tendency, as might be expected, to lower prices. The accumulated stocks, January 1, 1882, had reached nearly 30,000,000 barrels.

The total value of the yearly production, as shown by this statement, has been subject to great fluctuations. For instance, the 4,215,000 barrels produced in 1869 were worth $23,730,450, while the 10,809,852 barrels produced in 1874 were worth only $12,647,526. The most valuable production of any year was that of 1877, when 13,135,771 barrels brought $31,788,565, while the 26,032,421 barrels of 1880 brought only $24,600,637. From these figures it is readily perceived that up to the present time the demands of this century for light have been more than satisfied, and that while new uses and applications for petroleum and its products are being constantly discovered the increasing demand has been more than met by an increasing production.

Looking toward the past, it may be said that petroleum has become the light of the world. It is fast displacing vegetable and animal oils as a lubricator on all classes of bearings, from railroad axles to mule spindles. It is also displacing animal and vegetable oils where such oils are liable to spontaneous combustion; it is becoming one of the most largely used materials for fuel in stoves, both for cooking and for heating purposes; it is very successfully used for steam purposes where other fuel is scarce and petroleum is plenty; it is found to be available in the metallurgy of iron, and is likely to be in demand for the production of pure iron for special purposes; its merits have been long recognized in medicine, and it is rapidly becoming a necessity to the apothecary in the form of petroleum ointment; in fact, petroleum has become one of the indispensable needs of civilized man, and ministers to his wants in such a multitude of forms and under such a multitude of circumstances that it may be safely said that it ameliorates the conditions of his struggle with external nature, adds comfort to health, and soothes in sickness, prolonging his active life by extending the day into the domain of night over all that portion of the earth's surface accessible to commerce.

Looking toward the future, what assurance have we that these varied wants, the wonderful creation of twenty-four years, will be satisfied? In answering this inquiry I wish to emphasize the futility of prophecy and the abundance of the present supply. All through the census year, when each successive month brought an addition to the production without precedent, the entire literature representing the oil interest was each month prophesying that the end was being reached, the Bradford field was outlined, the production next month would surely show a decline, the yield of wells was rapidly running down, and so on. As an illustration I quote from Mr. J. C. Welch's *Views of Future Production* for June, 1879:

Reality has been constantly outrunning estimates on the Bradford production. The subject of the amount of production has been somewhat abandoned recently, in the light of the supply being so greatly in excess of any immediate demand, or of any probable demand in a reasonable time in the future. The May production from the wells will be exceeded, no doubt, by the production of some of the summer months. I think a shut-down movement, on account of depleted bank accounts, lack of credit, and a cash system inaugurated by the well-supply dealers of the Bradford district, will be a very important check on the starting of new wells, and the Bradford production probably is about at its height.

He estimated the total daily production for this month at 58,700 barrels. In his *Views of Future Production* for January, 1880, he says:

While the present situation regarding production is bad, great hopes are that in six months the production will necessarily show a very important falling off.

He estimated the total daily production for this month at more than 65,000 barrels. In his report for June, 1880, he says:

The next point is for the production to show an appreciable falling off. This point has not arrived yet, although producers, on account of the falling off of wells throughout the district, expect it will do so pretty soon.

Total daily production for this month, 80,804 barrels. January, 1881, he says:

Public opinion is very greatly in accord with the following extract from a letter of a producer to me: "In some districts the United lines are cleaning out the tanks. Do you get your statements on stocks at wells from the same parties as the *Era* and *Derrick* get

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a Revue des Deux Mondes, April, 1869.

theirs? I sometimes think they back up oil purposely on those who furnish reports. I have interviewed a large number of producers from all sections of the field, and all make the same statement, namely, our production is falling off. I cannot understand, in view of the facts, how there can be an increase in the production, and, in plain words, don't believe it."

Total daily production for this month, 70,427 barrels. In June, 1881, he says:

The sanguine hopes for an important decrease in the production have been postponed for some months at least. Bradford is expected to decline rapidly at some time, and it was confidently hoped the time was near at hand; but the figures on the May production have been disappointing, and any marked decrease in the production is still a matter of the future.

Total daily production for this month, 81,455 barrels. January, 1882, he says:

For the time being the increase at Allegheny equals the loss at Bradford, but this relation is likely to change soon, and not only Bradford will decline, but Allegheny will accelerate the decline by declining itself.

Total daily average production for—

	Barrels.
October, 1881	81,110
November, 1881	80,985
December, 1881	81,462

The following paragraphs were written by an intelligent oil producer of large experience, and express the opinion of conservative operators at the date of their publication, August, 1881:

In the twenty-one years that oil mining has been the chief industry of northwestern Pennsylvania there have been discovered, besides numerous minor deposits, three great basins of petroleum, known among oil men as the Venango, the Butler, and the Bradford districts. The first centers on Oil creek, Venango county; the second on Beaver creek, Butler county; and the third covers an area of about 60,000 acres in the northeastern corner of McKean county, and extends a short distance into the state of New York. The first two named are so far exhausted that a majority of the wells have been abandoned, while those that are still pumped have fallen off until they average less than two barrels each per day. The Bradford district in extent of area and volume of oil exceeds the other two combined. It was discovered in 1875, but it was not until two years later, when its rich character became apparent, that it began to attract the oil men from all other fields. Since then it has been the scene of greatest activity, the magnitude of operations exceeding anything ever known in the business.

In the autumn of 1880, after four years' continuous drilling within and around the Bradford district, the boundaries of this great reservoir were accurately defined; more than 9,000 wells had then been drilled there and were producing oil. These lines being fixed, the producers began to retrace their steps, and to select within these limits such locations as seemed desirable among their old wells and to drill what is technically called the "second crop" of wells. This was the first manifest proof of the limitation of the Bradford district and of its approaching final exhaustion.

The percentage of successful ventures in Bradford surpassed all former experience. Of the whole number of wells drilled in exploring and defining this district about 5 per cent. only were dry or failed to produce oil in paying quantity. In Venango and Butler the average of failure was much larger, and if we except the years when these districts were in their prime, and take those intervening periods in oil mining when the producer had to depend upon the discovery of such minor deposits as lay outside of the great basins, and yet within the oil region proper, it will be found that half of the wells then drilled were failures.

* * * * * * * *

The distinctive features which have marked the development of the Bradford district, and which have given to the Bradford producer advantages over all his predecessors, are: first, the insignificant risk to be taken in drilling; second, the durability of the wells; and third, the expense saved of pumping the wells, which have until recently yielded their oil by flowing. To these natural advantages may be added cheaper machinery and cheaper labor. He has also gained facility by enlarged experience and by his improvements in well machinery. His greatest advantages have no doubt been in the long life of his wells and in the fact that they have been flowing wells; but these conditions have changed. Half of the wells in the Bradford district are now pumped, and the average product per well has fallen to six barrels per day. It is estimated that before the close of the year nearly every well in Bradford must be pumped. They are now passing rapidly from flowing to pumping wells.

The longevity of these wells is accounted for by the thickness of the sand-rock, the natural receptacle of deposit for the oil, which is never found in the Pennsylvania oil region except in this rock. The Bradford rock averages from 50 to 60 feet in thickness, while the Venango and Butler sand-rocks are from 20 to 40 feet. The volume of oil found in any deposit is determined by the extent and porousness of the sand-rock. In one of the minor districts, viz, Triumph, Warren county, the sand-rock was found to be 120 feet thick, and the wells there lasted the longest of any that have been struck; but the area of this deposit was limited to about 1 mile square.

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We have seen that the extent of the Bradford basin was ascertained last autumn. Its margin had been previously defined at many points, but it was not until then that the limits of the whole district became known. We can now see that the greater magnitude of this oil-field will not save it from the fate of the fields that preceded it. The same evidences which marked their decline have already appeared here, and we need not doubt that the same results will follow. The 9,000 wells of last autumn have now increased to over 10,000, and a total of 55,000,000 barrels of petroleum has been drawn from them. It is therefore not to be wondered at that the great reservoir begins to show symptoms of exhaustion. True, these symptoms have only passed the premonitory stage, yet they are as real and significant to the oil-producer as his figures of production. They are to him the "handwriting on the wall", for he knows well how insidiously the same symptoms developed in other districts, and with what accelerating speed the decline went on month by month, as his tables of production showed.

Ordinarily these monthly tables of production are a sufficient guide in forming a judgment of the field; but the condition of the Bradford business for many months has been such as to preclude the possibility of accuracy in them. The product of the district rose so rapidly last year above the receiving capacity of the pipe-lines that much of the oil flowed over on the ground and was lost. This waste continued in varying degrees through the greater part of 1880 and into the second quarter of this year. The extreme cold of last winter, and the aptness to congeal of the Bradford oil (which differs widely in this respect from Venango oil, and in a less degree from Butler oil), complicated the working of the pipe-lines, while diminishing their capabilities; so that the waste of oil was estimated to rise sometimes as high as 5,000, 10,000, and even 15,000 barrels per day. This led the producer to suppress the flow of his wells as much as possible, and to increase the wooden tankage which he uses for temporary storage at his wells until the oil can be conveyed into the large iron tanks of the pipe-lines. These iron tanks have a capacity of from 20,000 to 30,000 barrels each, the usual size of a wooden tank being 250 barrels—1,200 being the largest.

In making up the monthly tables of production it has been found that the greatest accuracy is attained by computing the "runs" of oil into the pipe-lines during the month and omitting the oil held at the wells. When the business is moving normally these well stocks remain nearly stationary and average about a hundred barrels per well; and this average does not seem to be much affected by the fluctuations of the market. A measurement taken in the Butler district in 1876 to ascertain this average gave 100 barrels per well, and this at a time when there were five pipe-lines competing for the oil, and when the price was $4 per barrel. When we consider that the average product of the wells is now 6 barrels each per day, that 200 barrels is usually the minimum taken by the pipe-line in one "run", and that there are 10,400 wells in the Bradford district, it will be seen that the time required for oil to gather to make up these "runs" necessarily leaves stock at the wells at all times, and that there must be a point below which this stock cannot sink until the number of wells decreases, when it will gradually decline with the decline of the district, until both are exhausted.

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The total marketable stocks of the region at the end of June, 1881, may be estimated as follows:

	Barrels.
Stocks in United Pipe lines	20,641,285
Stocks in Tide-water Pipe line	1,924,658
Stocks in the minor pipe lines	76,222
Stocks in iron tanks of individuals	420,930
Stocks at wells	335,095
	23,398,190

In a less degree perhaps than any other industrial product is the supply of crude petroleum governed by the price. There have been periods in the business when prices have ruled high, and yet production has declined because of the oil-man's inability to find new productive fields to work. On the other hand, production has not infrequently continued to rise long after the price has declined below cost. A powerful incentive to overproduction is found in the mobile quality of petroleum and its tendency to shift its location in the sand-rock, its passage from place to place through the channels of this natural receptacle having been the cause of many an energetic struggle along the dividing lines of adjoining tracts for the possession of the treasure beneath. These subterraneous currents set toward the first drill-hole on any given tract of land, and are not readily diverted toward subsequent openings; so that the chances for a larger share of the oil and for a more lasting well favor the first well drilled. The exceptions to the rule are rare, and arise from conditions that will readily suggest themselves, such as a natural center of deposit, or, still more rarely, a crevice in the oil-rock. As an oil district is always divided among numerous ownerships, the stimulus to excessive drilling pervades the whole field, and when the deposit happens to be large is sure to lead to excessive production.

Another cause of overproduction is found in the tenure, the tracts being mostly held by lease, the land-owner receiving a rent or royalty in oil varying from an eighth to a half of the total product; a bonus in money is often added when the chances of success seem favorable. The lease always stipulates the number of wells to be drilled and limits the time of drilling them, and also contains clauses of forfeiture to enforce execution of the work. The producer is thus compelled to drill wells at times when the market price of oil does not warrant the outlay rather than forfeit a lease on which he may have already made valuable investments, or which he believes will subsequently prove valuable.

Still another agent, acting in the same direction, is the discovery at a time when the supply is already sufficient to fill the market demand of a new oil-field, richer than any then being worked. The yield of the larger wells in the new district makes the cost of production less than in the old districts, the price declines, let us say, until the producer in the older district receives for his product barely enough to pay the cost of lifting it to the surface, though the producer in the new district still has a profit in his products; both continue their work and production is further enlarged. The first man is impelled to pump his well to save his property from destruction; the second is prompted by the profit he makes. The first man cannot shut his wells down and wait for an advance in price until the new district is depleted, for, besides the inconvenience which such stoppage entails in any business, he would risk the ruin of his wells by the clogging with paraffine of the oil-ducts in the sand-rock, or by the diversion of the oil into other channels by the suction of other wells. The first would be more apt to occur in a waning district and the second in a fresh district, but either is likely enough to happen to admonish him against a shut-down.

Since the discovery of Bradford two other districts of minor importance have been opened. One is known as the Wellsville district, and lies north of Bradford, in Allegany and Cattaraugus counties, New York; the other is the Warren district, lying south of Bradford, in Warren and Forest counties, Pennsylvania. The first has been worked for about three years, and yields the heavy oils only, the gravity varying greatly in different wells, being from 36° to 43° B.; the second is two years old, and yields a light-colored oil of 47° to 48° gravity. About two-thirds of the wells drilled in the first district and one-third of those drilled in the second have been failures. The total daily product in the Wellsville district was, at the close of July, 1881, 350 barrels. Neither gives evidence of large capabilities for increasing production, though of the two the Warren is undoubtedly the more promising. Neither can by any known possibility contain what may be termed "a great basin", for the drilling already done is sufficient to establish the character of both fields. These districts are not even pointers to such a deposit, and if they possess any significance in that direction it is rather against than in favor of such a discovery, so that no marks or guide-posts yet exist to point the way to new fields.

In Wellsville a good quality of oil-bearing rock, varying in thickness from 25 to 35 feet, is found in the productive wells, but that it is of a sporadic character is proved by the large percentage of unproductive wells; and this idea is further confirmed by the remarkable variation in the color of the oil obtained, which ranges from the ordinary green to black. Salt water is produced with the oil in all the wells in the Wellsville district, which is another distinguishing feature of heavy-oil districts, the light oils being always found in the sand-rock entirely free from water. Also, the rock here lies at a higher level than the Bradford rock, and therefore belongs to the upper strata, in which the heavy oils are found.

The Warren oil-rock is from 12 to 25 feet thick, and there are two strata about 100 feet apart; but no well has yet found oil in paying quantity in both rocks, where one overlies the other, as occurs in some parts of the district. The drilling here has been so extended as to leave no space sufficient for a new basin of large capacity; and as north of Wellsville the geological formation changes, the metamorphic rock cropping out in the immediate neighborhood, the oil district cannot extend far in that direction, and at all other points it has been thoroughly tested by the drill.

Stimulated by the large prosperity attending the development at Bradford, test drilling advanced in every direction to the extreme limits of what is geologically regarded as the oil region. For a period of nearly three years, ending with 1880, more of this work was done than during the previous seventeen years since oil mining began; but the want of success in finding new oil-fields, and the enhanced cost and diminished price of petroleum, have all contributed to discourage and arrest this pioneer work.

The impression that there are no more great basins like those of Venango, Butler, and Bradford remaining to be discovered is gradually growing into a conviction that Bradford is indeed the last, and that hereafter this region will have to depend entirely upon minor deposits and districts for its supply. This belief is supported both by the practical experience of oil-men and by the observation of geologists. We are satisfied that no one can make a careful survey of the oil region without being impressed by the great amount of test drilling that has been done. This work has been quietly prosecuted in the depths of the forest and other unfrequented places, and is little noticed and little talked about unless oil is found. It is only the successful adventurer who receives public attention; the unsuccessful man is seldom heard of, but the abandoned well, with its dilapidated "rig", everywhere attests his energy.

From the foregoing statement the following deductions may be drawn:

1st. That the Bradford field, from its uniformity and extent, constitutes the true oil center of the whole region, and that it is already declining; that, as all statistics show, the decline of the old wells averages about 150,000 barrels per month; that this decline has hitherto only been overcome by large and continuous drilling; that the field has now reached a condition where the production cannot be maintained by the incoming new wells; that the number of openings in the field has so drawn upon the common reservoir that further drilling is simply subdivision of what is left and will only tend to hasten exhaustion, and that therefore the decline must proceed month by month with increasing rapidity.

2d. That the production to supply hereafter the large demands upon this region (which will amount this year to 19,000,000 or 20,000,000 barrels) must come from minor deposits.

3d. That to supply this production from these minor deposits will be attended with greater uncertainty and a greater degree of cost than heretofore.

4th. That under these circumstances the stock of crude oil in the region will be held more firmly, and that consequently the range of prices must be permanently higher than during the last three years.

Artificial conditions and the influence of speculation may for a time interfere with, but cannot prevent this result; indeed, nothing can prevent it save that of which there is now no sign—the discovery of a new, great basin. (*a*)

In still further illustration, the following admirable survey of the available resources for future production is quoted from the correspondence of the *Oil and Drug News* for February 28, 1882:

How far off is the date when the production of petroleum will not be in excess of the demand is the great question of the hour to all parties concerned. Daily, monthly, and yearly reports are printed by many parties, a large proportion of which differ one from another. In giving the amount of oil taken from private, wooden, and iron tankage and run into the pipe-lines some reports give the year 1881 credit for the production of the same, when it really was produced in 1879 or 1880. This, of course, would swell the production of 1881 on paper only.

Opperman, a civil engineer and map-maker of this county, and who is good authority, gives the total producing territory in the Bradford field, including Cattaraugus county, New York, at 68,250 acres. February 1, 1882, there were 11,764 wells; and if we estimate 5 acres to the well, 11,764 by 5 gives us 58,820 acres drilled, leaving a balance of 9,430 acres of the lightest territory yet to be drilled, of which from 2,000 to 3,000 can, and probably will, be drilled at present prices, but the balance cannot be operated at less than $1 or $1 25 per barrel.

In November, 1880, there were about 7,000 wells in this field which had been shot with light torpedoes. At this date the large torpedo was found to be more productive, and since this time the greater part of the 7,000 wells have been cleaned out and reshot with the heavy torpedo with good results. (A medium size torpedo nowadays is 60 quarts, which costs, net cash, $290 40.)

Production was further encouraged in 1881 by a great deal of crowding, which I explain as follows:

A wishes to drill one well per month, or wait for higher prices, while B leases his land in small lots. The outcome of this is, a number of wells are drilled along the border of B, which compels A to do the same or lose his oil. This is one of the principal reasons why producers bring their oil to the top of the ground instead of leaving it in the rock at present prices.

The Forest and other large oil companies show by their statements that the cost of production in 1881 was from 30 to 40 cents per barrel more than in 1879 and 1880. This is owing to the pressure of gas and oil upon the rock exhausting, wells ceasing to flow, and pumping resorted to.

The cost per barrel for production in 1879 and 1880 was from 65 to 75 cents, and if the companies are right in their figures the present cost must be considerably above the present market price.

During the six months from July, 1880, to January 1, 1881, the total production of the country was estimated at 90,000 barrels per day, and during much of this time from 3,000 to 6,000 barrels per day was running on the ground in the Bradford field, owing to the inability of the pipe-lines to store and ship the same, and in part owing to the inability of the producers to build private iron and wooden tankage.

During these six months the highest production of the Bradford field was reached, being about 75,000 barrels per day (15,000 being the average production of the other fields). This has gradually declined, until on January 1, 1882, it was about 61,000 barrels per day. This decline includes all drilling of new wells up to that date.

There were more wild cat (or, in other words, prospective) wells put down in 1881 than in all previous years of the oil business, which developed nothing new except the Richburg or Allegany field, in Allegany county, New York. This goes to show that a large territory has been condemned which was counted on as a possible oil-field.

The Allegany field consists of from 7,000 to 8,000 acres, of which about 4,500 is good for 10-barrel wells and upward. The balance from 2- to 10-barrel wells.

On February 1 there were over 600 wells producing from 4,500 acres, and allowing 5 acres to each well, this 4,500 acres will be drilled by April 1, at the present rate of drilling, which is 175 wells per month.

It is estimated that one well to 10 acres is sufficient to drain the land, but where one well is put down to every 5 acres the territory exhausts more rapidly, on the principle of a glass of lemonade exhausting itself sooner when five straws are applied instead of one.

If the Allegheny field is to become a second Bradford, as some seem to say, why is it that the producers have drilled wells so thickly on the 4,500 acres, which is the cream of the territory, and how do they account for the 125 or 130 dry wells immediately surrounding the field? Bradford, in its early development, has scarcely a dry hole in its producing area. In the early days of Bradford torpedoes from

a Stowell's Petroleum Reporter, August 23, 1881.

2 to 6 quarts were used, while to-day Allegheny wells are treated to from 40 to 120 quarts, thereby forcing the production to an unnatural large amount for a short time, but the land is being drained correspondingly rapidly.

The following shows the condition of the oil production, etc.:

	Barrels.
Total oil in all pipe-lines, January 1, 1881 (*a*)	16,606,343
Total oil at wells in Bradford field, January, 1881 (*b*)	2,403,500
Total oil in private iron tankage, Bradford field, January 1, 1881 (*c*)	692,750
	19,702,593
Total oil in all pipe-lines, January 1, 1882 (*a*)	25,333,413
Total oil at wells in Bradford and Allegheny fields, January 1, 1882 (*c*)	1,135,848
Total oil at private iron tanks, Bradford and Allegheny fields, January 1, 1882 (*c*)	104,256
	26,573,517
Deduct amount for January 1, 1881	19,702,593
Total net increase of stock in oil regions on January 1, 1882	6,870,924

This amount divided by 365 days gives:

Total net average daily increase in stocks in 1881	18,824
Total net average daily shipments from oil regions in 1881 (*a*)	55,774
Add the daily average increase and shipments for net production	74,598
Add the daily average evaporation and shrinkage (*a*)	2,150
Giving the daily average gross production	76,748
The daily average shipments of 1880 (*a*) were	42,916
The daily average shipments of 1881 (*a*)	55,774
Shows increase in 1881 over 1880 to be per day	12,858

Our export trade has increased nearly every year since 1852. I copy the following from the *American Exporter* for December, 1881:

	Gallons.
Total exports of petroleum and petroleum products for October, 1881	54,244,846
Total exports for same, October, 1880	34,065,254
Increase for October, 1881, over October, 1880	20,179,592
Total for 10 months ending October 31, 1881	422,713,216
Total for 10 months ending October 31, 1880	295,520,798
Increase foreign demand in ten months	127,192,418

The *Oil and Drug News* of January 31, 1882, says:

The total exports of petroleum and petroleum products from the port of New York, in gallons, from January 1 to January 28, 1882, as compared with those of the same period in 1881, are:

	1882.	1881.
Crude, gallons	2,913,442	2,641,430
Refined, gallons	16,556,230	10,035,481
Naphtha, gallons	153,131	541,297
Total	19,622,803	13,218,208
Total increase in foreign demand for the first 28 days of this year, gallons.		6,404,595

Now let us take into consideration the increase in home consumption.

For illuminating purposes it is universally used throughout the country, except where gas exists, and with the wonderful increase in railroads to the far west and south, including all the mining regions, and the increase of population, an unusual increase is sure to follow.

The exact amount of home consumption has never been actually given; it has only been estimated.

In 1880 it was placed at 13,000 barrels per day; in 1881 there were 55,774 barrels (*a*) per day shipped from the oil country, and 40,800 barrels (*b*) per day exported from the United States. The difference between the exports and the shipments from the oil country would show the home consumption to have been 15,000 barrels per day, but there was estimated to have been a large amount of the stocks used, which was stored at the refinery centers and sea-boards, estimated at about 3,000 barrels per day; add this to the 15,000 shows the estimated home consumption for 1881 to have been 18,000 barrels per day, which is an increase over 1880 of 5,000 barrels per day. Owing to the rapid development of the far south and west, and the general prosperity of the country, the home consumption may safely be estimated at 22,000 barrels per day for 1882.

Eight persons out of ten say that Allegheny is at its height, and I have shown where it is probable that the cream of her territory will be drilled by April 1 next, from which time her production will decline. Then consider the number of dry wells which have been drilled in all parts of the country, which shows that the prospects for developing a new oil-field are not very promising.

With Allegheny so near drilled out, the Bradford field declining at from 75,000 to 100,000 barrels per month, and other territory not increasing, is it not natural to predict that the quantities of production and demand must soon come together, at which time prices will naturally advance rapidly? Taking into consideration the reshooting of wells in Bradford field in 1881, the finding of the Allegheny field, the extra amount of crowding lines, etc., after all this the total net increase of stocks in oil regions, January 1, 1882, over January 1, 1881, is only 6,870,923 barrels, while the increase in shipments were 12,858 barrels. Add to this the decrease of stocks at refinery centers, 3,000 barrels, gives 15,858 barrels increase demand per day, or 5,757,510 barrels for the year.

a Official. *b Bradford Era.* *c* Producers' report.

The consumptive demand of the world for 1881 was about 21,535,902 barrels, or 59,000 barrels per day, and the demand for 1882 is estimated at, at least, 15 per cent. more (15 per cent. is the average increase the past ten years), which will amount to 24,766,187 barrels for the year, or 67,852 barrels daily average, exclusive of evaporation and shrinkage. The 25,333,413 barrels in pipe-lines seem to lead some people astray.

The above figures show that the entire amount, if drained from the lines, would be only one year's demand, and all knew that we could only spare, say, 10,000,000 barrels, as about 15,000,000 is required to carry on the business in the same way as a bank requires capital. Should a few million barrels be taken from the present stock, this, together with the increased consumption, would revolutionize prices.

These illustrations received increased significance when it is understood that within twelve months of the time the first paper was written and immediately following the date of the last the Warren district yielded some of the largest wells on record, and the price of oil tumbled to a still lower figure, instead of being permanently higher.

While it is not probable that the deposits of petroleum within the crust of the earth are being practically increased at the present time, there is reason to believe that the supply is ample for an indefinite period. When prophecy, indulged even by the most sagacious producers of longest experience, proves so futile, I think I am warranted in expressing the opinion that, as regards the future supply of petroleum, the drill alone gives valid testimony. Yet this fact is worthy of the most serious consideration: the production of petroleum as at present conducted is *wasteful in the extreme.* No thoughtful person can escape the conviction that future generations will want what this present generation is destroying to no purpose. "After us the deluge," is written all over the oil region in the destruction of forests and in the waste of the oil itself.

STATISTICS OF THE EXPORTS OF PETROLEUM DURING THE CENSUS YEAR.

The following tables have been prepared for the purpose of showing the relative magnitude of the export trade in petroleum during the census year, the relative amount exported from different ports of the United States during that year, the points to which it was sent, and the relative amount of such export trade in the different manufactured products of petroleum during different years. These tables consist of:

Table I.—Shipments of crude and refined oil out of the producing region to the following points during the census year, by months.

Table II.—Receipts of crude and refined petroleum, etc., at New York, weekly, by routes, during the census year.

Table III.—Exports of petroleum and petroleum products from New York to foreign ports for 1878, 1879, 1880, and the census year; also from Philadelphia for the same time.

Table IV.—The charters reported for crude and refined petroleum, naphtha, and residuum, from New York, Philadelphia, Boston, Baltimore, Richmond, and Portland, to the different ports of the world, exclusive of North America, during the census year.

Table V.—Petroleum and its products exported from the United States during the years ending June 30, 1879 and 1880.

Table VI.—Exports of petroleum and petroleum products from all United States ports to all foreign countries, and the declared value thereof, from 1873 to 1880, inclusive, and the census year, by months.

Table VII.—Quantity of petroleum produced, and the quantity and value of petroleum products exported from the United States during each fiscal year from 1864 to 1880, inclusive.

Table VIII.—New York petroleum market, average prices per year.

Table IX.—Imports of refined petroleum at five principal ports of the United Kingdom, with stocks at the same ports, January 1, 1874, to 1881, inclusive.

Table X.—Imports of petroleum at the undermentioned European ports for seven years ended December 31, from 1874 to 1880, inclusive.

Table XI.—The various products of crude oil, including petroleum, crude oil, refuse oil, and grease, and all products of naphtha exported from Baku, from 1832 to 1879, in poods of 36 pounds each.

Table XII.—Imports of American petroleum (refined) into Japan, from the time of the first importation, in 1872, to the end of 1880.

An inspection of these tables shows a steady increase in the quantity of petroleum and petroleum products exported to the end of 1879; 1880 showed a slight decrease. The months constituting the census year—from June 1, 1879, to May 31, 1880—exhibit an unparalleled activity in almost every item where the statistics were to be found in such form that the months of the census year could be separated from the totals for 1879 and 1880.

Table I shows that the shipments of refined oil from the producing region to New York declined during 1880 more than 1,100,000 barrels, or about 68 per cent. This decline took place mainly after the close of the census year, as the shipments for that year amounted to nearly 85 per cent. of those for 1879. Shipments to both Philadelphia and Baltimore of refined oil were merely nominal both during the census year and during 1880, while there were no shipments in 1879 to either of these points.

The shipments of refined oil to Boston and local points were not materially changed in the aggregate for the two years, but the amount shipped during the census year exceeded that moved during either 1879 or 1880.

The shipments of crude oil out of the producing region to New York, Philadelphia, Cleveland, the Ohio river, and local points show a marked increase in 1880 over 1879, while the shipments to Baltimore, Boston, and Pittsburgh show a considerable decline during the same time; yet to all of the points mentioned above, excepting the local points, the shipments during the census year were larger than during either of the years of which it forms a part. The total shipments of crude oil out of the producing regions in 1879 to the points above mentioned was 15,987,370 barrels; in 1880, 15,675,492 barrels; and during the census year, 17,769,656 barrels, an amount 11 per cent. greater than the average for the two years.

Table II shows in the totals the same steady increase in the movement of crude oil to New York, and an equally steady decline in the movement of refined oil to the same point. During 1877, 103,662,216 gallons of refined oil entered New York, and by 1880 the receipts had fallen to 42,847,577 gallons, although the amount received during the census year was nearly equal to that received during 1879. During 1877 the receipts of crude oil at New York were 179,214,244 gallons, an amount which was increased to 256,878,660 gallons during 1880, and to 285,839,983 gallons during the census year. These figures indicate a diversion of the product of the refineries located in the interior cities from the export trade and an increase in the proportional supply of that trade by New York city. Table I also shows a similar increase in the consumption of crude oil for Philadelphia and Cleveland, while Boston, Baltimore, and Pittsburgh exhibit a large decline in receipts of crude oil during 1880. It seems, therefore, fair to assume that the manufacture of oils for export has steadily increased in New York, Philadelphia, and Cleveland, and has declined in Baltimore, Boston, and Pittsburgh, notwithstanding the movement of refined oil toward New York has steadily declined, and has been merely nominal toward Philadelphia and Baltimore, while the amount received at Boston has remained practically unchanged.

Table III shows the relative amount of petroleum and petroleum products exported from New York and Philadelphia to different countries during 1878, 1879, 1880, and the census year. The special activity of the export trade during the census year is illustrated by this table, not only in the totals, but also in the items.

Table IV exhibits the destination of the petroleum and petroleum products sent from the country during the census year, the manner in which it was packed, and the kind of material sent to different ports and countries As this table was compiled from the charters reported, some of which were vessels that arrived or were filled after the census year closed, the amounts do not correspond with those given in other tables, which were compiled from the clearances. This discrepancy does not vitiate the statistics of the table for the purpose given above.

The charters for crude oil were for—

	Barrels.	
France	395,560	
Belgium	85,500	
Spain	61,400	191,600 cases.
Bremen	30,800	
Continental ports	18,500	
Mediterranean ports	7,509	
Ireland	5,000	
Total	604,269	191,600 cases.

The charters for refined petroleum were—

For Europe, including the Mediterranean islands:	
Barrels	5,213,081
Cases	1,366,150
Miscellaneous Mediterranean ports, the Levant, Asia Minor, and Syria:	
Barrels	50,800
Cases	874,000
Africa and Mauritius:	
Barrels	2,000
Cases	380,000
Asia, Australia, and the East Indies:	
Cases	6,003,800
South America:	
Cases	17,000

The charters for naphtha were for—

England:	
Barrels	106,050
France:	
Barrels	87,650
Cases	4,900
Belgium:	
Barrels	23,200
Cases	10,000
Sweden:	
Barrels	13,900
Continental ports:	
Barrels	10,300

The charters for residuum were for—

	Barrels.
England	89,900
France	2,000
Antwerp	300

The following-named geographical sections took charters in the census year as given below:

	Refined.		Naphtha.		Crude.		Residuum.	
	Barrels.	Cases.	Barrels.	Cases.	Barrels.	Cases.	Barrels.	Cases.
Great Britain	1,218,150		106,050		5,000		89,900	
Sweden and Norway	77,800		13,900					
Denmark	97,800							
Miscellaneous Baltic ports	361,650							
Russia:								
Baltic	13,950							
Black sea		48,000						
Holland	177,300							
Germany	1,594,256				30,800			
Belgium	552,800	1,000	23,200	10,000	85,500		300	
Continental Europe	706,000		10,300		18,500			
France		7,000	87,650	4,900	395,560		2,000	
Spain:								
Outside	15,400	155,700			61,400	191,600		
Inside	12,300	244,250						
Portugal	32,509	17,000						
Sardinia		12,000						
Sicily		113,000						
Italy	76,700	298,000						
Malta		15,000						
Adriatic ports	7,000	102,000						
Trieste	268,966							
Ionian islands and Greece		73,200						
Turkey in Europe		280,000						
Levant		186,000						
Miscellaneous Mediterranean ports	50,800	602,500			7,509			
Syria and Asia Minor		85,500						
Egypt		230,000						
Algiers	1,000	53,000						
Liberia	1,000	21,000						
Zanzibar		45,000						
South Africa		6,000						
Mauritius		25,000						
British India		1,149,800						
Ceylon		95,000						
Rangoon		151,500						
East Indies		153,000						
Java		2,555,000						
Australia		50,000						
New Zealand		20,000						
Manila		17,000						
China		650,500						
Japan		1,028,000						
Singapore		112,000						
Saigon		22,000						
Buenos Ayres		10,000						
Brazil		7,000						

Commencing at the head of the list, it will be observed that 4,799,706 barrels of refined oil were chartered for Great Britain and the continent of Europe north of France. This amount was all chartered in barrels, with the exception of only 1,000 cases, probably of a special brand, which went to Antwerp. In addition to this vast quantity, amounting to nearly 68.5 per cent. of the total charters of refined oil, there were chartered for the same region 153,450 barrels and 10,000 cases of naphtha, 139,800 barrels of crude oil, and 90,200 barrels of residuum, of which latter material all but 300 barrels were for Liverpool and London, England.

There were chartered for France only 7,000 cases of refined oil, which was for the port of Marseilles, and probably consisted of some special brand. The charters for France, however, included 87,650 barrels and 4,900 cases of naphtha, 395,560 barrels of crude and 2,000 barrels of residuum. France has for many years laid an import duty on refined oils and admitted crude oil free, thus fostering the manufacture of refined oils on her own soil. This fact accounts for the heavy charters of crude oil for French ports.

The charters for Spanish ports embraced both refined and crude oil in barrels and cases. There were chartered for Spain 61,400 barrels and 191,600 cases of crude oil. It will be observed that the charters for the inside ports of Spain include a larger proportion of case oil than the outside. Nearly two-thirds of the oil chartered for Portugal is in barrels. With the exception of 7,509 barrels of crude oil chartered for miscellaneous Mediterranean ports, probably Spanish and French, no crude oil, naphtha, or residuum was chartered east of France or south of the straits of Gibraltar. All of the refined oil chartered for Austria through Trieste was in barrels, besides which 135,500 barrels were chartered for Italy and various Mediterranean and Adriatic ports in barrels. The remainder of the oil chartered for ports between France and Port Said was all case oil, and amounted to 2,098,200 cases. All of the oil chartered for ports south and east of the Mediterranean sea, with the exception of 1,000 barrels for Las Palmas, Canary islands, was case oil. The trade with eastern Asia, including India, the islands, China, and Japan, in case oil is enormous, the charters amounting to 5,933,800 cases for the census year.

Table V shows the relative amounts of the different products of petroleum sent from the different ports, and also gives the amounts and values of lubricating oils exported. In 1879 New York exported of lubricating oils less than one per cent. of the amount of illuminating oils exported, while Boston sent out of lubricating oils nearly 10 per cent. of the amount of illuminating oils exported. The quantity of lubricating oils exported in 1880 was nearly double that of 1879. The total exports of 1880 were more than 45,000,000 gallons in excess of those of 1879, yet their total value was more than $4,000,000 less for the last-named year.

Table VI shows the quantity and value of petroleum and petroleum products exported from the United States from 1873 to 1880, inclusive. This table shows generally a steady increase in the quantity of the different products exported from year to year, but the value of these different quantities varied greatly. For instance, in 1876, 25,343,271 gallons of crude oil were exported, worth $3,343,763, and in 1880, while the quantity was increased to 35,481,168 gallons, the value was decreased to $2,679,193. In 1877, 309,778,832 gallons of refined oil were exported, worth $51,901,106, while the following year, although the amount was lessened only 882,525 gallons, the value was reduced $12,806,655, and in 1879, while the quantity reached 367,321,255 gallons, the value fell to $32,696,713, and in 1880 was still less. The exports of petroleum and its products were valued in 1877 at $57,497,164, a larger amount than has been realized from the same source in any one year prior to January 1, 1881.

Table VII shows the production and quantity and value of exports for seventeen years ending June 30, 1880; that is, for the last seventeen fiscal years prior to and including the census year. (*a*) The fluctuations in relative quantity and value are exhibited in this table.

As an illustration, in round numbers, the 425,000,000 gallons exported in 1880 brought $500,000 less than the 150,000,000 gallons exported in 1871, and about 65 per cent. of the amount obtained for 309,000,000 gallons in 1877. The exports of the fiscal year 1877 were valued at $61,789,438.

The remaining tables need no explanation.

THE CONSUMPTION OF PETROLEUM AND PETROLEUM PRODUCTS IN THE UNITED STATES.

The amount of petroleum and petroleum products consumed in the United States in any given time is a residual quantity consisting of elements very difficult to estimate with absolute accuracy. An approximate estimate, however, has been repeatedly made by subtracting the exports, reduced to crude equivalent from the production, less the accumulated stocks. This method, never of much value, is becoming more unreliable each year as the increasing demand for mineral oil residues increases the production of reduced petroleum, and, consequently, the proportion of illuminating oil manufactured without cracking, and therefore not representing 75 per cent. of the crude oil. The production of oil out of the ground for the census year has been already estimated at 24,354,064 barrels. Of this amount 315,000 barrels were estimated to have been wasted or burned, leaving 24,039,064 barrels as the available production, of which 5,350,863 barrels were added to the stocks already accumulated. Of the remaining 18,688,201 barrels, 17,417,455 barrels were manufactured in this country and 673,763 barrels were exported, leaving 596,983 barrels for consumption in this country.

Of illuminating oils of all grades there were manufactured 11,002,249 barrels, of which 7,346,516 barrels were exported, leaving 3,655,733 barrels for home consumption, an average of about 10,000 barrels per day.

Of lubricating oils there were manufactured of all kinds and grades 380,739 barrels, of which 103,257 barrels were exported, leaving 277,482 barrels for home consumption. Oils consisting in part of crude petroleum are not included in the above amount.

Of naphthas of all grades, including gasoline, there were manufactured 1,508,049 barrels, of which 368,221 barrels were exported, leaving 1,139,828 barrels, of which 57,843 barrels were used as fuel by the manufacturers of petroleum, leaving 1,081,985 barrels for home consumption.

It is impossible to assign any definite amount as representing the consumption of residuum; 229,173 barrels were sold by the manufacturers and 235,314 barrels were burned by them as fuel. Of the 229,173 barrels, 94,141 were exported, leaving a remainder of 135,032 barrels, nearly the whole of which was used as raw material by the manufacturers of lubricating oils. The term "residuum", as it has been used in this report, is probably not properly applied to the whole of the 94,141 barrels reported as exported; but it is impossible to distinguish in the statistics of exports between the different materials, denominated "tar", "pitch," etc., included under the term "residuum."

I have not met with any notice of the export of paraffine wax, but it is not therefore safe to infer that the 7,889,626 pounds manufactured were all consumed in the United States. One firm manufactured 900,000 pounds of candles. While the manufacture of candles represents the largest use for any one purpose, the great number of uses to which it is now applied in the arts represents an enormous consumption of this substance.

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a The census year closed May 31. Practically the last fiscal year is the census year.

The actual consumption of crude petroleum represented by these figures is, after all, only an approximation to a correct result. If the illuminating oils are assumed to represent 75 per cent. of the crude oil, the consumption of crude oil as illuminating oil was 4,874,310 barrels, or 13,354 barrels daily; but in reality the illuminating oil, all grades taken together, does not represent 75 per cent. of the crude oil, and I am inclined to think that 15,000 barrels daily is not far from a correct estimate for the consumption of crude petroleum in the United States during the census year.

TABLE I.—SHIPMENTS OF CRUDE AND REFINED OIL OUT OF THE PRODUCING REGION TO THE FOLLOWING POINTS DURING THE CENSUS YEAR.

[Compiled from the reports of the New York Produce Exchange.]

Month and year.	REFINED REDUCED TO CRUDE.					CRUDE.									
	New York.	Philadelphia.	Baltimore.	Boston.	Local points.	New York.	Philadelphia.	Baltimore.	Boston.	Cleveland.	Pittsburgh.	Ohio river.	Local points.	Fire.	Total.
1879.	*Barrels.*	*Barr'ls.*	*Barr'ls.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barr'ls.*	*Barrels.*
June	210, 488	....	....	37, 830	24, 984	643, 817	29, 151	53, 957	10, 087	114, 810	207, 697	17, 720	18, 773	....	1, 369, 314
July	240, 311	....	....	62, 493	15, 516	465, 824	139, 968	57, 187	23, 203	292, 924	278, 030	20, 336	29, 243	....	1, 625, 005
August	177, 407	....	....	37, 350	25, 806	655, 416	196, 915	57, 337	10, 178	314, 477	284, 563	15, 214	33, 576	....	1, 808, 239
September	135, 043	....	....	26, 977	42, 468	623, 832	169, 062	65, 459	16, 169	296, 116	207, 863	5, 403	38, 728	....	1, 627, 120
October	169, 335	....	....	33, 942	30, 666	502, 400	149, 349	74, 648	10, 352	369, 779	267, 975	5, 932	48, 791	....	1, 663, 159
November	183, 386	....	....	28, 625	55, 245	611, 630	137, 997	56, 778	8, 428	228, 634	193, 770	12, 597	36, 555	....	1, 553, 645
December	91, 114	....	....	55, 085	40, 267	667, 533	221, 743	77, 310	11, 433	242, 415	70, 072	27, 257	28, 356	....	1, 532, 585
1880.															
January	55, 071	90	....	33, 911	49, 098	810, 131	171, 360	78, 017	11, 541	228, 145	152, 330	20, 254	40, 491	....	1, 650, 409
February	24, 382	....	....	18, 050	54, 100	758, 157	179, 145	96, 146	....	156, 041	53, 418	9, 850	42, 862	....	1, 392, 151
March	62, 740	....	....	23, 989	18, 269	084, 808	220, 517	80, 645	9, 489	151. 775	32, 590	7, 400	21, 240	....	1, 613, 462
April	19, 225	....	....	13, 502	21, 079	385, 727	97, 147	12, 816	5, 758	141, 197	65, 619	62, 194	15, 004	....	839, 268
May	2, 001	175	499	18, 940	23, 781	513, 704	61, 503	31, 779	4, 042	102, 358	105, 657	3, 818	26, 402	200, 000	1, 095, 259
Total, census year	1, 370, 503	265	499	390, 691	401, 279	7, 622, 979	1, 773, 827	742, 079	121, 280	2, 638, 671	1, 919, 584	207, 975	380, 021	200, 000	17, 769, 656
Total, 1879	1, 612, 550	....	....	379, 293	333, 446	6, 318, 532	1, 607, 998	677, 273	120, 584	2, 502, 570	1, 901, 649	183, 131	350, 344	....	15, 987, 370
Total, 1880	509, 769	2, 248	7, 322	378, 635	397, 369	6, 461, 465	1, 741, 286	604, 183	99, 819	2, 535, 216	958, 336	206, 577	935, 810	582, 490	15, 420, 525

PERCENTAGE OF DELIVERIES OF CRUDE AND REFINED OIL AT THE ABOVE NAMED POINTS.

Census year	63. 35	0. 01	0. 03	18. 06	18. 55	48. 85	11. 37	4. 75	0. 78	16. 91	12. 30	1. 33	2. 43	1. 28	....
1879	69. 35	....	....	16. 31	14. 34	46. 25	11. 77	4. 96	0. 88	18. 32	13. 92	1. 34	2. 56	....	....
1880	39. 35	0. 17	0. 57	29. 23	30. 68	45. 74	12. 33	4. 28	0. 71	17. 95	6. 78	1. 46	6. 63	4. 12	....

TABLE II.—RECEIPTS OF CRUDE AND REFINED PETROLEUM, ETC., AT NEW YORK, WEEKLY, BY ROUTES, DURING THE CENSUS YEAR.

[Compiled from the reports of the New York Produce Exchange.]

For week ending—	BY ERIE RAILWAY.			BY HUDSON RIVER RAILROAD.		BY PENNSYLVANIA RAILWAY.			CANAL.	TOTAL.		
	Crude.	Refined.	Naphtha.	Crude.	Refined.	Crude.	Refined.	Naphtha.	Crude.	Crude.	Refined.	Naphtha.
1879.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
June 5	1, 641, 465	358, 093	....	1, 805, 265	1, 031, 321	2, 619, 193	26, 220	....	567, 730	6, 633, 353	1, 409, 634	....
June 12	1, 356, 695	982, 488	....	1, 862, 235	699, 501	3, 227, 714	....	....	....	6, 456, 644	1, 681, 989	....
June 19	640, 080	378, 256	....	1, 780, 065	1, 273, 512	2, 765, 171	21, 798	....	901, 108	6, 086, 424	1, 673, 566	....
June 26	1, 730, 340	756, 606	....	1, 557, 630	1, 162, 451	2, 558, 377	64, 296	....	250, 914	6, 097, 261	1, 983, 353	....
July 3	1, 513, 080	709, 324	....	1, 223, 370	1, 626, 623	2, 453, 333	144, 572	....	....	5, 189, 783	2, 480, 519	....
July 10	840, 375	818, 223	....	982, 215	1, 268, 483	1, 584, 893	78, 900	....	....	3, 407, 483	2, 165, 666	....
July 17	616, 770	1, 188, 630	....	1, 029, 420	2, 086, 612	2, 379, 670	520, 525	....	48, 005	4, 073, 865	3, 795, 767	....
July 24	539, 955	931, 869	....	1, 407, 960	2, 170, 037	2, 207, 696	849, 901	....	....	4, 155, 611	3, 951, 607	....
July 31	1, 733, 945	1, 127, 248	....	1, 687, 860	1, 546, 310	2, 166, 219	885, 762	....	....	5, 588, 619	3, 659, 326	....
August 7	1, 048, 595	464, 172	....	1, 712, 025	2, 139, 487	2, 278, 433	957, 719	....	....	5, 038, 553	3, 561, 378	....
August 14	1, 126, 575	830, 537	....	2, 379, 240	2, 579, 830	2, 080, 899	1, 617, 082	....	....	5, 586, 714	5, 027, 449	....
August 21	1, 570, 050	952, 925	....	1, 915, 200	1, 428, 236	1, 517, 964	1, 257, 156	....	....	5, 003, 214	3, 638, 317	....
August 28	1, 854, 720	771, 787	....	2, 429, 010	1, 496, 574	2, 161, 847	1, 530, 884	....	....	6, 445, 577	3, 799, 245	....
September 4	2, 090, 880	188, 141	....	2, 343, 555	923, 823	1, 744, 387	1, 210, 391	....	....	6, 178, 822	2, 322, 364	....
September 11	1, 655, 460	110, 732	....	2, 178, 405	684, 837	1, 544, 964	70, 359	....	....	5, 378, 829	865, 928	....
September 18	634, 545	371, 300	....	2, 840, 085	1, 056, 184	2, 002, 126	782, 315	....	....	5, 476, 756	2, 209, 799	....
September 25	1, 134, 135	479, 400	....	977, 895	1, 435, 944	2, 973, 266	449, 367	....	....	5, 085, 296	2, 364, 711	....

Table II.—RECEIPTS OF CRUDE AND REFINED PETROLEUM—Continued.

For week ending—	By Erie Railway.			By Hudson River Railroad.		By Pennsylvania Railway.			Canal.	Total.		
	Crude.	Refined.	Naphtha.	Crude.	Refined.	Crude.	Refined.	Naphtha.	Crude.	Crude.	Refined.	Naphtha.
1879.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
October 2	991, 485	564, 000	....	2, 601, 360	1, 404, 783	2, 388, 762	450, 100	....	....	5, 981, 607	2, 418, 883	....
October 9	535, 185	826, 730	....	1, 088, 325	792, 796	2, 227, 820	402, 057	....	....	3, 851, 330	2, 021, 583	....
October 16	455, 400	1, 312, 788	....	280, 575	551, 733	1, 840, 110	240, 358	....	....	2, 576, 085	2, 104, 879	....
October 23	1, 297, 575	633, 090	....	358, 830	689, 302	2, 516, 842	93, 718	....	....	4, 173, 247	1, 416, 110	....
October 30	1, 704, 960	593, 093	....	1, 019, 225	1, 226, 465	2, 916, 481	11, 938	....	....	5, 640, 666	1, 831, 496	....
November 6	1, 246, 680	84, 224	....	843, 210	487, 625	2, 778, 771	34, 028	....	....	4, 868, 661	605, 877	....
November 13	1, 871, 640	745, 796	....	781, 920	752, 705	2, 608, 972	74, 307	....	....	5, 262, 532	1, 527, 808	....
November 20	2, 614, 590	587, 453	....	683, 910	656, 138	1, 910, 763	667, 024	....	....	5, 209, 263	1, 910, 615	....
November 27	2, 166, 435	560, 522	....	719, 585	596, 195	1, 781, 129	252, 531	....	....	4, 667, 049	1, 409, 248	....
December 4	1, 568, 340	629, 988	....	726, 930	287, 311	3, 773, 693	736, 866	....	....	6, 068, 963	1, 654, 165	....
December 11	1, 192, 230	379, 525	....	1, 364, 040	492, 137	2, 365, 794	306, 205	....	....	4, 922, 064	1, 177, 867	....
December 18	1, 192, 275	379, 713	....	1, 235, 475	250, 510	2, 007, 899	299, 249	....	....	4, 435, 649	929, 472	....
December 25	2, 349, 360	1, 044, 105	....	861, 480	623, 643	2, 154, 420	32, 900	....	....	5, 365, 260	1, 700, 648	....
December 31	2, 859, 795	1, 744, 452	....	887, 805	364, 062	2, 618, 748	35, 673	....	....	6, 366, 348	2, 144, 187	....
1880.												
January 8	2, 495, 655	1, 193, 850	....	1, 039, 140	794, 100	4, 051, 321	107, 771	....	....	7, 586, 116	2, 095, 721	....
January 15	3, 411, 810	963, 200	....	1, 158, 120	440, 950	3, 288, 166	401, 756	....	....	7, 856, 096	1, 805, 906	....
January 22	2, 306, 205	501, 250	....	1, 306, 170	340, 100	1, 386, 682	438, 050	....	....	4, 999, 057	1, 279, 400	....
January 29	2, 708, 460	653, 300	66, 150	1, 369, 980	221, 800	2, 601, 312	254, 350	....	....	6, 679, 752	1, 129, 450	66, 150
February 5	1, 562, 805	368, 750	....	1, 392, 608	156, 600	3, 683, 581	210, 200	....	....	6, 639, 054	735, 550	....
February 12	2, 336, 680	181, 300	....	1, 309, 005	173, 500	3, 301, 056	89, 450	....	....	6, 946, 841	444, 250	....
February 19	2, 263, 320	51, 300	....	1, 786, 185	109, 500	2, 451, 109	19, 500	....	....	6, 500, 714	180, 300	....
February 26	1, 873, 170	41, 100	....	1, 485, 495	136, 900	2, 453, 912	11, 600	....	....	5, 812, 577	189, 600	....
March 4	1, 482, 840	30, 900	47, 150	1, 934, 820	96, 250	3, 663, 640	2, 500	....	....	7, 081, 000	129, 650	47, 150
March 11	48, 500	2, 983, 950	89, 350	1, 886, 625	112, 750	3, 040, 501	6, 750	....	....	4, 976, 626	3, 103, 450	89, 350
March 18	3, 701, 520	2, 800	59, 150	2, 088, 755	108, 600	3, 442, 571	27, 500	....	....	9, 232, 846	138, 900	59, 150
March 25	3, 074, 220	2, 800	132, 850	1, 779, 345	171, 300	3, 201, 898	5, 000	....	....	8, 055, 463	179, 100	132, 850
April 1	2, 834, 100	1, 302, 500	....	2, 066, 445	428, 100	3, 626, 020	2, 500	....	....	8, 526, 565	1, 733, 100	....
April 8	1, 124, 910	....	....	1, 310, 445	714, 700	2, 122, 824	16, 000	....	....	4, 557, 539	730, 700	....
April 15	817, 875	2, 650	....	595, 620	71, 000	411, 573	....	....	....	1, 825, 468	73, 650	....
April 22	1, 711, 845	....	....	444, 815	44, 000	1, 144, 611	2, 500	....	....	3, 301, 271	46, 500	....
April 29	2, 195, 280	19, 450	....	716, 500	32, 000	208, 583	5, 000	....	....	3, 120, 363	56, 450	....
May 6	1, 097, 640	38, 700	....	1, 727, 010	96, 000	777, 995	2, 500	....	....	3, 602, 645	137, 200	....
May 13	2, 803, 770	....	....	1, 751, 670	140, 000	450, 614	17, 400	....	....	5, 006, 054	157, 400	....
May 20	3, 674, 385	35, 300	....	1, 733, 400	108, 000	617, 924	6, 600	....	....	6, 025, 709	149, 900	....
May 27	4, 367, 835	16, 050	....	1, 519, 200	78, 100	250, 314	7, 500	....	....	6, 137, 349	101, 650	....
Total, census year	91, 675, 935	29, 894, 360	394, 650	73, 965, 518	38, 459, 426	118, 332, 563	15, 732, 688	....	1, 767, 757	285, 740, 033	84, 041, 483	394, 650
Total, 1880	119, 842, 560	19, 271, 650	1, 061, 250	80, 825, 203	18, 439, 950	56, 210, 897	5, 135, 977	....	....	256, 878, 660	42, 847, 577	1, 553, 850
Total, 1879	77, 580, 610	28, 460, 996	256, 620	68, 061, 215	43, 657, 858	98, 434, 951	15, 406, 718	394, 337	2, 830, 045	246, 906, 821	87, 525, 572	650, 957
Total, 1878	67, 263, 973	26, 541, 352	664, 380	47, 579, 410	42, 389, 953	68, 110, 155	15, 873, 717	....	7, 103, 634	189, 798, 589	79, 600, 602	....
Total, 1877	63, 734, 244	51, 117, 982	860, 850	36, 882, 450	45, 319, 665	78, 597, 550	7, 184, 614	....	....	179, 214, 244	103, 662, 216	....

TABLE III.—EXPORTS OF PETROLEUM AND PETROLEUM PRODUCTS FROM NEW YORK TO FOREIGN PORTS FOR 1878, 1879, 1880, AND THE CENSUS YEAR.

[From the reports of the New York Petroleum Exchange.]

REFINED PETROLEUM. 1 barrel = 50 gallons.

	1878.		1879.		1880.		Census year.	
	Gallons.	Barrels.	Gallons.	Barrels.	Gallons.	Barrels.	Gallons.	Barrels.
Great Britain:								
London	13,158,960	263,180	21,192,079	423,842	14,026,865	280,537	22,367,521	447,350
Liverpool	5,013,377	100,268	7,993,254	159,865	6,482,959	129,659	8,943,434	178,869
Bristol	2,537,886	50,758	4,280,209	85,604	4,195,827	83,917	3,299,266	65,985
Ireland	5,444,392	108,888	7,158,319	143,166	4,261,677	85,234	6,967,157	139,343
Other ports	3,277,117	65,542	5,266,440	105,329	3,935,042	78,701	4,639,210	92,784
Germany:								
Bremen	28,279,351	565,587	40,035,341	800,707	43,953,350	879,067	47,494,457	949,889
Hamburg	7,971,865	159,437	11,638,166	232,708	15,344,524	306,890	11,925,646	238,513
Königsburg and Stettin	7,977,223	159,544	7,425,684	148,514	3,430,726	68,615	7,036,048	140,721
Dantzic	3,386,423	67,728	1,874,059	37,481	804,144	16,083	1,149,168	22,983
Other ports	739,317	14,786	1,949,384	38,808	334,550	6,691	1,094,486	21,890
Norway and Sweden	3,928,374	78,567	5,480,157	109,603	5,771,784	115,436	5,704,219	114,084
Russia	1,811,288	36,226	2,670,900	53.418	1,024,632	20,493	2,062,717	41,254
Denmark	5,886,528	117,731	5,809,642	116,193	8,120,126	162,403	5,038,410	100,768
Belgium	10,909,641	218,193	16,156,629	323,133	18,560,737	371,215	17,640,481	352,810
Holland	8,623,656	172,473	11,010,971	220,219	11,858,877	237,178	11,421,878	228,438
Spain	6,658,785	133,176	7,693,336	153,867	2,618,769	52,375	7,163,521	143,270
Portugal	1,356,800	27,136	1,973,427	39,469	1,336,379	26,728	1,735,029	34,701
Gibraltar and Malta	2,480,342	49,607	1,857,396	37,148	2,573,923	51,478	1,746,220	34,924
Italy	3,018,291	60,366	2,331,628	46,633	1,960,057	39,201	2,161,160	43,223
Trieste	5,807,423	116,148	9,787,224	195,744	10,142,010	202,840	8,967,587	179,352
Greece	1,594,220	31,884	1,513,650	30,273	334,310	6,686	1,205,250	24,105
Turkey in Europe	4,453,916	89,078	3,605,440	72,109	1,727,350	34,547	3,048,380	60,968
Turkey in Asia	2,803,850	56,077	1,404,660	28,093	660,990	13,220	1,331,160	26,623
India	....	....	7,588,460	151,769	9,120,710	182,414	13,178,760	263,575
China and Japan	24,271,545	585,431	18,803,770	376,075	6,751,392	135,028	17,021,352	340,427
East Indies	8,861,345	177,227	22,145,090	442,902	14,949,765	298,995	26,926,105	538,522
Africa:								
Alexandria	1,555,666	31,113	3,616,633	72,333	2,203,620	44,072	2,829,560	56,591
Canary islands	109,033	2,181	72,976	1,460	74,095	1,482	88,974	1,779
Other ports	1,719,518	34,390	2,350,170	47,183	2,077,655	41,553	2,798,510	55,970
Australia	2,476,982	49,540	2,277,346	45,547	1,910,324	38,206	2,954,956	59,099
New Zealand	811,993	16,240	352,260	7,045	565,482	11,310	328,730	6,575
Sandwich Islands	32,000	640	45,850	917	74,000	1,480	64,000	1,280
South America:								
Brazil	3,388,078	67,762	4,215,973	84,319	4,036,850	80,737	3,986,652	79,733
Argentine Confederation	1,632,085	32,660	1,659,210	33,184	2,060,810	41,216	1,705,210	34,104
Chili and Peru	1,062,115	21,242	926,872	18,537	334,123	6,682	638,993	12,780
United States of Colombia	2,640	53	38,060	761	42,068	841	42,946	859
Venezuela	403,682	8,074	523,958	10,479	672,162	13,443	483,220	9,664
Other ports	13,500	270	26,100	522	31,496	630	45,477	910
Central America	162,244	3,245	215,383	4,308	239,680	4,794	232,355	4,647
Mexico	532,921	10,658	784,483	15,690	696,359	13,927	735,613	14,712
British North America	412,329	8,247	237,654	4,753	171,337	3,427	126,835	2,537
Cuba	2,117,267	42,345	703,186	14,064	433,528	8,671	430,839	8,617
British West Indies	1,222,602	24,452	1,386,679	27,734	1,263,614	25,272	1,339,438	26,789
Other West Indies	801,449	16,029	968,776	19,376	928,393	18,568	929,361	18,587
Totals	188,708,939	3,774,179	249,046,884	4,980,938	212,097,080	4,241,942	261,030,291	5,220,606

CRUDE PETROLEUM. 1 barrel = 42 gallons.

	1878.		1879.		1880.		Census year.	
	Gallons.	Barrels.	Gallons.	Barrels.	Gallons.	Barrels.	Gallons.	Barrels.
France:								
Havre	5,862,304	139,579	7,803,090	185,788	7,687,297	183,031	7,994,545	190,346
Marseilles	1,765,159	42,028	2,041,059	48,596	2,116,256	50,387	2,038.590	48,538
Bordeaux	1,449,115	34,503	2,464,332	58,675	1,853,088	44,121	2,208,468	52,583
Dunkirk	2,929,780	69,733	2,704,475	64,392	3,831,438	91,225	3,278,011	78,048
Other ports	629,319	14,984	2,752,155	65,527	4,039,696	96,183	2,938,081	69,954
Antwerp	170,320	4,055	140,506	3,345	322,115	7,669	140,506	3,345
Bremen	1,102,060	26,240	2,133,847	50,806	3,703,109	88,169	2,773,370	66,023
Norway and Sweden	46,324	1,103	....	....	51,968	1,237	....	....
Spain	277,072	6,597	1,873,167	44,599	8,694,381	207,009	2,913,881	69,378
Cuba	344,786	8,209	1,614,300	38,436	1,610,710	38,350	1,297,500	30,893
Other ports	....	....	....	....	486	12	486	12
Totals	14,576,239	347,053	23,526,031	560,165	33,910,544	807,394	25,583,438	609,130

TABLE III.—EXPORTS OF PETROLEUM AND PETROLEUM PRODUCTS—Continued.

NAPHTHA. 1 barrel = 50 gallons.

	1878.		1879.		1880.		Census year.	
	Gallons.	Barrels.	Gallons.	Barrels.	Gallons.	Barrels.	Gallons.	Barrels.
Great Britain	4, 915, 361	98, 307	7, 497, 559	149, 951	6, 152, 564	123, 051	7, 024, 509	140, 490
France	2, 372, 820	47, 456	4, 864, 165	97, 283	4, 624, 955	92, 499	6, 768, 300	135, 366
Germany	712, 531	14, 251	937, 995	18, 760	781, 566	15, 631	1, 130, 037	22, 601
Other European ports	1, 304, 755	26, 095	1, 800, 010	36, 000	1, 053, 883	21, 078	1, 777, 404	35, 548
Various ports	109, 916	2, 198	81, 567	1, 631	68, 692	1, 374	74, 009	1, 480
Totals	9, 415, 383	188, 308	15, 181, 296	303, 626	12, 681, 660	253, 633	16, 774, 259	335, 485

RESIDUUM. 1 barrel = 50 gallons.

To all ports	2, 617, 039	52, 341	4, 177, 704	83, 554	2, 863, 552	57, 271	4, 135, 260	82, 705

SUMMARY.

Total refined, crude equivalent	251, 611, 919		332, 062, 500		282, 796, 100		348, 040, 400	
Total crude	14, 576, 239		23, 526, 931		33, 910, 544		25, 583, 438	
Total from New York, crude equivalent	266, 188, 158		355, 589, 431		316, 706, 644		373, 623, 838	

EXPORTS OF PETROLEUM AND PETROLEUM PRODUCTS FROM PHILADELPHIA TO FOREIGN PORTS FOR 1877, 1878, 1879, AND 1880.

[From the report of the New York Produce Exchange.]

	1877.	1878.	1879.	1880.
	Gallons.	*Gallons.*	*Gallons.*	*Gallons.*
United Kingdom	2, 812, 745	4, 340, 407	2, 037, 860	2, 342, 234
Northern Europe	32, 159, 144	47, 539, 968	50, 542, 743	41, 539, 471
Mediterranean ports	13, 728, 475	18, 884, 404	26, 691, 586	8, 763, 135
East Indies	208, 881			204, 500
China and Japan	216, 500	2, 840, 000	1, 855, 250	1, 342, 100
South and Central America	29, 617	29, 815	361, 646	22, 605
West Indies	274, 821	32, 100	58, 448	5, 000
British North America	3, 450	277, 268		
Other countries				454, 901
Totals	49, 433, 633	73, 943, 962	81, 547, 533	54, 673, 946

TABLE IV.—THE CHARTERS REPORTED FOR CRUDE AND REFINED PETROLEUM, NAPHTHA, AND RESIDUUM FROM NEW YORK, PHILADELPHIA, BOSTON, BALTIMORE, RICHMOND, AND PORTLAND TO THE DIFFERENT PORTS OF THE WORLD, EXCLUSIVE OF NORTH AMERICA, DURING THE CENSUS YEAR.

[From the reports of the New York Petroleum Exchange.]

	REFINED.		NAPHTHA.		CRUDE.		RESIDUUM.	
	Barrels.	Cases.	Barrels.	Cases.	Barrels.	Cases.	Barrels.	Cases.
Aarhuus	3, 000							
Adriatic sea	7, 000	102, 000						
Adelaide		5, 000						
Alexandria		209, 000						
Alicante	500	98, 000				13, 600		
Algiers	200	27, 000						
Amsterdam	45, 700							
Ancona	300	25, 000						
Anjier		889, 000						
Antwerp	552, 800	1, 000	23, 500	10, 000	11, 000		300	
Baltic ports	361, 650							
Barcelona					3, 300			
Bari		18, 000						
Belfast	20, 700							
Bergen	8, 800							
Beyrout		12, 000						
Bilboa	7, 600	8, 000			16, 200	158, 000		
Blaye			3, 500		49, 100			
Bombay		627, 800						
Bona		6, 000						

TABLE IV.—THE CHARTERS REPORTED FOR CRUDE AND REFINED PETROLEUM, ETC.—Continued.

	REFINED.		NAPHTHA.		CRUDE.		RESIDUUM.	
	Barrels.	Cases.	Barrels.	Cases.	Barrels.	Cases.	Barrels.	Cases.
Bordeaux			19,550		39,400			
Bremen	1,337,106		23,200		30,800			
Bristol	60,100		18,850					
Cadiz	500	35,800						
Cagliari		12,000						
Calcutta		477,000						
Cartagena		30,000						
Cette					12,400			
China		215,000						
Christiana	15,200							
Civita Vecchia		11,000						
Constantinople		140,000						
Continent of Europe	706,500		10,300		18,500			
Copenhagen	32,200							
Corfu		34,000						
Cork	108,100				5,000			
Corunna		6,000			14,200			
Cronstadt	10,950							
Dantzig	21,700							
Drontheim	2,800							
Drammen	1,500							
Dublin	19,200							
Dunkirk					74,500			
Dutch ports	30,100							
East Indies		153,000						
East Indies, British		25,000						
Elsinore	60,400							
Exeter	9,950		9,800					
Exmouth			1,700					
Flensborg	2,200							
French ports			2,000	4,900	3,500			
Galway	3,000							
Gefle	2,400							
Genoa	26,600	150,000						
German ports	5,500							
Gibraltar		18,500						
Gottenburg	30,700		1,000					
Hamburg	221,750							
Havre			52,800		185,700			
Hiogo		50,000						
Hong-Kong		82,500						
Hull	9,000		3,300					
Ireland, east coast	21,350							
Italian ports	3,000							
Japan		806,000						
Java		1,666,000						
Königsburg	6,000							
Leghorn	10,000	40,000						
Levant		186,000						
Limerick	5,000							
Lisbon	13,709	6,000						
Liverpool	185,400		19,500				82,400	
London	616,300		50,700				7,500	
Malaga		43,000						
Malmo	2,200							
Malta		15,000						
Manila		17,000						
Marseilles		7,000	600		61,560		2,000	
Mauritius		25,000						
Mediterranean ports	50,800	602,500			7,509			
Messina		37,000						
Montevideo		10,000						
Naples	27,600	8,000						
Newcastle	7,600							
New Zealand		20,000						

TABLE IV.—THE CHARTERS REPORTED FOR CRUDE AND REFINED PETROLEUM, ETC.—Continued.

	REFINED.		NAPHTHA.		CRUDE.		RESIDUUM.	
	Barrels.	Cases.	Barrels.	Cases.	Barrels.	Cases.	Barrels.	Cases.
Norway	4,300							
Odessa		48,000						
Oporto	18,800	11,000						
Oran	800	12,000						
Palermo		49,000						
Passages					17,000	2,000		
Piræus		31,000						
Palmas	1,000	21,000						
Penang		20,000						
Phillipsville		8,000						
Plymouth	2,000		2,200					
Port d'Gallo		95,000						
Port Philip Head		45,000						
Port Said		21,000						
Rangoon		151,500						
Riga	3,000							
Rivadeo		1,000						
Rostock	2,200							
Rotterdam	101,500							
Rouen			3,000		39,200			
Sables d'Oloun					2,500			
Saigon		22,000						
Salonica		128,000						
Santander	2,100	13,000						
Santos		7,000						
Seville	200	15,900						
Shanghai		353,000						
Sicily		27,000						
Singapore		112,000						
Smyrna		73,500						
South Africa		6,000						
Spanish ports	10,100	53,000			5,500	2,000		
Stockholm	5,000							
Sundsval	2,700							
Swedish ports	2,200							
Tarragona	2,100				5,200	16,000		
Tarranti		8,000						
Toulon					2,200			
Tralee	1,500							
Trieste	268,966							
United Kingdom	148,950							
Valencia	4,600	27,750						
Venice	9,300	38,000						
Vigo		50,000						
Volo		12,000						
Yokohama		172,000						
Zante		8,200						
Zanzibar		45,000						
Totals	5,265,981	8,640,950	245,500	14,900	604,269	191,600	92,200	

	Barrels of 50 gallons each.	Gallons.
Refined:		
In barrels	5,265,981	349,758,550
In cases	1,729,190	
Naphtha:		
In barrels	245,500	12,424,000
In cases	2,980	
Crude:		
In barrels	604,269	32,129,450
In cases	38,320	
Residuum:		
In barrels	92,200	4,610,000
	7,978,440	398,922,000

TABLE V.—PETROLEUM AND ITS PRODUCTS EXPORTED FROM THE UNITED STATES DURING THE YEARS ENDING JUNE 30, 1879 AND 1880.

[From report of Bureau of Statistics.]

	NEW YORK.		PHILADELPHIA.		BALTIMORE.		BOSTON.		OTHER PORTS.		TOTAL.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Qnantity.	Value.
	Gallons.	*Dollars.*	*Gallons.*	*Dollars.*	*Gallons.*	*Dollars.*	*Gallons.*	*Dollars.*	*Gallons.*	*Dollars.*	*Gallons.*	*Dollars.*
Crude	17, 716, 883	1, 517, 701	4, 687, 786	377, 197	1, 166, 825	98, 292	....	....	2, 302, 994	187, 223	25, 874, 488	2, 180, 413
Naphtha..........	11, 477, 029	987, 145	2, 729, 037	207, 928	600, 782	42, 500	52, 750	4, 623	194, 763	16, 584	15, 054, 361	1, 258, 780
Illumiuating......	206, 520, 009	23, 088, 504	76, 307, 729	7, 795, 749	32, 662, 045	3, 231, 700	5, 090, 871	640, 553	11, 005, 788	1, 243, 356	331, 586, 442	35, 909, 862
Lubricating	1, 709, 556	452, 257	7, 182	3, 367	269, 759	56, 249	478, 998	134, 903	22, 186	8, 692	2, 487, 681	655, 468
Residuum	2, 684, 052	173, 563	144, 564	7, 952	216, 342	12, 693	....	....	262, 080	16, 518	3, 307, 038	210, 726
Total, 1879...	240, 107, 529	26, 219, 170	83, 876, 298	8, 302, 193	34, 915, 753	3, 441, 434	5, 622. 619	780, 079	13, 787, 811	1, 472, 373	378, 310, 010	40, 305, 249
Crude	24, 034, 260	1, 652, 200	2, 730, 147	160, 549	... .	....	500	65	1, 533, 090	114, 393	28, 297, 997	1, 927, 207
Naphtha..........	15, 257, 520	996, 398	2, 366, 622	148, 464	682, 702	36, 200	385	93	103, 815	11, 074	18, 411, 044	1, 192, 229
Illuminating......	266, 841, 227	23, 489, 496	77, 083, 630	6, 234, 608	17, 921, 548	1, 399, 975	4, 611, 433	507, 511	867, 985	151, 985	367, 325, 823	31, 783, 575
Lubricating	4, 151, 597	822, 388	34, 943	6, 980	367, 240	68, 713	600, 837	137, 378	8, 218	3, 665	5, 162, 835	1, 039, 124
Residuum	3, 885, 588	217, 677	395, 094	28, 161	416, 430	24, 000	....	....	69, 888	6, 652	4, 767, 000	276, 490
Total, 1880...	314, 170, 192	27, 178, 159	82, 610, 436	6, 578, 762	19, 387, 920	1, 528, 888	5, 213, 155	645, 047	2, 582, 996	287, 769	423, 964, 699	36, 218, 625

TABLE VI.—EXPORTS OF PETROLEUM AND PETROLEUM PRODUCTS FROM ALL UNITED STATES PORTS TO ALL FOREIGN COUNTRIES, AND THE DECLARED VALUE THEREOF, COMPILED FROM RETURNS OF THE UNITED STATES BUREAU OF STATISTICS.

[From the report of the New York Produce Exchange for 1880.]

Year.	CRUDE.		REFINED.		NAPHTHA, ETC.		RESIDUUM.	
	Quautity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Gallons.	*Dollars.*	*Gallons.*	*Dollars.*	*Gallons.*	*Dollars.*	*Gallons.*	*Dollars.*
1873	19, 643, 740	2, 665, 771	209, 021, 305	41, 854. 841	10, 250, 547	1, 264. 962	2, 069, 616	145, 398
1874	14, 430, 851	1, 428, 494	208, 635, 382	30, 497, 191	10, 617, 268	997, 355	2, 263, 776	167, 794
1875	16, 536, 800	1, 738, 589	204, 616, 798	28, 417, 339	14, 048, 726	1, 392, 192	2, 655, 984	169, 671
1876	25, 343, 271	3, 343, 763	221, 900, 446	44, 448, 361	13, 252, 751	1, 502, 798	3, 273, 024	239, 461
1877	28, 772, 233	3, 267, 309	309, 778, 832	51, 901, 106	19, 565, 665	1, 938, 672	4, 778, 641	390, 077
1878	23, 883, 508	2, 150, 390	308, 896, 307	39, 094, 451	13, 431, 783	1, 077, 402	3, 145, 506	221, 019
1879	27, 841, 900	2, 182, 573	367, 321, 255	32, 696, 713	22, 695, 223	2, 081, 210	4, 457, 486	273, 045
1880	35, 481, 168	2, 679, 193	284, 470, 800	29, 126, 985	22, 010, 074	2, 615, 094	3, 324, 804	204, 324
Total	191, 933, 471	19, 456, 082	2, 114, 641, 125	298, 036, 987	125, 871, 977	12, 869, 685	25, 968, 837	1, 810, 789
Average	23, 991, 684	2, 432, 010	264, 330, 141	37, 254, 623	15, 733, 997	1, 608, 711	3, 246, 105	226, 349
CENSUS YEAR.								
1879.								
June	1, 350, 713	102, 755	30, 221, 930	2, 719, 090	1, 305, 136	129, 170	62, 664	3, 568
July	3, 297, 347	205, 781	44, 972, 481	3, 882, 095	1, 568, 370	136, 419	194, 082	14, 166
Augnst	1, 483, 108	94, 086	41, 883, 762	3, 325, 565	2, 579, 406	207, 179	451, 500	26, 781
September	1, 496, 109	135, 931	40, 046, 705	3, 092, 885	2, 187, 854	168, 749	328, 272	21, 615
October	2, 808, 561	163, 935	42, 837, 294	3, 530, 654	3, 651, 526	296, 224	758, 478	36, 364
November	2, 924, 488	187, 481	32, 684, 161	2, 810, 061	2, 947, 099	175, 141	769, 062	35, 530
December	3, 223, 457	248, 822	37, 455, 351	3, 352, 574	3, 794, 884	305, 022	594, 258	33, 029
1880.								
January	2, 299, 624	170, 399	34, 219, 503	3, 159, 460	1, 407, 958	158, 877	495, 768	39, 334
February	2, 756, 776	211, 236	20, 593, 427	1, 934, 975	1, 030, 129	146, 119	582, 330	31, 035
March	1, 945, 020	136, 152	20, 545, 746	1, 939, 466	2, 059, 438	280, 083	410, 718	22, 641
April	1, 745, 150	121, 418	18, 130, 976	1, 724, 732	1, 129, 941	162, 784	2, 604	248
May	1, 645, 181	121, 887	13, 090, 549	1, 150, 665	897, 004	102, 064	187, 152	10, 199
Total	26, 975, 534	1, 899, 883	376, 681, 885	32, 622, 222	23, 658, 745	2, 267, 831	4, 836, 888	274, 510

TABLE VII.—QUANTITY OF PETROLEUM PRODUCED, AND THE QUANTITY AND VALUE OF PETROLEUM PRODUCTS EXPORTED FROM THE UNITED STATES DURING EACH FISCAL YEAR FROM 1864 TO 1880, INCLUSIVE.

[From the report of the New York Produce Exchange for 1880.]

Years ending June 30—	PRODUCTION.*		EXPORTS FROM THE UNITED STATES.										Total.	
					Mineral, refined or manufactured.									
	Barrels produced of 42 gallons each.	Gallone produced.	Crude oil, including all natnral oils, without regard to gravity.		Naphtha, henzine, gasoline, etc.		Illuminating.		Lubricating (heavy paraffine, etc.).		Residuum (tar, pitch, and all other from which the light hodies have been distilled).			
			Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars.	Gallons.	Dollars.
1864 ...	2, 478, 709	104,105,778	9,980,654	3,864,187	438,197	154,091	12,791,518	6,764,411	....	....	....	....	23,210,369	10, 782, 689
1865....	2, 424, 905	101,846,010	12,293,897	6,868,513	480,947	173,943	12,722,005	9,520,957	....	....	....	....	25,496,849	16, 563, 413
1866....	3, 165, 700	132,959,400	16,057,943	6,015,921	673,477	188,825	34,255,921	18,626,141	....	....	....	....	50,987,341	24, 830, 887
1867....	3, 591, 900	150,859,800	7,344,248	1,864,001	224,576	34,175	62,686,657	22,509,466	....	....	....	....	70,255,481	24, 407, 642
1868....	3, 613, 709	151,775,778	10,029,659	1,564,933	1,517,268	267,873	67,909,961	19,977,870	....	....	....	....	79,456,888	21, 810, 676
1869 ...	4, 046, 558	169,955,436	13,425,566	2,994,404	2,673,094	445,770	84,403,492	27,636,137	†134,532	51, 122	....	....	100,636,684	31, 127, 433
1870....	4, 411, 016	185,262,672	10,403,314	2,237,292	5,422,604	564,864	97,902,505	29,864,193	†6,871	2, 611	....	....	113,735,294	32, 668, 960
1871....	5, 558, 775	233,468,550	9,859,038	1,971,847	7,209,592	746,797	132,608,955	34,138,736	†59,632	22, 660	†155, 474	14,770	149,892,691	36, 894, 810
1872 ...	5, 842, 497	245,384,874	13,559,768	2,307,111	8,092,635	932,160	122,539,575	30,566,108	541,419	211, 287	438,186	41, 724	145,171,583	34, 058, 390
1873....	7, 242, 343	304,178,406	18,439,407	3,010,050	9,743,593	1,487,439	158,102,414	37,195,735	748,699	277, 966	781,074	79, 566	187,815,187	42, 050, 756
1874....	11, 188, 741	469,927,122	17,776,419	2,099,696	9,737,457	1,038,622	217,220,504	37,560,995	1,244,305	404, 243	1,827,798	142, 299	247,806,483	41, 245, 855
1875....	10, 083, 828	423,520,776	14,718,114	1,406,018	11,758,940	1,141,440	191,551,933	27,030,361	1,173,473	313, 646	2,752,848	187, 103	221,955,308	30, 078, 568
1876....	8, 823, 142	370,571,964	20,520,397	2,220,268	14,780,236	1,442,811	204,814,673	28,755,638	963,442	303, 863	2,581,404	193, 206	243,660,152	32, 915, 786
1877 ...	10, 822, 871	454,560,582	26,819,202	3,756,729	15,140,183	1,816,682	262,441,844	55,401,132	1,601,065	497, 540	3,196,620	317, 355	309,198,914	61, 789, 438
1878....	14, 738, 262	619,007,004	26,936,727	2,694,018	16,416,621	1,411,812	289,214,541	41,513,676	2,304,624	639, 381	3,968,790	316, 087	338,841,303	46, 574, 974
1879....	16, 917, 606	710,539,452	25,874,488	2,180,413	15,054,361	1,258,780	331,586,442	35,999,862	2,487,681	655, 468	3,307,038	210, 726	378,310,010	40, 305, 249
1880....	22, 382, 509	940,065,378	28,297,997	1,927,207	18,411,044	1,192,229	367,325,823	31,783,575	5,162,835	1, 039, 124	4,767,000	276, 490	423,964,699	36, 218, 625

* As a given number of gallons of refined petroleum represents the product of a larger number of gallons of crude petroleum, it is necessary to reduce the exports of petroleum to their equivalent in crude oil in order to arrive at a knowledge of the percentage of the total product of mineral oil exported.

† Estimated.

TABLE VIII.—NEW YORK PETROLEUM MARKET.

AVERAGE PRICES PER YEAR.

[From reports of the New York Produce Exchange.]

Year.	CRUDE IN BULK, PER GALLON.		CRUDE IN BARRELS, PER GALLON.		REFINED STANDARD WHITE, PER GALLON.		NAPHTHA IN BARRELS, PER GALLON.	
	Extremes.	Average price.	Extremes.	Average price.	Extremes.	Average price.	Extremes.	Average price.
	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.
1873	....	7.62	....	....	....	18.21	....	11.07
1874	....	5.92	....	....	....	13.09	....	9.04
1875	....	6.52	....	....	....	12.92	....	9.67
1876	....	16.53	....	10.50	....	19.19	....	11.36
1877	....	9.09	....	9.12	....	15.72	....	9.75
1878	....	6.86	....	6.37	....	10.77	....	7.13
1879	....	3.62	....	7.10	....	8.08	....	6.40
1880	....	7.14	....	7.14	....	9.12	....	7.62
CENSUS YEAR, 1879.								
June	....	3.60	5 to $7\frac{3}{4}$	6.44	$6\frac{5}{8}$ to $7\frac{3}{8}$	7.23	5 to 8	6.42
July	....	2.50	5 to $6\frac{1}{4}$	5.41	$6\frac{5}{8}$ to $7\frac{3}{8}$	6.97	4 to 6	5.14
August	....	2.38	$4\frac{7}{8}$ to $6\frac{1}{4}$	5.42	$6\frac{1}{8}$ to $7\frac{1}{4}$	6.57	4 to 5	4.50
September	....	2.50	$4\frac{7}{8}$ to $6\frac{3}{8}$	5.50	$6\frac{1}{4}$ to $7\frac{1}{2}$	6.79	4 to 5	4.62
October	....	3.10	$5\frac{3}{8}$ to $7\frac{1}{2}$	6.55	7 to $7\frac{7}{8}$	7.43	$4\frac{1}{2}$ to 6	5.23
November	....	3.90	$6\frac{1}{2}$ to $8\frac{1}{2}$	7.45	$7\frac{1}{8}$ to $8\frac{7}{8}$	8.03	6 to $6\frac{3}{4}$	6.27
December	....	....	$7\frac{1}{4}$ to $8\frac{1}{2}$	7.92	$8\frac{1}{4}$ to 9	8.56	$6\frac{1}{2}$ to $6\frac{3}{4}$	6.63
1880.								
January	$7\frac{1}{16}$ to 8	7.53	7 to $8\frac{3}{8}$	7.55	$7\frac{1}{2}$ to $8\frac{1}{4}$	7.94	$6\frac{1}{2}$ to 7	6.71
February	$6\frac{7}{8}$ to $7\frac{11}{16}$	7.03	$6\frac{5}{8}$ to $7\frac{3}{4}$	7.29	$7\frac{5}{8}$ to 8	7.81	$6\frac{1}{4}$ to 7	6.65
March	$6\frac{9}{16}$ to $7\frac{5}{16}$	6.68	$6\frac{1}{2}$ to $7\frac{1}{2}$	6.11	$7\frac{5}{8}$ to $7\frac{7}{8}$	7.75	$5\frac{1}{4}$ to $6\frac{3}{4}$	6.06
April	$6\frac{13}{16}$ to $7\frac{5}{8}$	6.97	$6\frac{5}{8}$ to $7\frac{3}{4}$	7.22	$7\frac{1}{2}$ to $7\frac{7}{8}$	7.66	$5\frac{1}{2}$ to $5\frac{3}{4}$	5.63
May	$6\frac{7}{16}$ to $7\frac{5}{8}$	7.03	$6\frac{1}{4}$ to $7\frac{3}{4}$	7.03	$7\frac{3}{8}$ to $7\frac{3}{4}$	7.56	$5\frac{1}{2}$ to $5\frac{1}{2}$	5.50

TABLE IX.—IMPORTS OF REFINED PETROLEUM AT FIVE PRINCIPAL PORTS OF THE UNITED KINGDOM.

[From reports of the New York Produce Exchange.]

	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.
	Barrels.	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*
London	247, 024	169, 394	227, 305	348, 412	261, 385	492, 292	369, 259	....
Liverpool	157, 700	94, 170	145, 679	144, 000	136, 059	203, 509	163, 800	....
Bristol	37, 175	36, 460	52, 792	65, 584	54, 267	93, 485	90, 622	....
Hull	10, 331	6, 902	24, 657	26, 365	25, 420	30, 884	34, 057	....
Exeter	19, 319	18, 175	7, 598	8, 911	13, 103	10, 789	....	....
Total	471, 549	325, 101	458, 031	593, 272	490, 234	830, 950	657, 738	....

STOCKS AT SAME PORTS, JANUARY 1.

	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.
London	....	117, 345	41, 193	40, 078	94, 326	61, 500	160, 000	99, 518
Liverpool	....	62, 400	14, 500	22, 880	26, 700	21, 089	48, 000	32, 000
Bristol	....	8, 000	6, 500	11, 699	14, 000	8, 000	17, 000	20, 000
Hull	....	5, 444	350	650	4, 050	2, 300	800	1, 300
Exeter	....	3, 577	2, 200	612	921	1, 300	1, 134	....
Total	....	196, 766	64, 743	75, 919	139, 997	89, 189	226, 934	152, 818

TABLE X.—IMPORTS OF PETROLEUM AT THE UNDERMENTIONED EUROPEAN PORTS FOR SEVEN YEARS ENDED DECEMBER 31.

[From reports of the New York Produce Exchange.]

At—	1874.	1875.	1876.	1877.	1878.	1879.	1880.
	Barrels.	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*	*Barrels.*
Hamburg	....	154, 581	131, 822	324, 936	293, 600	408, 869	525, 974
Antwerp	617, 338	720, 637	603, 251	840, 086	834, 400	649, 845	719, 017
Rotterdam	1, 885, 260	158, 214	177, 988	229, 258	219, 293	189, 850	212, 433
Amsterdam	110, 198	121, 261	65, 507	65, 026	132, 708	150, 209	217, 046
Bremen	811, 121	1, 643, 137	969, 971	1, 463, 264	1, 165, 746	1, 345, 772	1, 324, 591
Stettin	189, 476	228, 547	211, 875	204, 214	208, 767	249, 469	276, 515
Dantzic	67, 019	101, 848	83, 793	143, 620	111, 422	102, 474	107, 849
Königsburg	85, 937	121, 114	86, 207	116, 455	79, 198	79, 345	72, 223
St. Petersburg (*a*)	105, 399	68, 895	82, 914	121, 451	108, 105	101, 571	69, 652
Trieste (*b*)	113, 523	112, 822	145, 627	254, 644	199, 723	304, 392	273, 459
London	246, 323	169, 834	226, 432	333, 234	275, 707	380, 499	340, 717
Total barrels	4, 231, 594	3, 000, 890	2, 785, 387	4, 096, 188	3, 628, 669	3, 962, 295	4, 139, 476
a Includes 4 cases to barrel ......cases	59, 421	19, 701	60, 023	183, 160	48, 965	56, 707	33, 195
b Includes Baku ......barrels	....	....	21, 714	34, 517	38, 311	55, 694	52, 174

STOCKS OF PETROLEUM HELD AT THE SAME PLACE AND TIME.

	1874.	1875.	1876.	1877.	1878.	1879.	1880.
Hamburg	....	17, 640	9, 072	53, 726	22, 195	27, 749	86, 376
Antwerp	124, 643	109, 477	34, 160	106, 627	126, 894	109, 979	109, 338
Rotterdam	41, 203	15, 801	3, 124	35, 054	21, 954	11, 924	18, 540
Amsterdam	12, 344	10, 395	449	10, 737	32, 329	27, 874	50, 511
Bremen	199, 580	196, 365	42, 281	255, 907	225, 550	343, 738	559, 339
Stettin	20, 064	31, 335	24, 180	11, 598	16, 277	15, 305	42, 832
Dantzic	10, 891	17, 993	7, 118	37, 483	25, 833	20, 189	20, 295
Königsburg	10, 602	21,341	3, 328	21, 699	16, 160	14, 173	12, 956
St. Petersburg (*a*)	66, 886	41, 398	29, 115	55, 787	69, 786	60, 301	22, 108
Trieste	24, 200	4, 500	6, 350	47, 005	12, 970	37, 500	21, 600
London	117, 347	43, 035	36, 616	80, 481	59, 570	156, 786	99, 188
Total barrels	627, 760	509, 280	195, 793	716, 104	629, 518	825, 518	1, 043, 083
a Includes Baku	....	....	11, 782	10, 027	14, 412	18, 856	7, 315

TABLE XI.—THE VARIOUS PRODUCTS OF CRUDE OIL, INCLUDING PETROLEUM, CRUDE OIL, REFUSE OIL, AND GREASE, AND ALL PRODUCTS OF NAPHTHA, EXPORTED FROM BAKU FROM 1832 TO 1879, IN POODS OF 36 POUNDS EACH.

[From report New York Prodnce Exchange, 1880.]

Year.	Poods.	Year.	Poods.	Year.	Poods.	Year.	Poods.	Yoar.	Poods.
1832	261, 000	1842	327, 578	1852	No report	1862	No report	1872	1, 535, 990
1833	300, 000	1843	327, 167	1853	do	1863	340, 000	1873	3, 400, 000
1834	346, 109	1844	332, 854	1854	do	1864	538, 966	1874	5, 000, 000
1835	352, 720	1845	31, 685	1855	do	1865	554, 291	1875	3, 462, 382
1836	352, 862	1846	288, 112	1856	do	1866	691, 820	1876	4, 853, 461
1837	344, 147	1847	255, 476	1857	do	1867	998, 905	1877	6, 816, 971
1838	340, 554	1848	327, 802	1858	do	1868	735, 734	1878	9, 931, 644
1839	358, 357	1849	328, 280	1859	do	1869	1, 685, 229	1879	12, 541, 646
1840	337, 010	1850	No report	1860	do	1870	1, 704, 465	1880, to June 1	3, 586, 059
1841	326, 695	1851	do	1861	do	1871	1, 375, 981		

EXPORTED FROM BAKU IN POODS OF 36 POUNDS.

	1875.	1876.	1877.	1878.	1879.	1880 to June 1.
Crude oil	323, 851	323, 561	177, 983	281, 423	436, 673	61, 902
Refined oil	1, 990, 041	3, 325, 233	4, 594, 766	6, 254, 920	6, 562, 140	1, 484, 374
Refuse	1, 131, 725	1, 275, 321	2, 038, 890	3, 382, 859	5, 528, 208	20, 016, 270
Oil and grease	1, 077	1, 095		306	409	23, 503
Asphalt	4, 586	13, 100	723	9, 300	10, 491	
Benzine, etc	11, 102	5, 151	4, 600	3, 130		

TABLE XII.—IMPORTS OF AMERICAN PETROLEUM (REFINED) INTO JAPAN.

Year ending June 30—.	Gallons.	Dollars.	Years.	Gallons.	Dollars.	Years.	Gallons.	Dollars.
1872*	41, 470	21, 150	1875	2, 826, 636	573, 671	1878	5, 524, 604	1, 115, 162
1873	1, 000, 959	330, 598	1876	3, 151, 639	520, 387	1879	17, 721, 645	2, 557, 509
1874	1, 291, 180	306, 723	1877	3, 304, 926	599, 966	1880	17, 923, 499	1, 803, 555
						Total	52, 745, 088	7, 807, 571

* First importation.

CHAPTER VIII.—THE BIBLIOGRAPHY OF BITUMEN AND ITS RELATED SUBJECTS.

An examination of the literature of petroleum shows that the subject is properly treated as a portion of the general subject "Bitumen". It is impossible to separate it from asphalt, maltha or mineral tar, rock oil, earth oil (German *Erdöl*), naphtha, coal oil, and paraffine. These several subjects are also treated as pertaining to history, geology, chemistry, technology, commerce, and statistics, and often in such a manner as to render a separation impossible. In ascertaining what articles have appeared in different periodicals, the indices have been searched for "Asphaltum", "Bitumen", "Gas", "Hydrocarbons", "Maltha", "Mineral tar", "Naphtha", "Oils", "Paraffine", and "Petroleum", with their equivalents in other languages.

Two attempts have previously been made to prepare lists of books and of periodical articles relating to this subject. Professor Paul Schweitzer, of the University of Missouri, published his list, in 1879, in connection with his pamphlet on petroleum. Another was prepared in the East Indies, in 1875, by Mr. Benjamin S. Lyman, but was not published. This latter list of titles has been placed in my hands, and has been incorporated with my own work, the 175 titles being distinguished by printing the authors' names preceded by an asterisk. Professor Schweitzer's list was not prepared in such a manner as to admit of such incorporation, but for the most part his titles will be found in the present list.

In submitting this list of titles to my fellow-workers in this field, it is not claimed that it is either complete or free from error. Mr. Lyman's titles were transferred, and many of the others are quoted without being verified; but, so far as has been possible in the time at my command, the work has been proved correct. Only titles to articles of exceptional value have been inserted when the authors are unknown. This, of course, excludes a large number of editorial notices, both good and bad, that are found in reputable scientific journals, as well as in newspapers. I have endeavored, however, to include what is of material value.

So far as I have been able to do it, I have inserted the title to a work in the language in which it was originally written, and I have also endeavored to insert the reference to the work in which the article first appeared, as the first in the list of references. I am aware, however, that in a few instances I have not met the original articles, and that the titles appear translated into other languages. The material was all collected in the course of the preparation of the report, and only required the labor of arrangement to put it in this form.

ABBREVIATIONS.

A. C. et P.	Annales de Chimie et de Physique.
A. C. u. P.	Annalen der Chemie und Pharmacie.
A. der P.	Archiv der Pharmacie.
A. J. Ph.	American Journal of Pharmacy.
A. J. S.	American Journal of Science and Arts (Silliman's Journal).
Am. C.	American Chemist.
Am. J. G. L.	American Journal of Gaslighting.
An. G. C.	Annales du Génie Civil.
An. M.	Annales des Mines.
A. of P.	Annals of Philosophy.
A. S. D.	Annual of Scientific Discovery.
B. D. C. G.	Berichte der Deutschen Chemischen Gesellschaft zu Berlin.
B. I. u. Gbl.	Bayerisches Industrie- u. Gewerbeblatt.
B. N. A. W. M.	Bulletin of the National Association of Wool Manufacturers.
B. S. C. P.	Bulletin de la Société Chimique de Paris.
B. S. d'E.	Bulletin de la Société d'Encouragement.
B. S. G. F.	Bulletin de la Société Géologique de France.
B. u. H. J.	Leobener Berg- und Hütten-Jahrbuch.
B. u. H. Z.	Berg- und Hütten- Zeitung.
Bull. A. I. St. P.	Bulletin de l'Académie Impériale des Sciences de Saint-Pétersbourg.
C. Cbl.	Chemisches Centralblatt.
C. Ind. Z.	Chemische Industrie-Zeitung.
C. N.	London Chemical News.
. Nat.	Canadian Naturalist.
C. R.	Comptes-Rendus des Séances de l'Académie Française.
C. Z.	Chemische Zeitung.
D. Ill. G. Z.	Deutsche Illustr. Gewerbe-Zeitung.
D. Ind. Z.	Deutsche Industrie-Zeitung.
Dingler.	Dingler's Polytechnisches Journal.
E. M. W. S.	English Mechanic and World of Science.
Eng.	Engineering.
F. Gztg.	Fürther Gewerbezeitung.
G. Ind.	Génie Industriel.
H. Gbl.	Hessisches Gewerbeblatt.
Hübner's Z.	Hübner's Zeitschrift für die Paraffin-, Mineralöl-, und Braunkohlen-Industrie.
Ind. B.	Industrie-Blätter.
Int. Obs.	Intellectual Observer.
J. A. S. B.	Journal of the Asiatic Society of Bengal.
J. C. S.	Journal Chemical Society of London.
J. F. I.	Journal of the Franklin Institute.
J. f. P. C.	Journal für Praktische Chemie (Erdmann's Journal).
J. G. B.	Journal für Gasbeleuchtung.
J. K. K. G. R.	Jahrbuch der K. K. Geologischen Reichsanstalt.
J. S. A.	Journal of the Society of Arts.
L'A. S. et I.	L'Année Scientifique et Industrielle.
Le Tech.	Le Technologiste.
L. J. G. L.	London Journal of Gas Lighting.
L. u. B. J.	Leonhardt und Bronn Jahrbuch.
Mem. A. A.	Memoirs American Academy of Arts and Sciences, Boston.
M. P. L. S.	Proceedings of the Manchester Philosophical and Literary Society.
M. Sci.	Moniteur Scientifique.
N. E. P. J.	New Edinburgh Philosophical Journal.
N. J. Ph.	Neues Jahrbuch für Pharmacie.
N. Z. R. I.	Neue Zeitschrift für Rübenzucker Industrie.
Oest. Z. f. B. u. H.	Oesterreich. Zeitschrift für Berg- und Hüttenwesen.
P. A. A. A. S.	Proceedings of the American Association for the Advancement of Science.
P. A. Ph. A.	Proceedings of the American Pharmaceutical Association.
P. A. P. S.	Proceedings of the American Philosophical Society, Philadelphia.
P. B. A. A. S.	Proceedings of the British Association for the Advancement of Science.
P. C. A. S.	Proceedings of the California Academy of Science.
P. G. S.	Proceedings of the Geological Society, London.
Pharm. Cbl.	Pharmaceutisches Centralblatt.
Ph. J.	Pharmaceutical Journal, London.
P. I. C. E.	Proceedings of the Institution of Civil Engineers, London.
P. J.	Philosophical Journal.
P. M.	Philosophical Magazine.
Pog. An.	Poggendorf's Annalen der Physik.
Poly. Cbl.	Polytechnisches Centralblatt.
Poly. Nbl.	Polytechnisches Notizblatt.
P. R. I.	Proceedings of the Royal Institution.
P. R. S.	Proceedings of the Royal Society.
P. S. M.	Popular Science Monthly.
P. T.	Philosophical Transactions of the Royal Society.
Q. J. G. S.	Quarterly Journal of the Geological Society of London.
R. C. A.	Repertoire de Chimie Appliquée.
R. I.	Revue Industrielle.
R. U. M.	Revue Universelle des Mines.
Sci. Am.	Scientific American.
S. M. & Sci. P.	San Francisco Mining and Scientific Press.
S. P. Z.	Schweiz. Polytechnische Zeitschrift.
T. A. I. M. E.	Transactions of the American Institute of Mining Engineers.
T. A. Ph. A.	Transactions of the American Pharmaceutical Association.
T. G. S.	Transactions of the Geological Society, London.
T. P. S. E.	Transactions of the Pharmaceutical Society (English).
Trans. Am. P. S.	Transactions of the American Philosophical Society.
Trans. R. S.	Transactions of the Royal Society.
W. B.	Wagner's Berichte.
Z. A. C.	Zeitschrift für Analytische Chemie.
Z. A. O. A.	Zeitschrift des Allgemeinen Oesterreich. Apotheker-Vereins.
Z. C.	Zeitschrift für Chemie.

The few abbreviations of the titles to other journals are extended so as to need no reference.

BIBLIOGRAPHY OF PETROLEUM.

Date.	Name.	Subject.	Reference.
B. C.			
Circa 450	*Ctesias	Gas in Karamania	Fragment (ed. Baehr.), cap. x, p. 250.
Circa 450	*Herodotus	lib. iv, 195	Translated into French in B. S. G. F., xxv, 62.
Circa 350	*Aristotle	Albanian bitumen; in De mirabilibus auscultationibus, chap. cxxvii (Ed. de F. Didot, 1857).	Translated into French in B. S. G. F., xxv, 25.
Circa 25	*Diodorus Siculus	Dead Sea bitumen; t. i, l. ii, cap. xxix. Hist. Univers., t. vi, l. xix, cap. xxv.	Translated into French in B. S. G. F., xxiv, 14.
Circa 25	*Strabo	vi, 763; xvi, c. 2; c. 12; French translation, 1, xiv, p. 665, Casab.	Translated into French in B. S. G. F., xxiv, 13. Geographie, 1812, iii, 8. B. S. G. F., xxv, 20.
Circa 25	Vitruvius	lib. vii, cap. 3	Translated into French in B. S. G. F., xxv, 50.
A. D.			
Circa 25	*Seneca		Epist. 79, § 3. Ed. Ruhkopf.
Circa 50	*Pliny	N. H., lib. ii, § 106; vii, 13; lib. xxxv	Quoted in B. S. G. F., xxv, 21.
Circa 66	*Plutarch	Albanian bitumen; Life of Sylla	Quoted in B. S. G. F., xxv, 22. Sir Thomas North's translation, ed. 1631, p. 702.
Circa 80	*Tacitus		Hist., v, 6.
Circa 100	*Josephus		H. J., iv, 8, 4.
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1865	Paul, B. H	On paraffine oil	P. B. A. A. S., 1865, p. 36.
1865	*Posepny, Fr	Petroleum im Sanoker u. Samborer Kreise, Galizien	J. K. K. G. R., xv, 351; B. u. H. Z., 1865, No. 36–41.
1865	Rand, Theo. D	On the occurrence of petroleum in Canada	J. F. I., lxxx, 59.
1865	Report to United States Navy Department, Wood, Whipple, and Steniers, engineers.	Employment of petroleum as a fuel for marine boilers	R. U. M., xviii, 220.
1865	Rey, Alphonse	L'huile de pétrole; connaissance de l'huile de pétrole dans les temps anciens, importance de son exploitation, procédés employés pour l'extraire et la raffiner, applications diverses de ses dérivés.	Paris, 1865, 8°.
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1865	Schmidt, Ed	Das Erdöl Galiziens, dessen Vorkommen und Gewinnung, nebst Beiträgen zur fabrikmässigen Darstellung seiner Produkte.	Wien, 1865. Verlag des Gründung's-Comités der Hamburg-Galizischen Petroleum Aktien-Gesellschaft.
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1865	*Shuffeldt, G. A., jr	On an oil-well boring at Chicago	A. J. S., xl, 388.
1865	Silliman, B., jr	California oil is not asphaltum	Letter from Prof. Silliman to Hon. D. H. Harris, of Springfield, Mass., dated New Haven, April 8, 1865.
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1865	*Silliman, B., jr	Report upon the oil property of the Philadelphia and California Petroleum Company.	Philadelphia, E. C. Markley & Son, 1865, 36 pp.
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1865	Stenhouse, John	On the employment of paraffine for water-proofing	J. F. I., lxxix, 340; C. N., vii; A. J. Ph. (3), xi, 320.
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1865	Warren, C. M	Researches on the volatile hydrocarbons	Mem. A. A. (n. s.), ix, 135; A. J. S. (2), xl, 89; C. N., xii, 261, 279, xiii, 13, *et seq.*
1865	Warren, C. M., and F. H. Storer	Researches on the volatile hydrocarbons	Mem. A. A. (n. s.), ix, 176; A. J. S. (2), xli, 139.
1865	Whitney, J. D	Asphalt at Hill's ranche, near Santa Barbara, California.	Geological Survey of California: Geology, i, 132.
1865	Winchell, A	On the oil formation of Michigan and elsewhere	Detroit, 1864, 8 pp. 8°; A. J. S. (2), xxxix, 350.
1865	*Wright, William	The oil regions of Pennsylvania, etc	New York, Harper & Bro., 1865.
1865	Wurtz, Henry	Report on a mineral formation in West Virginia	New York, Francis & Loutrell, 1865.
1865	*By the author of "Ten Acres Enough"	Derrick and drill	New York, James Miller, 1865.
1865		Das Naphta-Vorkommen im Trans-Kubangebiet u. auf der Habinsel Taman.	Gornyi Journal, 1865, p. 73.
1865		The oil district of Canada	Am. News Co., New York, 1865, 40 pp.
1866	*Andrews, E. B., Marietta, Ohio	Petroleum in its geological relations	A. J. S. (2), xlii, 33.
1866	*Ansted, D. T	On mud volcanoes of the Crimea, and on the relation of these and similar phenomena to deposits of petroleum.	P. R. I., iv, 628; J. S. A., xiv, 479; Physical Geography 5th ed., 1871, 8°, pp. 336–339.
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1866	Attfield, John	On the igniting point of petroleum	C. N., xiv, 257; A. S. D., 1868, p. 188; Dingler, clxxxiii, 244; Z. A. C., 1867, p. 261; D. Ind. Z., 1867, p. 198; W. B., 1867, p. 725.
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1866	Berthelot, M	Action de la chaleur sur quelques carbures d'hydrogène	A. C. et P. (4), ix, 467.
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1866	Bizard und Labarre	Gasometer zum Magaziniren von Petroleum und ähnlicher Oele.	G. Ind., 1866, p. 39; Dingler, clxxxii, 63; Poly. Cbl., 1866, p. 1467; D. Ind. Z., 1866, p. 325; W. B., 1866, p. 667.
1866	*Clarke, W. B	On the occurrence and geological position of oil-bearing deposits in New South Wales.	A. J. S. (2), xlii, 267; P. G. S.; Reader, Apr. 21, 1866.
1866	Cotta, B. v	Das Vorkommen und die Gewinnung des Erdöls in Galizien	Oest. Z. f. B. u. H., 1866, No. 19; Dingler, clxxxi, 153; W. B., 1866, p. 663.
1866	*Daddow, S. H., and B. Bannan	Coal, iron, and oil	Philadelphia, J. B. Lippincott & Co., 1866.
1866	Dana, J. D	Mineral oil	Text-book of geology, 1866, p. 125.
1866	Eaton, S. J. M	Petroleum A history of the oil region of Venango county, Pennsylvania.	Philadelphia, J. P. Skelley & Co., 1866.
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1866	Evrard et Distère	Sur les huiles de pétrole	Paris, 1866, 8°.
1866	*Fenner, A	Punjab oil	Proc. of the Punjab Government: Pub. Works Dep't, June 17, 1866.
1866	Green, Joel	Process for rendering petroleum oil inodorous	Sci. Am., xiii, 383; Dingler, lxxx, 144; B. S. C. P., 1866, p. 356; Le Tech., xxvii, 533; Poly. Cbl., 1866, p. 873; W. B., 1866, p. 675.
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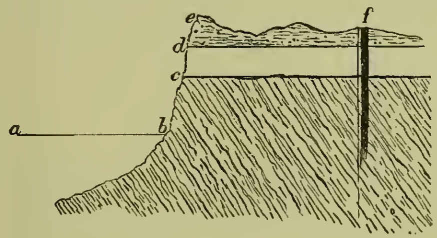
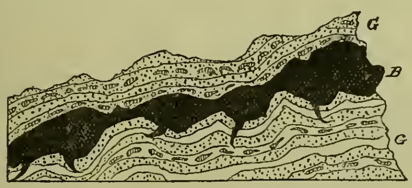


a, *b*, Sea-level.
b, *c*, Bituminous shale.
c, *d*, Unstratified sand saturated with bitumen
d, *e*, Soil.
f, Well, recently commenced (1866).

[Fig. 1—page 21.]

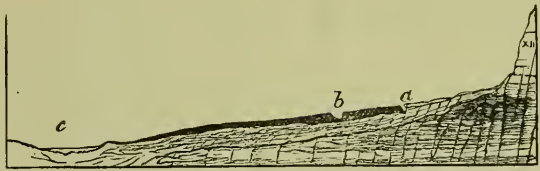
Section of bituminous rocks on Bigg's ranch, Santa Barbara Co., California.



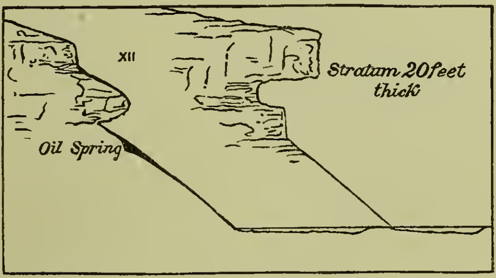
B, Solid bitumen. G, Sandstones and conglomerates.

[Fig. 2—page 32.]

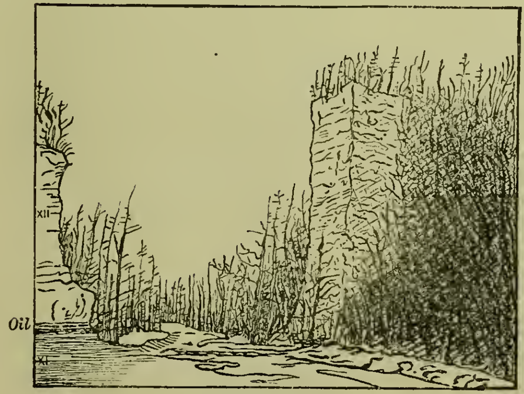
Bitumen at Selenitza, Albania.



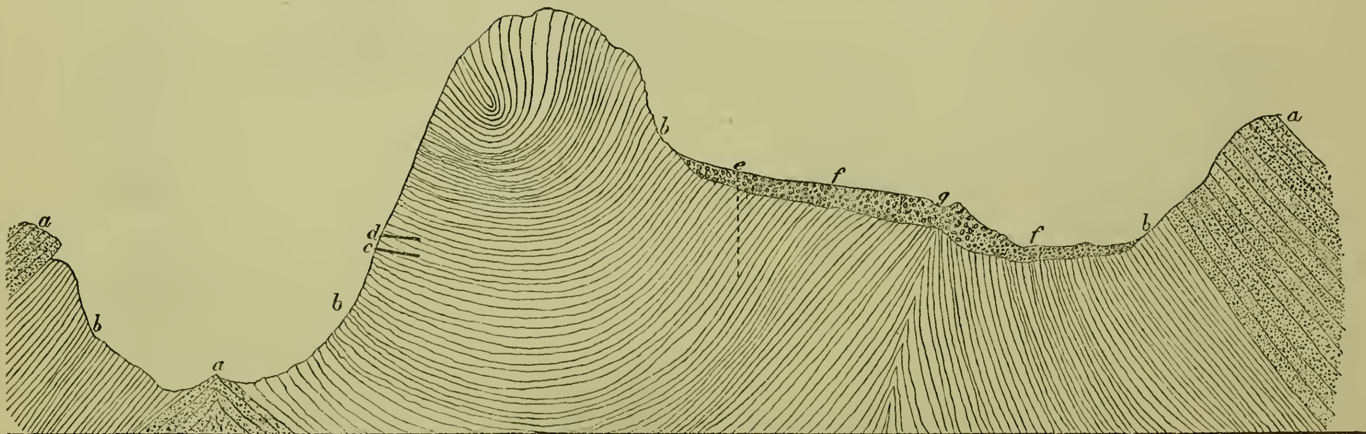
[FIG. 3—page 63.]
Old oil springs, Paint creek, Johnson Co., Ky.



[FIG. 4—page 63.]
Section on Little Paint creek, Johnson Co., Ky.



[FIG. 5—page 63.]
Crows' Nest, on Paint creek, Johnson Co., Ky.



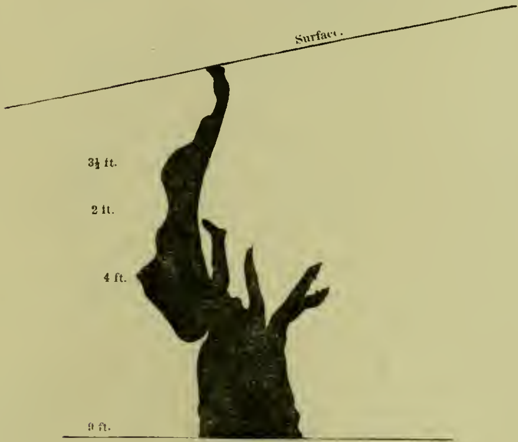
a, Sandstone. *c d*, Tunnels. *f*, Soil.
b, Shale. *e*. Well on Ojai ranch. *g*. Big spring on Ojai ranch.

[FIG. 6—page 68.]

Section through Sulphur mountain and Ojai plateau, Ventura county, California.

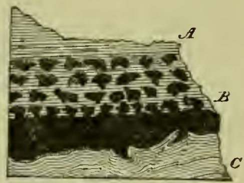
[FIG. 7—page 72.]

Section from Boryslaw to Schodnica, East Galicia.



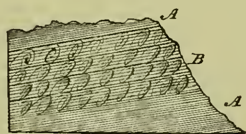
[FIG. ?—page 72.]

Section of vein of asphaltum near Havana, Cuba.



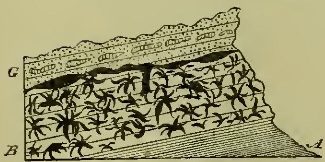
A, Slates. B, Asphalt. C, Breccia.
[FIG. 9—page 73.]

Bitumen in Albania.



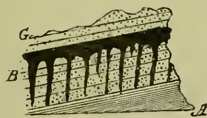
A. Slates. B, Pisolithic bitumen.
[FIG. 10—page 73.]

Bitumen in Albania.



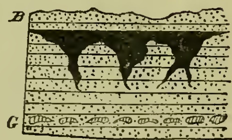
A, Slates. B, Reticulated bitumen.
G, Sandstones and conglomerates.
[FIG. 11—page 73.]

Bitumen in Albania.



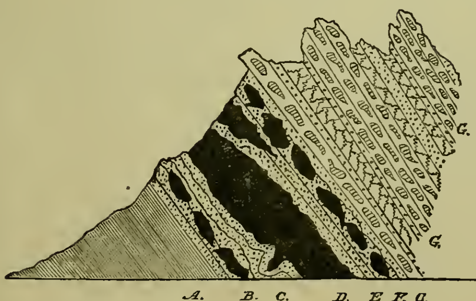
A, Slates. B, Bitumen.
G, Sandstones.
[FIG. 12—page 73.]

Bitumen in Albania.



B, Bitumen.
G, Conglomerate.
[FIG. 13—page 73.]

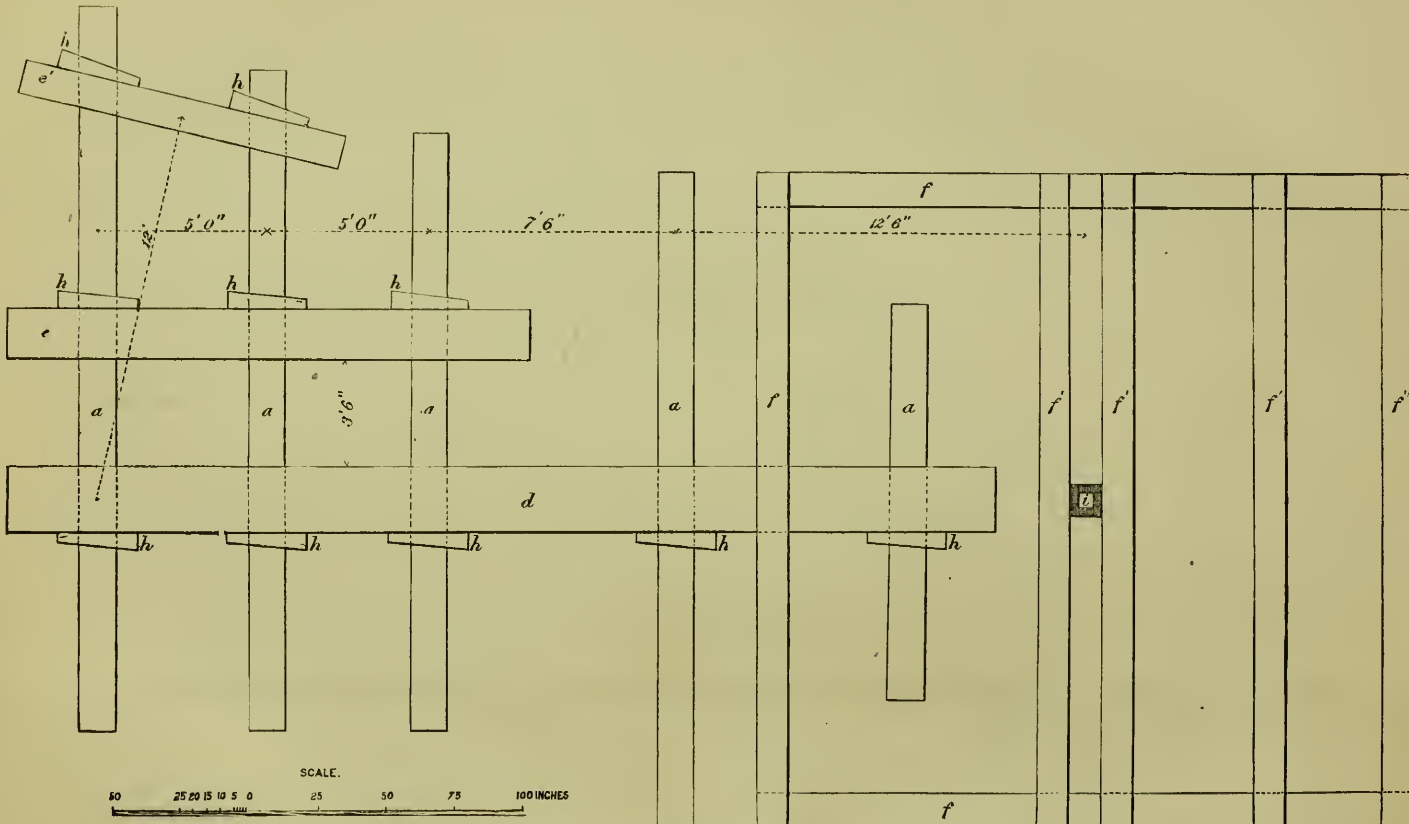
Bitumen in Albania.



[FIG. 14—page 73.]

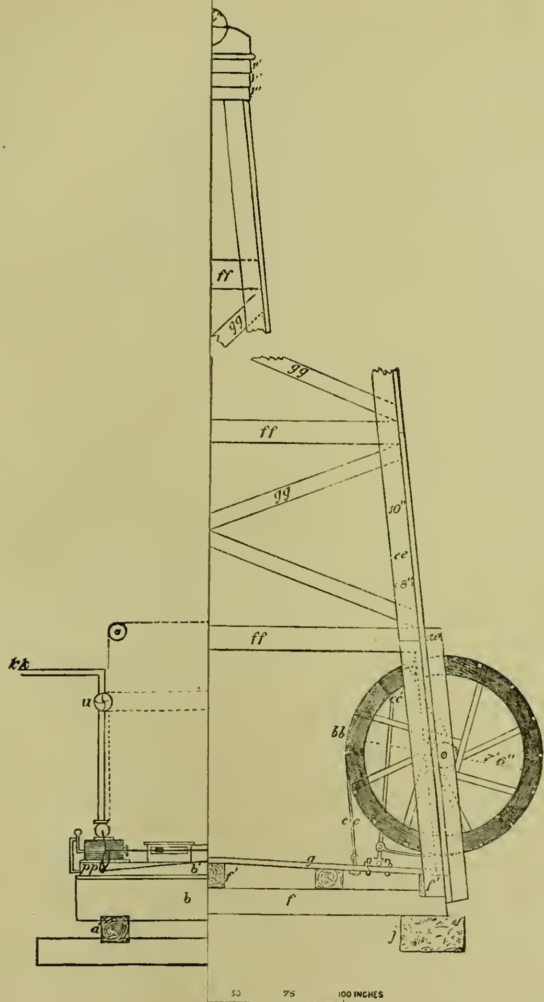
1. A, Slates, 90 meters.
2. B, Conglomerate, with balls of bitumen, 3 meters.
3. C, Yellow sandstone, with bivalves, 2 meters.
4. D, The great mass of bitumen, 45 meters.
5 E, Yellow sandstone with cardium edule, 2.5 meters.
6. F, Alternating sandstones and conglomerates, with balls of bitumen, 3.6 meters.
7. G, Conglomerates and sandstones, 60 meters.

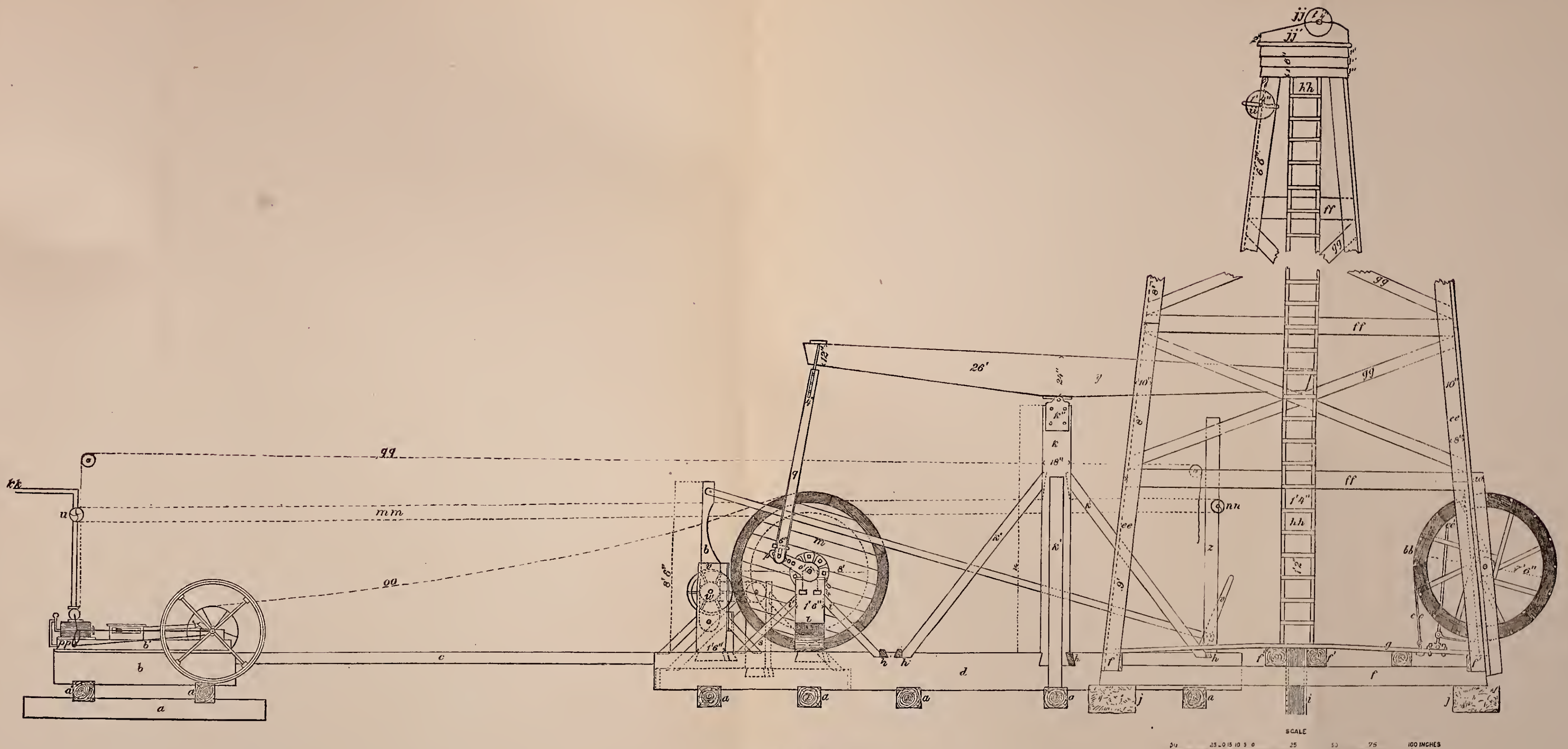
Bitumen in Albania.



[FIG. 15—page 79.]

Foundation timbers for rig.

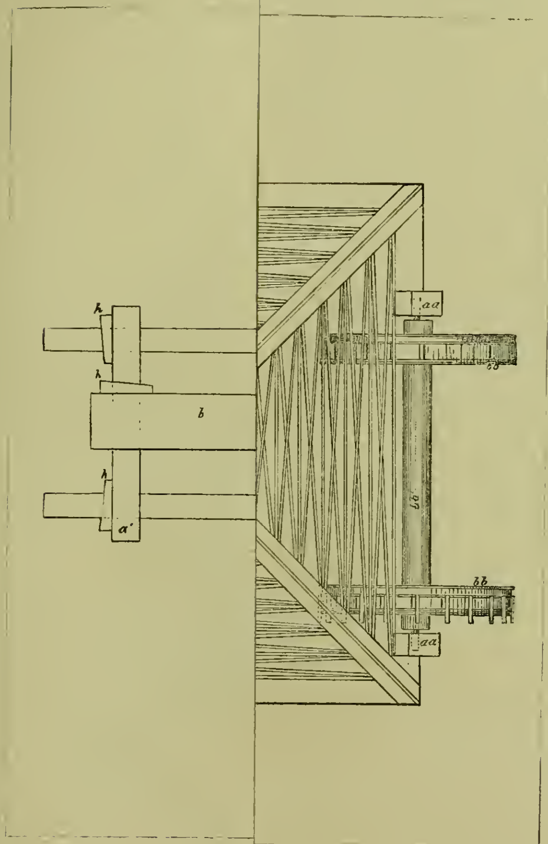

ff
gg
gg
ff
gg
10"
ee
8"
ff
kk
u
bb
7'6"
c e
g
pp
b'
f'
b
f
a
j
50
75
100 INCHES

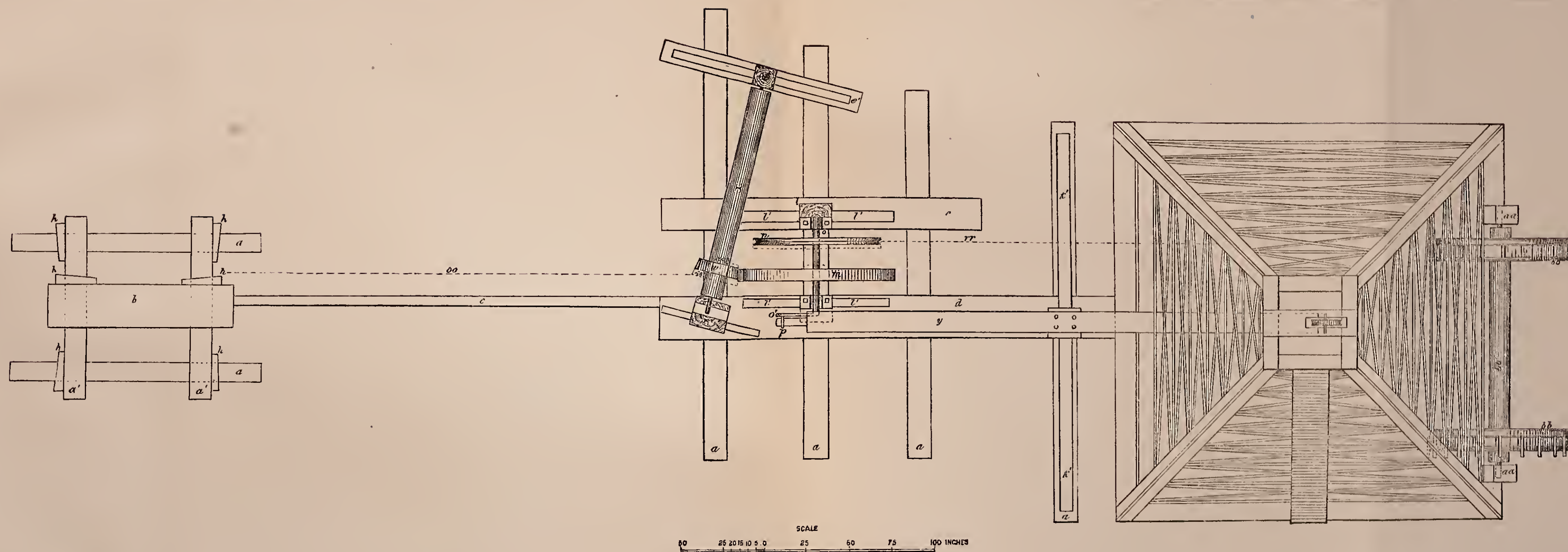


[FIG. 16—page 80.]

Side elevation of derrick and engine

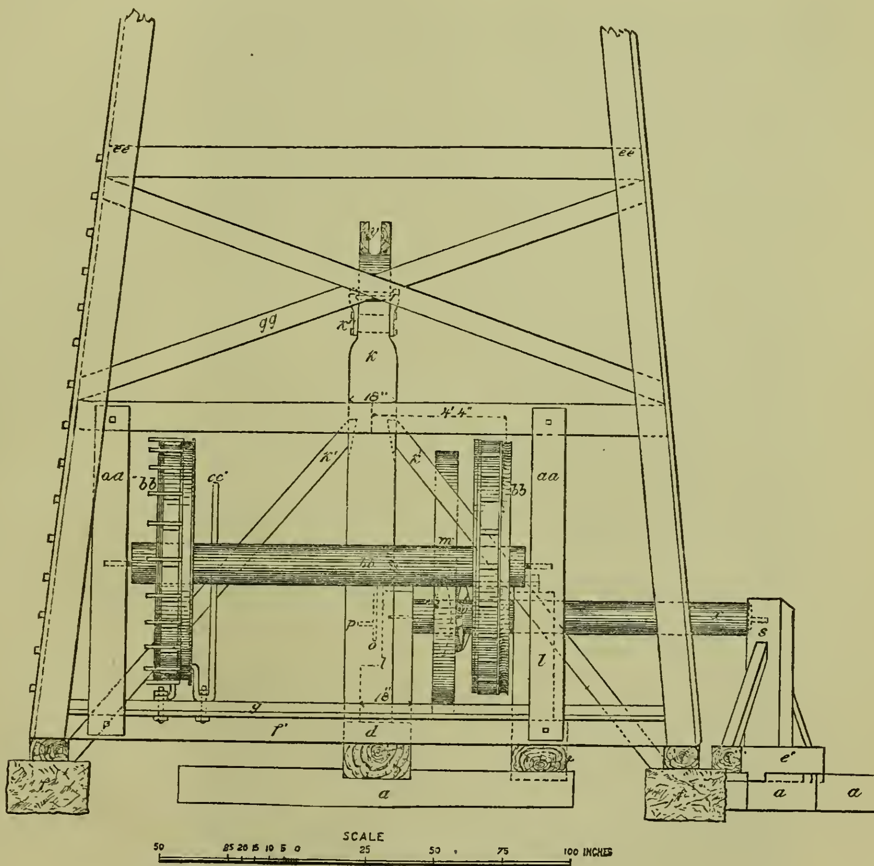
Plate XV. onograph on PETROLEUM.





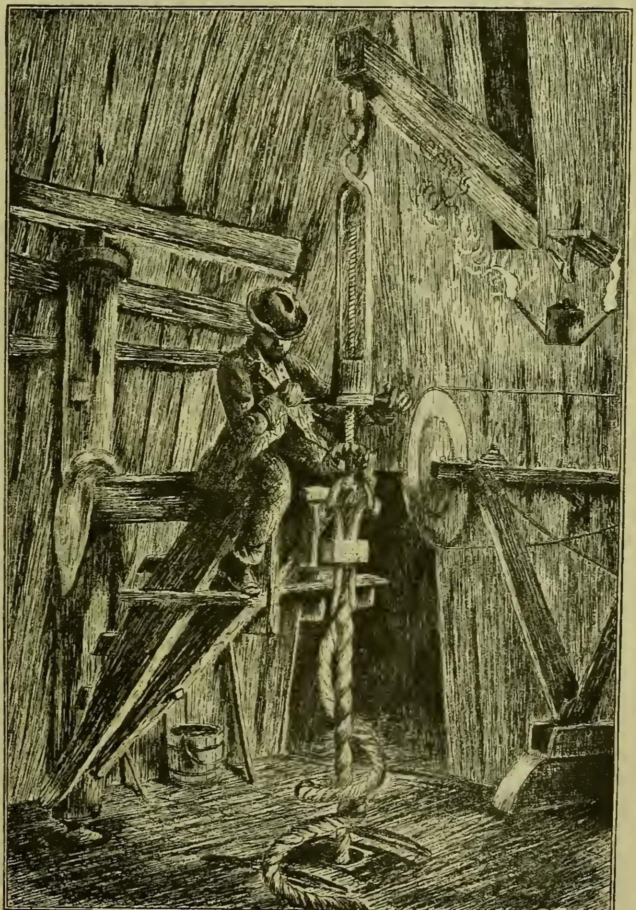
[FIG. 17—page 80.]

Horizontal projection of derrick and engine.

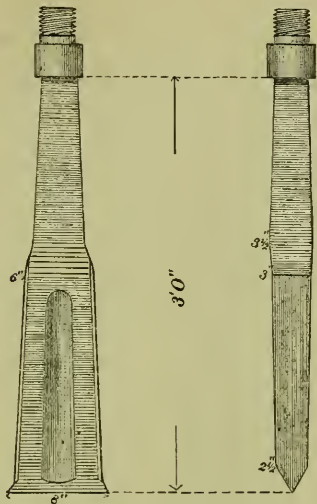


[FIG. 18—page 80.]

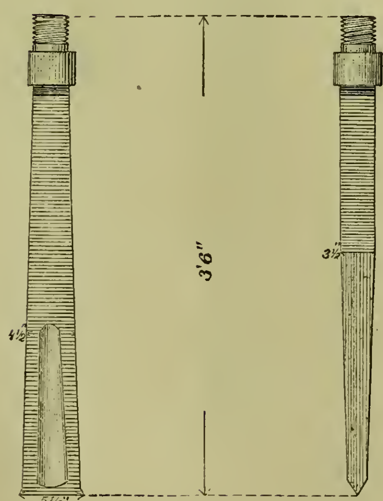
End elevation of derrick.



[FIG. 19—page 81.]
Inside view of derrick at night, showing use of temper-screw and derrick light.

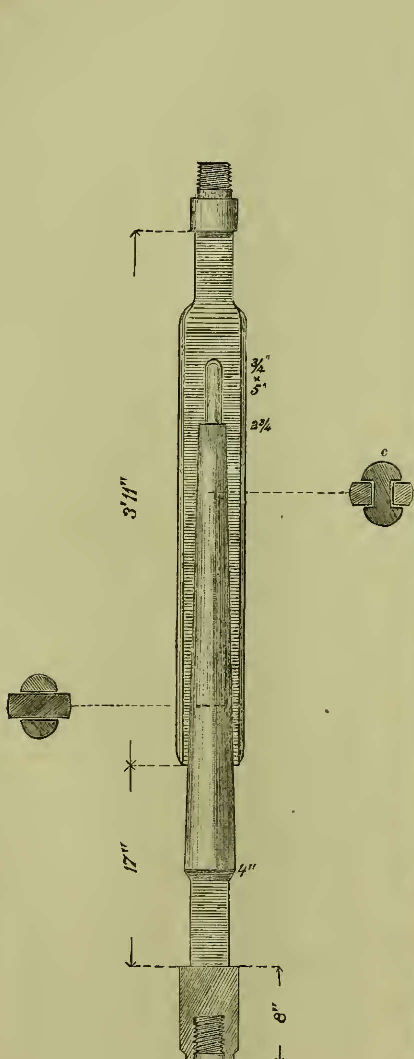


[FIG. 20—page 81.]
Eight-inch bit, 1-12 natural size.



[FIG. 21—page 81.]
Five-and-one-half-inch bit, 1-12 natural size.

[FIG. 22—page 81.] [FIG. 24—page 81.]
Auger stem. Sinker bar.
1-12 natural size.



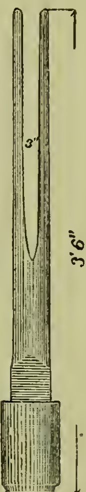
a
Closed.

b
Open.

c and *d*, cross-sections

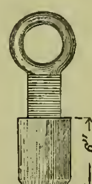
[Fig. 23—page 81.]

Jars, 1-12 natural size.



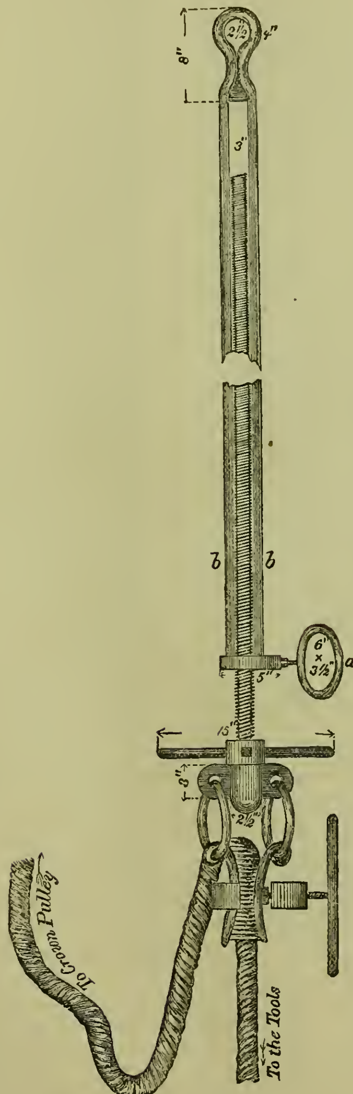
[Fig. 25—page 81.]

Rope socket, 1-12 natural size.



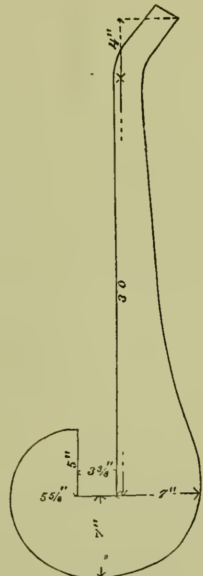
[Fig. 27—page 81.]

Ring socket, 1-12 natural size.



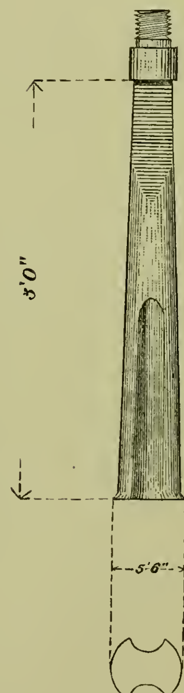
[Fig. 26—page 81.]

Temper-screw.



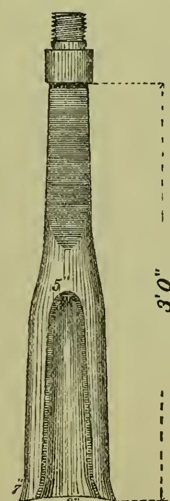
[Fig. 28—page 81.]

Wrench, 1-12 natural size.



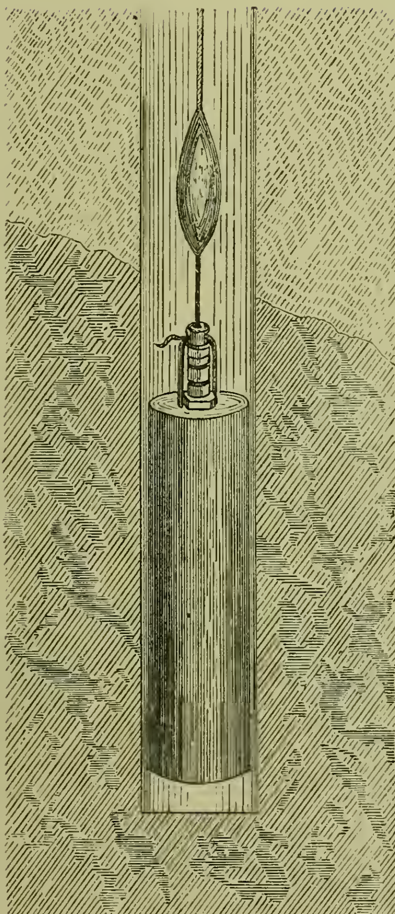
[Fig. 29—page 81.]

Five-and-one-half-inch reamer, 1-12 natural size.



[Fig. 30—page 81.]

Eight-inch reamer.



[FIG. 31—page 85.]
Torpedo before explosion.

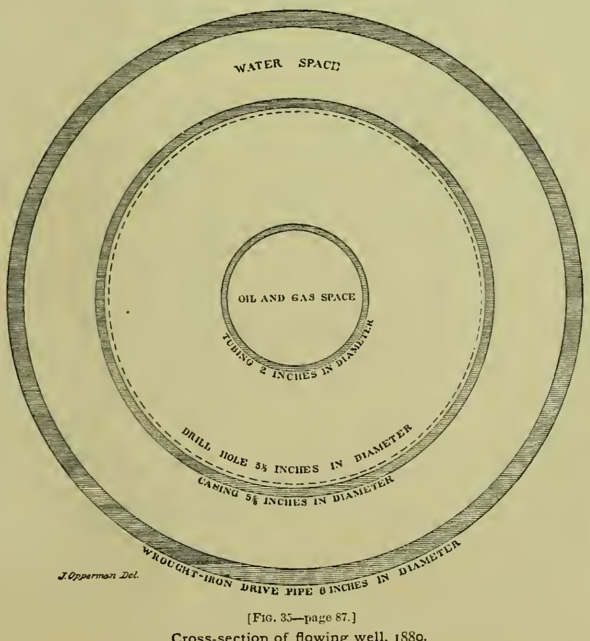
[FIG. 32—page 87.]

Cross-section of pumping well, 1861—wooden conductor.

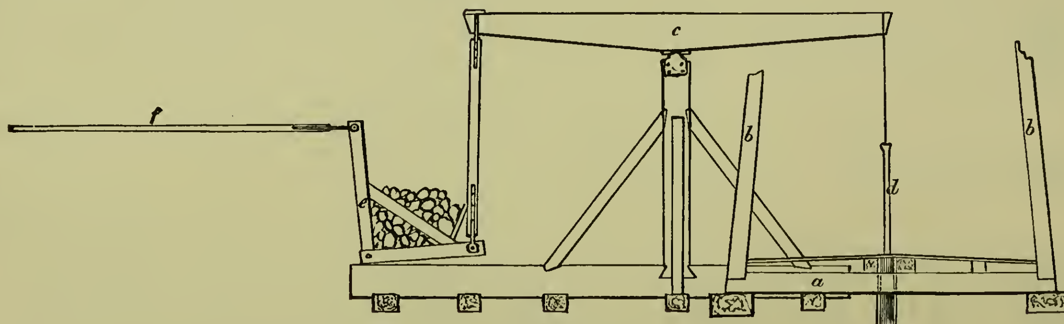
[FIG. 33—page 87.]

Cross-section of pumping well, 1868—cast-iron drive-pipe.

[FIG. 34—page 87.]
Cross-section of pumping well, wrought-iron drive-pipe, 1878.

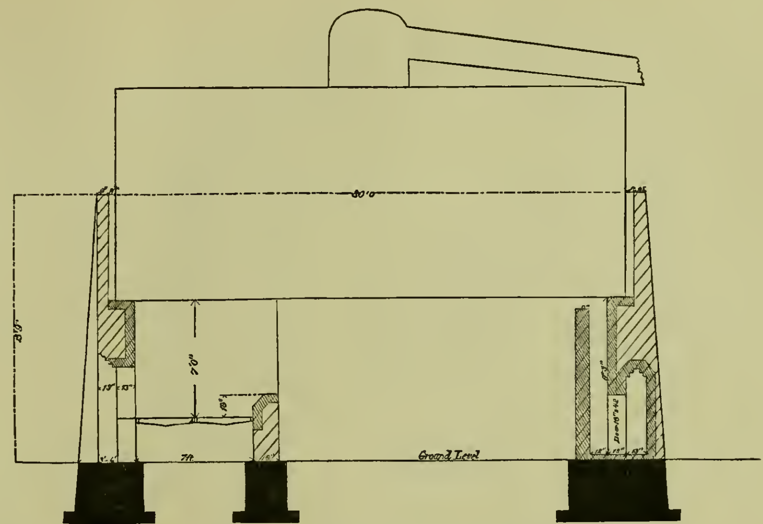


[FIG. 35—page 87.]
Cross-section of flowing well, 1880.



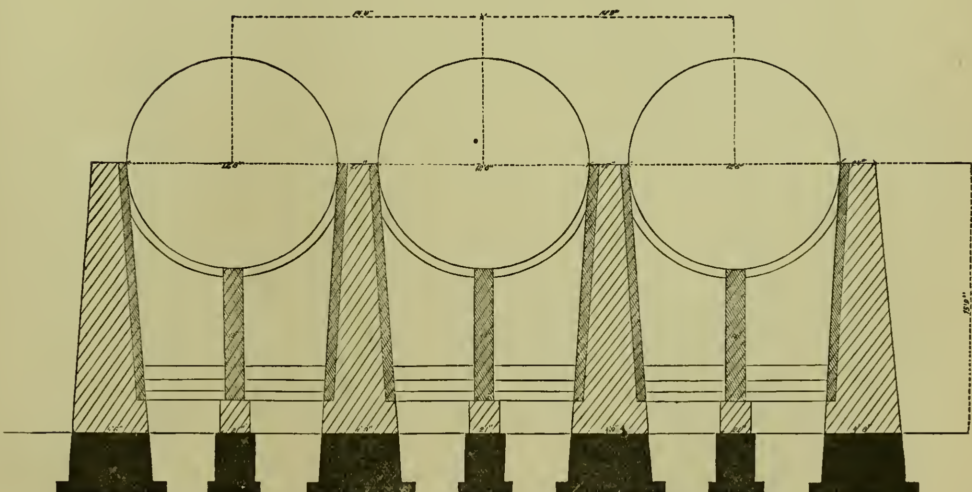
[FIG. 36—page 88.]

Sucker-rod movement.



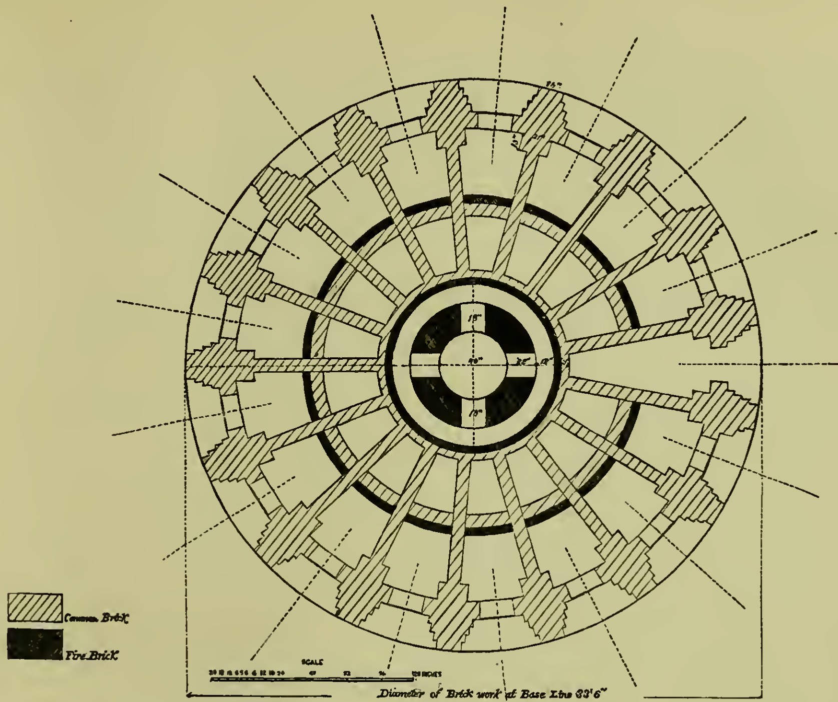
[Fig. 37—page 162.]

Lateral vertical section of cylindrical still.

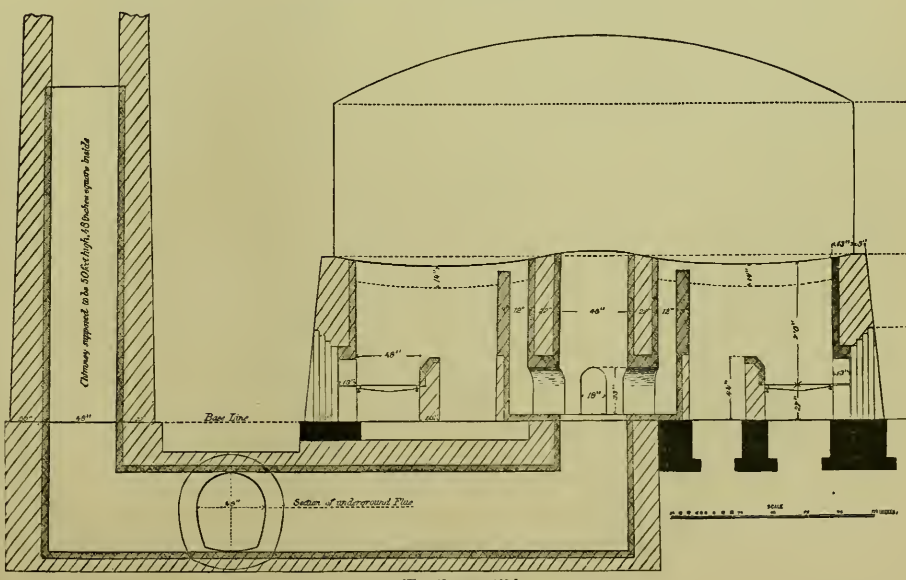


[Fig. 38—page 162.]

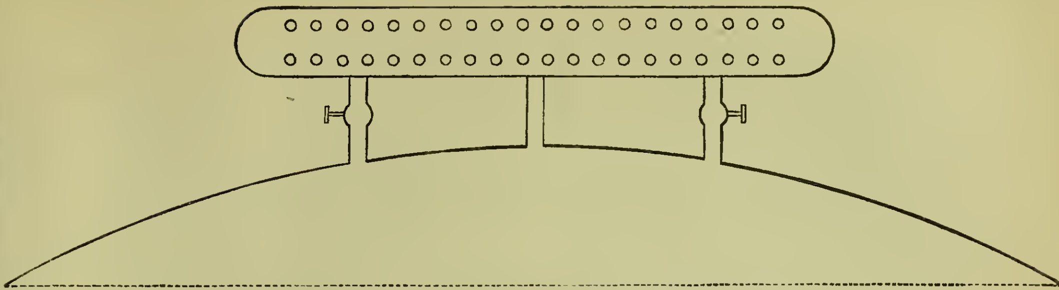
Transverse vertical section of cylindrical still.



[FIG. 39—page 162.]
Horizontal section of cheese-box-still setting.

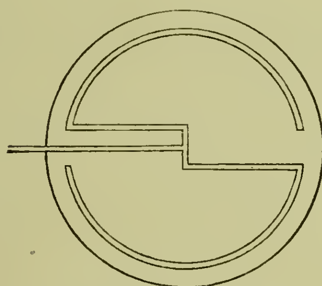


[FIG. 40—page 162.]
Vertical section of cheese-box-still setting.



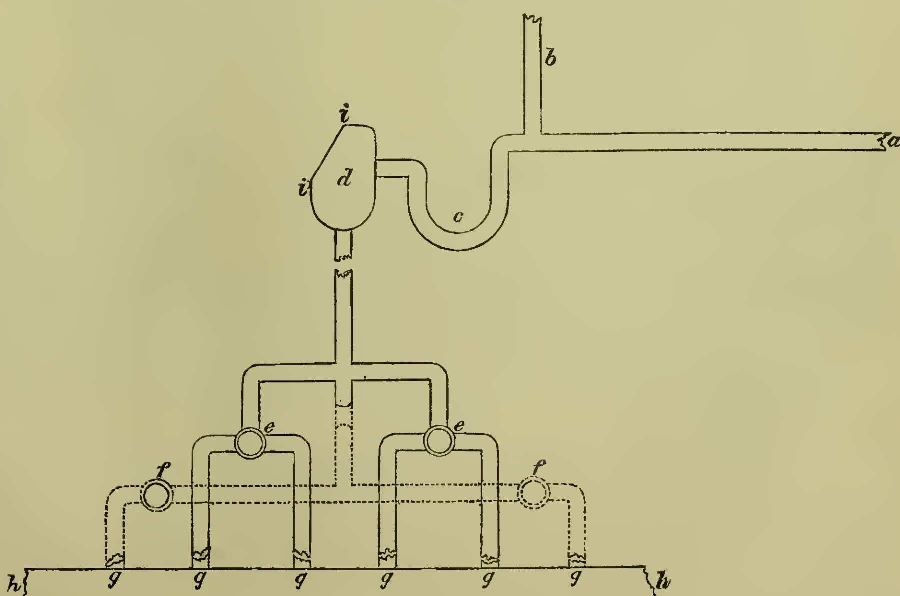
[FIG. 41—page 162.]

Section of condensing drum.



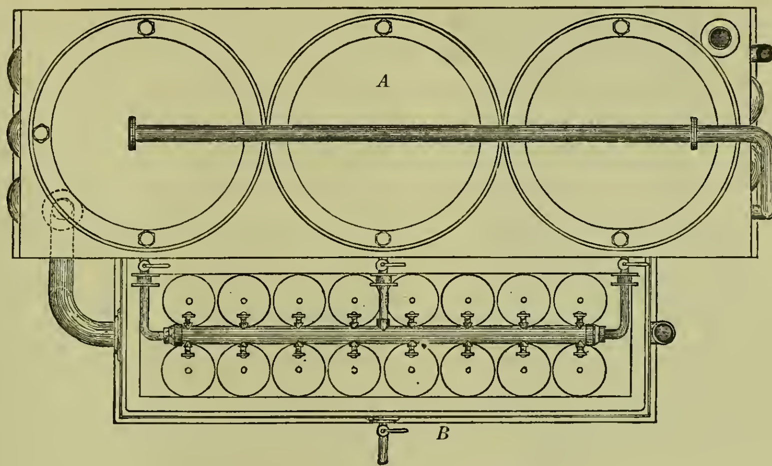
[FIG. 42—page 162.]

Section of steam-pipe for still head.

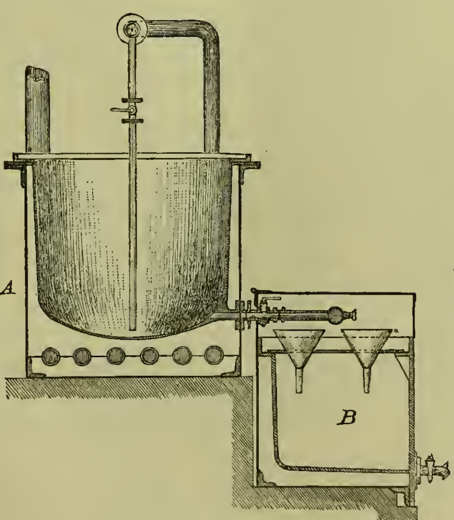


[FIG. 43—page 163.]

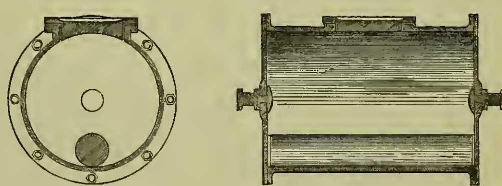
Diagram showing arrangement for distributing distillates.



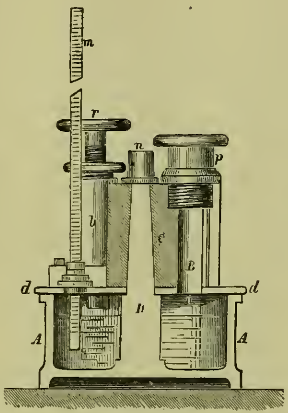
Horizontal section; A, Mixing apparatus; B, Filtering apparatus.
[FIG. 44—page 174.]
Ramdohr's paraffine filtering apparatus.



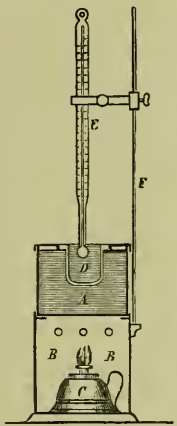
Vertical section; A, Mixing apparatus; B, Filtering apparatus.
[FIG. 45—page 174.]
Ramdohr's paraffine filtering apparatus.



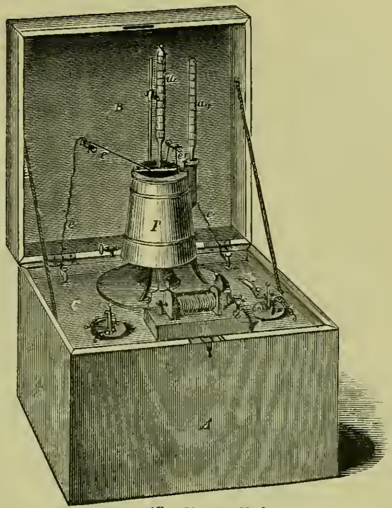
[FIGS. 46 and 47—page 175.]
Ramdohr's charcoal pulverizing drum or cylinder.



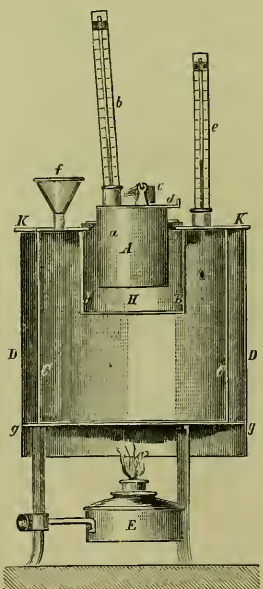
[Fig. 48—page 223.]
Salleron-Urbain tester.



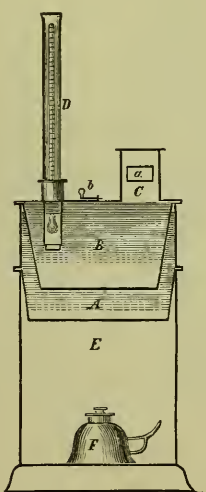
[Fig. 49—page 224.]
Tagliabue's open tester.



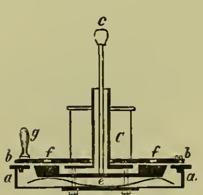
[Fig. 50—page 224.]
Saybolt's tester.



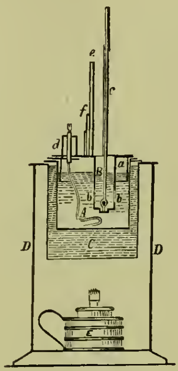
[Fig. 51—page 224.]
Abel's tester.



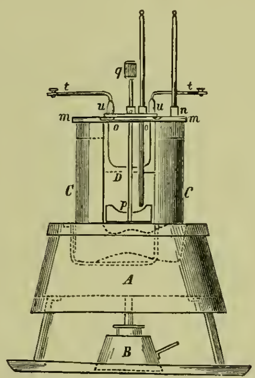
[Fig. 52—page 224.]
Tagliabue's closed tester.



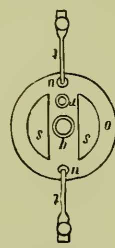
[Fig. 53—page 224.]
Tagliabue's closed tester.



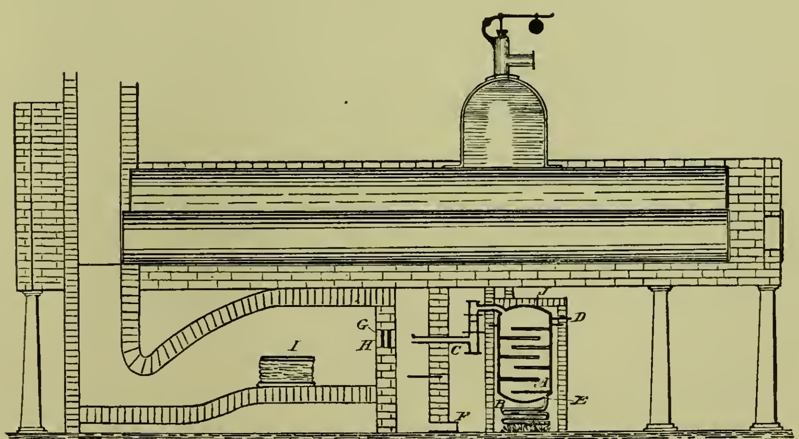
[FIG. 54—page 224.]
Parrish's naphtometer.



[FIG. 55—page 225.]
Engler's tester.



[FIG. 56—page 225.]
Engler's tester.



[FIG. 57—page 250.]
Vertical section of Eames' petroleum furnace.

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REPORT

ON THE

MANUFACTURE OF COKE.

BY

JOS. D. WEEKS,

SPECIAL AGENT.

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PITTSBURGH, PA., *February* 15, 1883.

HON. C. W. SEATON,

Superintendent of Census.

SIR: I have the honor to forward you herewith my final report upon the manufacture of coke in the United States in the census year 1880. This report embraces the complete statistics of the production of coke during that year, together with such information regarding the characteristics of the works, materials used, and labor employed as could be obtained. These are supplemented by such statements and explanations as seemed necessary to the correct understanding of the statistics. Considerable attention has also been given to the history of coke, both in this country and in Europe, as well as to such technical information as promised to add to the value of the report.

It should be carefully noted that this report includes only the statistics of that coke which was manufactured as a direct product, and not that produced in connection with the manufacture of gas. There is only one possible exception to this statement, which is noted in its proper place in the report.

The manufacture of coke is so intimately connected with the manufacture of pig-iron that its history is virtually a history of the manufacture of coke pig-iron, while the value of different cokes and of different methods of coking depends largely upon the adaptability of the coke to furnace use. The reason of this will be evident when it is known that more than four-fifths of all the coke manufactured is used in the production of pig-iron. This will explain the constant reference to pig-iron and blast furnaces in this report.

In view of the great variety of coal in this country adapted to the manufacture of coke, some statements regarding the different ovens in use and the results obtained in other countries with various ovens using different kinds of coal have been given, which I trust will be of importance in certain sections of the country. I have also given very full information as to the methods employed in the utilization of the waste products of coking.

In the historical and technical part of this report I have relied for information to some extent upon standard works, as well as upon fragmentary statements scattered through various publications. In most cases I have given in the body of the report the authority for the statements made, but it is no more than just to mention here my especial obligations to *The Iron Age*, of New York, *The Colliery Guardian* and *Engineering*, of London, England, among journals, and Percy's standard work, *Metallurgy*, volume *Fuel*, *Jordan's Album of Metallurgy*, and Mr. Richard Meade's *The Coal and Iron Industries of the United Kingdom*, among standard works. I also desire in a very especial manner to acknowledge my obligations to Mr. John Fulton, mining engineer of the Cambria Iron Company, to whom I am indebted, not only for permission to make use of extracts from the admirable papers published by him in the reports of the second geological survey of Pennsylvania, but also for the revision of certain chapters of this report and for very valuable suggestions and information. My thanks are also due to Major Jed. Hotchkiss, of Staunton, Virginia, Mr. I. Lowthian Bell, Mr. Charles Wheeler, and Mr. Richard Meade, of England, M. Max Goebel, of Belgium, and Dr. Herman Wedding, of Germany, for valuable information.

In the collection and compilation of these statistics I have had the intelligent assistance of Mr. S. C. Armstrong and Miss C. V. Young, of my office.

I am, sir, very respectfully, your obedient servant,

JOS. D. WEEKS,

Special Agent.

PART I.—STATISTICS OF THE MANUFACTURE OF COKE.

SCOPE OF REPORT.

In this report and its accompanying tables the word "coke" is used in a restricted sense, including only that coke made from bituminous coal, in ovens, pits, or "on the ground", and which, for convenience, may be termed "oven coke". "Gas coke" so called, or that which is a residual product of the manufacture of gas, is in no case included. An apparent exception is the coke of the Consolidated Gas Company, of Pittsburgh, which is made in bee-hive ovens, and is, therefore, a true oven coke. The gases escaping during its manufacture, however, are collected and utilized for lighting purposes, instead of being allowed to waste into the air.

By reason of this omission of "gas coke" the total of coke consumed in the United States, as shown by the fuel tables of the census, will not correspond with the total production of coke as shown in this report, the fuel tables showing the consumption of both oven and gas coke.

It is also to be noticed that, though there is a most intimate connection between the mining of coal and its manufacture into coke, this report covers only the latter industry. The coal-mining connected with coke manufacture is regarded as a separate industry, just as the mining of iron ore is an industry distinct from the manufacture of pig-iron. The statistics of such mining are not, therefore, except incidentally, included in this report. The coal is considered as material, and is so tabulated. To this statement there is no exception, not even in reporting concerning those establishments where all the coal mined is manufactured into coke and where the coal mines and coke works are virtually one establishment. The statements of capital, employés, wages, etc., relate only to the coke works. As illustrative, however, of the extent of the coke industry, some facts regarding the coal mines connected with coke works are given, but they are carefully separated from the figures regarding the latter.

In treating of coal as a material for the manufacture of coke it has been thought best to include some general statements regarding the character of our coking coals, but these statements have been for the most part confined to those deposits of coal which were actually used in the manufacture of coke in the census year. No attempt has been made to show the extent of the deposits of coking coal in the United States.

It should also be distinctly understood that from the statements and statistics given in this report it is not possible to ascertain, even approximately, what have been the profits of coke-making in the United States. A series of questions so framed as to show this would probably have received very few answers. All that the tables pretend to show is the cost of labor and materials and the selling price of the coke. The other items that enter into the cost, such as superintendence, insurance, taxes, interest, general office expenses, bad debts, with others that will readily occur to any business man, are not given, and all of these which are not ascertainable must be added to the cost of labor and materials before it would be possible to ascertain what the profit was.

SUMMARY FOR 1880.

There were produced in the United States in the census year, 1879-'80, 2,752,475 tons of coke, valued at $5,359,489, or $1 94+ per ton. In its production 4,360,110 tons of coal, valued at $2,761,657, or 63.3 cents per ton, were used. This would make the yield of the coal in coke 63.1 per cent., or it would require, on an average, 1.58½ tons of coal to produce a ton of coke. The average value of the coal in a ton of coke would therefore be a little over $1.

There were employed in the manufacture of this coke 3,140(a) persons, of whom 3 were women and 71 boys, the total wages paid being $1,198,654, or 43.5 cents per ton of coke produced. There were 10,116 ovens built May 31, 1880, and 2,163 building, making a total of 12,279 built and constructing.

SUMMARY OF STATISTICS FOR 1850, 1860, 1870, AND 1880.

In the tables included in this report will be found the detailed statistical results of the census of the manufacture of coke in the United States for the census year 1880. These results are summarized below, and, as far as possible, are compared with the results obtained at previous censuses.

a In addition there were two watchmen at an idle works.

As will be shown in the historical part of this report, the manufacture of coke in some considerable quantities for use in blast-furnaces began prior to 1840, and as early as 1817 coke was used for refining iron. It is also probable that as early as this, if not earlier, it was used to some extent in melting iron in founderies, in malting, and for other purposes. Coke does not appear, however, under the subdivisions of manufactures until the census of 1850. Prior to this date it was probably returned as coal.

It will also be evident, from considerations that will hereafter be advanced, that the figures prior to the present census are not complete. The comparisons made must therefore be regarded only as approximations, and not as showing the real advance made in the manufacture of coke.

In the following table is given a summary of the totals of the most important items covered by the census of 1880, compared with similar results obtained at the censuses of 1870, 1860, and 1850:

United States.	Total in 1880.	Total in 1870.	Total in 1860.	Total in 1850.	Percentage of increase in 1880 over 1870.	Percentage of increase in 1880 over 1860.	Percentage of increase in 1880 over 1850.
Number of establishments	149	25	21	4	496.00	609.52	3,625.00
Number of persons employed	3,142	528	198	14	495.08	1,486.87	22,342.86
Amount of capital, real and personal	$5,545,058	$1,202,043	$62,300	$3,700	361.30	8,800.57	149,766.43
Wages paid	1,198,654	288,695	61,368	3,444	315.20	1,853.22	34,704.12
Value of all materials used, including coal	2,995,441	615,268	73,552	6,038	386.85	3,972.55	49,509.82
Value of coke produced	5,359,489	1,132,386	189,844	15,250	373.29	2,723.10	35,044.19

This table indicates a most remarkable growth, especially during the past ten years. It must be remembered that coke is both bulky and low-priced, and in proportion to its weight it is one of the lowest, if not the lowest priced of any manufactured article. During the census year the average value of a railroad-car load of coke, containing from 12 to 14 tons, was from $24 to $28 at the ovens. But little of the coke is used where made, the nearest important point of consumption to the Connellsville region (which produced more than 68 per cent. of all the coke made) being Pittsburgh, about 60 miles distant, while hundreds of thousands of tons are carried to points much farther away. The growth of the industry in these years, then, means a growth where the margins of profit must be small and the tonnage handled immense, and the difficulties in the way of its growth, as is always the case with low-priced, heavy articles that must be transported long distances to market, are well-nigh insurmountable. To organize and operate effectively the railroad service in connection with this heavy increase of traffic has been of itself no small undertaking. All things considered, the development of the manufacture of coke during the past ten years must be regarded as one of the marked achievements in our industrial progress.

NUMBER OF ESTABLISHMENTS.

Each separate coke works, with its ovens and other plant, is classified as an establishment. In many instances it was found that an individual or firm operated several works, sometimes contiguous, in other cases widely separated; but notwithstanding this joint ownership each works is regarded as a separate establishment, and is so classified. The number of works and the number of owners are not, therefore, the same. The number of establishments returned at the last four censuses is as follows, there being no returns prior to 1850:

Number of establishments in 1880	149
Number of establishments in 1870	25
Number of establishments in 1860	21
Number of establishments in 1850	4

The increase in the number of establishments between 1870 and 1880 was nearly 500 per cent., assuming that the word "establishment" was used in the same sense at the census of 1870 as at that of 1880, which is probable, as the condition of the coke trade was such at the earlier date that an individual or a firm would hardly have more than one works.

The increase in 1880 over 1860 was about 600 per cent., the increase in the number of establishments in the ten years between 1860 and 1870 being but 4, or about 20 per cent., as will be seen from the table given above. The increase in product, however, was much greater, indicating a very rapid increase in the size and capacity of the works. The number of works returned in 1850 is probably not correct, and is so small as to be hardly worthy of notice. The manufacture of coke at that date was in its infancy in this country, but it was without doubt more of an industry than the returns for 1850 indicate.

WORKS IDLE AND WORKS BUILDING.

In the enumeration of establishments given in Table I are included all works, whether completed or building, that were in existence in the census year 1879–'80. A number of these, however, were idle during the entire year; others were building, and made no coke. In many cases extensive additions were made to old works, some of which were completed in whole or in part and put in operation during the census year; in other cases construction was going on at the date of this report. It will be necessary, therefore, in order to ascertain what capital, plant, etc., were used in the manufacture of the coke produced in the census year, to distinguish between works which were idle and building and those which were operated in whole or in part.

The following table, condensed from Tables III and IV, gives a statement of all of the works idle or building during the census year 1879–'80. It includes all works at which no coke was made, but does not include any statement of additions made during the census year to works that were completed and operated during any part of the year:

	Number of establishments.	Capital.	NUMBER OF OVENS BUILT.					NUMBER OF OVENS BUILDING.					NO. OF EMPLOYÉS.		COAL PROPERTY OWNED BY COKE WORKS.	
			Bee-hive.	Belgian.	Other forms.	Pits or mounds.	Total.	Bee-hive.	Belgian.	Other forms.	Pits or mounds.	Total.	Males over 16.	Wages paid.	Acres.	Capital.
Works idle	9	$248,700	304	49	......	......	353	21	......	......	......	21	2	*$910	1,550	$296,500
Works building	13	526,500	......	......	......	......	......	1,287	......	80	......	1,367	......	......	16,211	1,860,000
Total	22	775,200	304	49	......	......	353	1,308	......	80	......	1,388	2	910	17,761	2,156,500

* Wages paid watchman at works.

STATISTICS OF ESTABLISHMENTS AT WHICH COKE WAS MADE IN THE CENSUS YEAR 1879–'80.

Comparing the items of this table with the corresponding ones of Table I, and making the necessary deductions, it will be found that the coke made in the United States in the census year 1879–'80 was made in establishments the number and characteristics of which were as follows:

Total number of establishments at which coke was made during census year 1879–'80	127
Total capital invested in the same	$4,769,858
Total number of ovens built at the same May 31, 1880	9,763
Total number of ovens building at the same May 31, 1880	796
Total number of employés at the same May 31, 1880	3,140
Total wages paid at the same	$1,197,744
Total value of materials used at the same	2,995,441
Total tons of coal used at the same	4,360,110
Total value of same	$2,761,657
Total tons of coke produced	2,752,475
Total value of same	$5,359,489
Acres of coal connected with works that make coke	140,922
Capital invested in coal works connected with coke works that made coke in 1879–'80	$10,903,541

LOCALITIES IN WHICH COKE WAS MANUFACTURED.

Though coke was an article of manufacture in this country some years prior to 1850, it is not found enumerated among its manufactures until the census of that year, the very small amount returned being all credited to Pennsylvania. The published volume of statistics of manufactures for that census gives no indication as to the localities in the state where the works making this coke were situated, but an examination of the original returns shows that oven coke was made in Allegheny and Fayette counties. It is very probable that coke was also made in other localities in Pennsylvania, and some in Maryland and Ohio, and possibly in Virginia. The census contains no record of coke so made, and it may have been returned as bituminous coal.

At the census of 1860 coke is returned as made in Allegheny, Cambria, Clarion, and Fayette counties, Pennsylvania. These counties are respectively in the Pittsburgh, Allegheny Mountain, Allegheny River, and Connellsville districts, so that at that date what are now the chief coke-producing regions of Pennsylvania were engaged in its manufacture.

A remark similar to that made concerning the statistics of 1850 is also applicable to those of 1860, as coke was doubtless made in other counties of Pennsylvania than those named. In a work published in Pittsburgh in 1857 (*a*) the statement is made:

> The coke-iron consumed by the manufacturers of Pittsburgh is at present obtained both from a distance and from the neighborhood. The metal of this description made from the fossil ores of the central counties of Pennsylvania is excellent for castings. * * * From the neighboring counties of Fayette, Cambria, Beaver, Mercer, and Lawrence coke metal is now brought to Pittsburgh.

a *Pittsburgh As It Is*, by George H. Thurston (Pittsburgh, 1857), page 103.

This would add Beaver, Mercer, and Lawrence counties to the coke-producing sections of Pennsylvania. The Clinton furnace, at Pittsburgh, working entirely with coke as a fuel, was also blown in during the fall of 1859, and though small, its consumption of coke would have been a considerable proportion of that reported made in the census year 1860. Altogether, the indications are that the returns for 1860 are very incomplete, as they omit many localities at which coke was made, and fail to report much that was made, or do not report it as coke.

In 1870 Ohio for the first time appears in the census as a manufacturer of coke, it being made in Hamilton, Jefferson, and Tuscarawas counties. The coke made in Hamilton county was probably made from the screenings gathered from the different coal-yards. In this year, according to the report, coke was made in Pennsylvania in Allegheny, Armstrong, Cambria, Clarion, and Fayette counties, Armstrong being the only county in which coke was reported as made at the Ninth Census in which it was not reported as made at the Eighth.

In the census of 1880 it will be noticed that coke is reported as being manufactured in nine states: Alabama, Colorado, Georgia, Illinois, Indiana, Ohio, Pennsylvania, Tennessee, and West Virginia. Two establishments for the manufacture of coke are reported in Virginia near Richmond, but no coke was made in this state in the census year 1879–'80. Under the head of "Relative productive rank of the several states and counties" are given the details concerning the several localities at the Tenth Census.

From an inspection of the map accompanying this report and a comparison of the figures given in the tables showing the localities and production it will be seen that the coke-producing belt of the country is the bituminous coal-measures of the Appalachian chain. Beginning very nearly at the extreme northern point of the Allegheny mountains in Pennsylvania, the coke ovens follow this range of the Appalachians nearly to their southern limit, at Huntsville, Alabama. Outside the limit of this region the make of coke in the census year was but 26,600 tons out of a total of 2,752,475, or less than 1 per cent. It will also be noticed that the center of production is the Connellsville region of Pennyslvania.

No doubt coke in considerable quantities will be manufactured in the future in other states. Already there is promise of this in certain sections of Illinois and in Colorado, but for many years it is probable that the bulk of the coke of the country will be produced along the Allegheny Mountain range from the coal-measures of which such a large percentage is now supplied.

CAPITAL.

The capital invested in coke works, including that in ovens and appurtenances, buildings, etc., and employed in the coke business, but not including any of the capital properly belonging to the coal-mining part of coke-making, in the census year 1879–'80 was $5,545,058. This amount, however, does not fairly represent the amount of capital invested in the coke business of the country. Though in this investigation the statistics of the mining of coal for the manufacture of coke have not been included, it is nevertheless true that the capital invested at the mines which supply coal to the coke works is in many instances invested in them solely for the production of coke, and the capital employed at such mines should properly be included with that invested in the manufacture of coke as returned to the special agent. In Fayette and Westmoreland counties, Pennsylvania, the entire product of the mines at the coke works is, with the exception of a small percentage, made into coke. Sales of coal, as coal, are very rare, and are only made under exceptional circumstances, and probably did not equal 1 per cent. of the product in the census year, though it is larger in other years.

In stating the capital invested in the manufacture of coke it would be necessary, therefore, in order to show fairly the total of this capital, to add to that given in the tables of coke manufacture the amount of capital invested in the coal mines at coke works. This was $13,060,041, which would make the total capital invested in the manufacture of coke as follows:

Total capital invested in coal works supplying coal to coke works	$13,060,041
Total capital invested in works for the manufacture of coke	5,545,058
Total invested in the manufacture of coke	18,605,099

A large part of this total is invested in coal lands. There are connected with coal mines that furnish coal for the manufacture of coke 158,683 acres of coal lands, the value of this land varying from $100 or less to $800 an acre, according to its locality.

NUMBER AND KINDS OF OVENS.

The total number of ovens, and the number of each kind built and building in the United States May 31, 1880, was as follows:

	Bee-hive.	Belgian.	Other forms.	Pits and mounds.	Total.
Ovens built May 31, 1880	9,728	316	30	42	10,116
Ovens building May 31, 1880	2,083		80		2,163
Total built and building May 31, 1880	11,811	316	110	42	12,279

FIG. 1.—THE COKE-PRODUCING BELT.

The 316 Belgian ovens include a number of varieties, but are all constructed on the Belgian plan, with flues in the bottom or sides, or both. The other forms are a modification of the bee-hive, and resemble the oven used in Wales. They are known as the "Tunnel, or English drag".

The report on pits or mounds must necessarily be very unsatisfactory, the number used varying with the demand for coke. In seasons of great demand the number at old works—not only at those where only pits and mounds are used, but sometimes at those where usually all the coke made is burned in ovens—is largely increased, and in addition coke is made in mounds at coal works that do not make coke except at these times of increased demand. With a falling off of demand the number is reduced. As they are so variable in number and are not as permanent as ovens, no satisfactory report can be made of the number in use. Those given in the table may be regarded as the number reported in use May 31, 1880.

There are no statements in the census reports of previous years showing the number of ovens in existence at the dates of the reports, nor are exact data obtainable from other sources. A work published at Pittsburgh in 1870 (*a*) gives the number of coke ovens in Pittsburgh and vicinity in active operation in 1855 as 100. The same work states that—

In 1870 what are termed city coke ovens number 273. In addition to these there is a number of ovens owned by manufacturers, who consume their own material, or, in other words, mine their own coal and make their own coke.

The Connellsville coke ovens, the product of which is in universal demand throughout the West, number 790. (*b*)

This would give a total of 1,063 reported in the Pittsburgh and Connellsville districts. From other information it would appear that the number of ovens in western Pennsylvania in 1870 was not far from 1,200.

Of the coke reported as manufactured in the census year 1869–'70, 92 per cent. was reported as manufactured in Pennsylvania, all of which was made in western Pennsylvania. Ninety-four per cent. of the persons employed were employed in the same locality, and the relations of capital invested, wages paid, and material used are about the same. All of these facts would lead to the belief that the number of coke ovens in the United States at the census of 1870 did not exceed 1,300, all of which were of the bee-hive pattern. In addition to that made in ovens, some coke was made in pits and mounds in 1870. Much of that produced in the Allegheny Mountain region of Pennsylvania was so burned.

I have not been able to procure any satisfactory information regarding the number of ovens in use in either 1860 or 1850.

PLANT OTHER THAN OVENS.

As before stated, there are connected with the coal mines that furnish coal for the manufacture of coke 158,683 acres of coal land. This does not, however, represent the amount of coal land from which good coking coal can be mined, but only that attached to ovens, or the acreage of the various tracts of coal from which at the close of the last census year supplies of coal for coking were drawn.

Of the plant used at coal mines which supply coal to ovens, the data, for reasons elsewhere given, are not complete enough to justify any statement. There were 4,360,110 tons of coal and slack used in the manufacture of coke. From a comparison of this with the statistics of bituminous coal produced some rough idea of the proportion of the bituminous coal-plant used in the supply of coal to coke works can be obtained. The amount of bituminous coal produced as a regular product in the census year was 41,860,055 tons; the percentage of this used in the manufacture of coke was therefore 10½ per cent. This proportion of the capital, employés, wages paid, material used, and other items entering into the report on bituminous coal should therefore be regarded as employed or paid in connection with the production of bituminous coal for manufacture into coke.

There were in use at 28 coke works 38 coal-washers. Of these 38 washers, 12 are reported as Stutz's patent, 8 as Diescher's, 4 as Endres', 4 as Hybrid, 2 as Plunger—one of which has 4 jigs and the other 2; 2 as Lauders', each with four compartments; 1 as Osterspey's, with 14 jigs, and 1 each of the following: Slush, Common, Bradford, Waverly Coal Company's, and Floating Trough.

There were also in use by coke works 20 locomotives, 1,703 coke cars, and 26.37 miles of railroad track. These are exclusive of locomotives, cars, and track that are properly credited to the coal mines. The coke cars do not include the "larries", or cars in which the coal is run to the ovens, but only the cars used for transporting coke over railroads to consumers.

The ownership of these cars by the works has been found necessary to secure prompt shipment, though only a portion of the coke shipped is forwarded in these private cars, the railroads usually furnishing the necessary rolling-stock. The number of these private cars owned by certain manufacturers is quite large. One firm owns 500, another 222, a third 172, and a fourth 167.

In addition to the above there are at some establishments extensive works for the supply of water used in cooling coke. At those works using Belgian ovens engines are used to discharge the ovens. The number of these was not obtained.

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a Pittsburgh, its Industry and Commerce. Pittsburgh. Barr & Myers: 1870. *b Idem*, page 18.

The statement of washers used and of the number of locomotives, cars, and miles of railroad track is as follows:

States.	Counties.	Number of establishments at which washers were used.	Number of washers.	Kind of washer.	Remarks.
Alabama	Jefferson	1	1	Stutz	Not used.
Colorado	Las Animas	1	2	Stutz	
Illinois	Jackson	1	4 jigs	Plunger	Building.
	Saint Clair	1	14 jigs	Osterspey	Idle.
	Williamson	1	2 jigs	Plunger	
Indiana	Fountain	1	1	Endres	Experimental.
Pennsylvania	Allegheny	8	5	Diescher	
			4	Stutz	
			3	Endres	
			1	Sinsh.	
	Clarion	2	2	Diescher	
			1	Stutz	
	Clearfield	1	2	Stutz	
	Fayette	1	1	Stutz	
	Lawrence	1	1	Lauders	4 compartments.
	Tioga	1	4	Common	
	Westmoreland	4	4	Hybrid	
			2	Diescher	
			1	Lauders	4 compartments.
			1	Waverly Coal Company	
Tennessee	Marion	1	1	Floating Trough	
	Roane	1	1	Stutz	Experimental.
Total		26	58		

STATEMENT OF NUMBER OF COKE CARS, LOCOMOTIVES, AND MILES OF RAILROAD TRACK AT COKE WORKS OF UNITED STATES, MAY 31, 1880.

States.	Counties.	Number of coke cars.	Number of locomotives.	Miles of railroad track owned, not included in statement of coal works.
The United States		1,703	20	26.37
Alabama	Jefferson and Shelby		3	
	Jefferson	3	1	0.33
Total		3	4	0.33
Georgia	Dade	50	7	
Illinois	Jackson			3.00
Ohio	Columbiana	12		
	Hamilton	2		
	Jefferson	45		1.00
	Tuscarawas	3		0.05
Total		62		1.05
Pennsylvania	Allegheny	* 514		1.00
	Blair	44	1	3.75
	Clarion			0.18
Pennsylvania—c'd	Clearfield			0.37
	Fayette	717	2	4.78
	Jefferson	1		
	Lawrence	4		
	Westmoreland	96	3	2.70
Total		1,376	6	12.78
Tennessee	Grundy	100		
	Marion	† 53		0.09
	Roane	‡ 4		6.00
Total		157		6.09
Virginia	Alleghany	2		
West Virginia	Fayette	7		0.12
	Ohio	2		
	Preston	44	3	3.00
Total		53	3	3.12

* Five hundred cars also used in coal business. † Coke cars, employed in general traffic also. ‡ Iron.

MATERIAL USED.

The material of chief value used in the manufacture of coke is coal, of which 4,360,110 tons, valued at $2,761,657, were used during the census year 1879–'80. This would make the average value of the coal used 63.3 cents per ton. The average price per ton of bituminous coal at the mines for the whole United States during the census year was $1 25 per ton; that for Pennsylvania, in which state most of the coke was made, $1 01 per ton. This would make the average value of the coal used in coking a little more than one-half the average value of all bituminous coal, and about two-thirds the value of bituminous coal in Pennsylvania.

There are several reasons for this great difference. It is not because the coal used is inferior, for economically it is equal to the average of bituminous coal mined; indeed, it is much above the average. The average value of all bituminous coal is probably for screened coal chiefly, while that used in coking includes but little screened coal, but is mostly the "run of the mine", with considerable slack coal. This would reduce the value per ton considerably. As most of the coal used in coking is from mines that are part of the coke works, and as its mining is regarded as only incident to the manufacture of coke, and not as a separate industry, the coal is valued at the cost of production, with a small royalty added, with little or no account of profit. As the coal veins in the Connellsville region of Pennsylvania, where so large a proportion of the coke was made in the census year, are quite thick, the coal soft and easily mined, and the miners are paid for all coal brought out, the wages and consequent labor-cost per ton is much less than in mining for the coal market, where only screened coal is paid for, and for these several reasons the cost value put upon this coal for coke would be low. To indicate how low this might be, it can be stated that Connellsville coke was sold in some instances in 1878, delivered on the cars at the ovens, for 90 cents a ton. As it takes, say, an average of 1½ tons of coal to make a ton of coke, and as the cost of coking must be included, it will be seen that the value of coal at coke works at that time must have been very low, even less than the 63.3 cents a ton shown in this report. Indeed, the value of the coal in a ton of coke in Pennsylvania was only about 87½ cents, or, say, 58⅓ cents a ton of coal.

It will be noticed in Table I that the coal used is divided into three classes, "coal used," "slack used," and "washed coal used". Under the first class, "coal used," is included all lump coal, and also the coal used at works where the "run of the mine" or the entire product, lump, nut, and slack, is coked. All of these grades of coal, even though the lump may be crushed and washed, are included under the first class. Under "slack used" is included only the screenings of coal. The total of these two columns is the total amount of coal coked. The third class, "washed coal used", shows the total amount of coal washed. Most of this total is made up of slack coal, with a part of lump and the "run of the mine", which have been crushed and washed. All of the slack coal used, however, was not washed. At some coal mines a few ovens are built, in which the slack which cannot be sold for other purposes is coked without washing. Some works also find it injurious to the quality or yield of the coke to wash the slack.

Of the total amount of 4,360,110 tons of coal coked, 3,729,328 tons, or 85.5 per cent., valued at $2,392,449, or 64 cents per ton, was lump coal and "run of the mine"; 630,782 tons, or 14.5 per cent., valued at $358,558, or 56.8 cents per ton, was slack.

It will be noticed that the average value of "slack used", though slack is generally regarded at the mines as a waste product of little value, is very nearly that of "coal used", being only 7.2 cents per ton less. This is due to the fact that a large part of the slack used is not coked at the mines where it is produced, and the freight charges from the mines to the ovens, and the cost of handling, add to its value. On the other hand, the ovens using lump coal and the "run of the mine" are usually at the mouth of the mine. In many cases the ovens are charged from the cars that were loaded in the pit, and all expenses for freight and handling are saved. The value of the slack at some points is also enhanced by a demand for it for purposes other than coking, as at Pittsburgh, where it is used at some of the iron works for making gas.

Of the total amount of coal and slack used, 751,824 tons, or 17.2 per cent., valued at $533,818, or 71 cents per ton, was washed. This makes the value of the "washed coal and slack" greater per ton than the value of either the coal or slack. The crushing and washing of the lump and "run of the mine", before referred to, involve in some cases a cost of 20 cents a ton; this is above the average, however; and the washing of the slack would add from 2 to 12 cents a ton to its value.

No other material enters directly into the coke, the other materials reported being used for repairs and renewals of ovens, and for the tools and appliances used in the manufacture of coke. To arrive at the value of these materials has been the most difficult part of this investigation. In many cases it has been impossible to separate the materials and supplies used in the manufacture of coke from those used in mining the coal; but when it has been possible to make this separation, it has been done. Careful and extensive inquiries have been made, and an average has been taken from the reports of a number of works that have kept their cost of materials very carefully. As a result, it is estimated that the average cost of materials, other than coal, used in the manufacture of coke is about 7½ cents per ton of coke produced. When the value of material has been given it is reported; when statements of material have been omitted, or are imperfect, this average of 7½ cents per ton is used. As a result, it is estimated that the value of all materials used, other than coal, is $233,784.

The value of all materials used in the manufacture of coke in the census year is as follows:

Total value of coal and slack	$2,761,657
Total value of other materials	233,784
Total value of all materials	2,995,441

The chief materials other than coal were fire-brick, red brick, wood, and castings, but no reliable statement of the amount of each could be secured.

WEIGHT OF THE BUSHEL.

The weight of the bushel, which is so frequently employed as the unit of measure in the buying, selling, and using of coal and coke, varies but little in the different states. A bushel of coke is almost uniformly 40 pounds; but in exceptional cases, where the coke is very light, 38, 36, and even 33 pounds are regarded as a bushel. In one return 56 pounds, in four 50 pounds, in one 48 pounds, in one 45 pounds, and in one 42 pounds are given as the weight of the bushel; but in these cases the coke would be quite heavy. These exceptions, however, are so few that 40 pounds may be taken as the uniform weight of a bushel of coke.

The weight of a bushel of coal differs more than this. In Alabama the returns give it as 80 pounds, and the same is returned for Colorado, Georgia, Illinois, Ohio, Tennessee, and West Virginia; but in Pennsylvania it is 76 pounds, and in Indiana 70.

EMPLOYÉS.

Compared with the tonnage produced, the manufacture of coke requires the labor of but a small number of persons, the average number employed at each works that made coke in 1879–'80 being less than 25. There are but four works in the United States that employ over 100 men, and one of these is a works at which the labor is performed by convicts. With other labor a less number of men would have sufficed.

The total number of persons employed directly in the manufacture of coke, as returned at the last census, is 3,140, (*a*) of whom but 3 were women and 71 boys.

The number of employés in coke works at the last four censuses is as follows:

	All.	Males over 16.	Females over 15.	Youths.
Employés at census 1880	3,142	3,068	3	71
Employés at census 1870	528	522	....	6
Employés at census 1860	198	198	....	....
Employés at census 1850	14	14	....	....

Most of the employés are unskilled workmen, and would be classed as common labor. The operations connected with the manufacture of coke, for the most part, require only strength and endurance, and at many of the works, especially the smaller ones, even the term "superintendent" does not imply much more than a "labor boss". This is not universally true, however, as at some works the position of superintendent is one of importance and responsibility.

WAGES AND EARNINGS.

The total amount of wages paid during the census year in the manufacture of coke was $1,198,654. (*b*) This, however, does not include any wages paid in the mining of coal, but only the labor-cost, from the delivery of the coal at the ovens until the coke is loaded upon the cars.

As the amount of coke produced during the census year was 2,752,475 tons, and the total of wages paid $1,198,654, the average labor-cost of producing a ton of coke would be 43.5 cents.

Any attempt to deduce from the figures given in these tables the average yearly earnings of each person employed would be futile. The total amount of wages paid ($1,198,654), divided by the number of persons employed (3,142), would give a quotient of $381 50. Though such a quotient is often regarded as the average yearly earnings of each employé, a little consideration will make it evident that it does not represent such earnings, but that it really represents nothing but the result of the division of one number by another. A consideration of the circumstances attending the growth and development of the coke industry during the census year will show that this is especially true in its manufacture. Many of the old works, or those in existence at the beginning of the census year, were idle, in whole or in part, June 1, 1879, and did not resume in full until the census year was well advanced; in other cases additions were made to old works, and in still others entirely new works were built. To operate these various works additional persons were employed, not in place of others, but as an increase in their number, and therefore the number reported May 31, 1880, would be much above the average for the year, and very greatly in excess of the number at work June 1, 1879. These additional persons would, of course, be paid only for the time they were employed in making coke, and in the wages-total only the amount so paid, say, for two, three, or six months, as the case might be, would appear. Now, it would be manifestly misleading under these circumstances to say that the quotient resulting from dividing the entire amount of wages paid during the whole year by the number of persons employed May 31, 1880, some of whom had been at work but a month, would give the average yearly earnings. If there had been no increase in plant or in the number of persons employed during the year, if no persons had been brought into this industry from other industries or from idleness, and if, when the coke works were idle, the men employed at them performed no labor, then such a quotient might represent with some degree of accuracy the average yearly earnings of the persons employed in the coke industry; but when not one of these conditions exists, it is evident that the average yearly earnings of the men employed at the coke works was not $381 50, but more than this—what, we have no data for ascertaining.

a In Table I 3,142 employés are reported, but 2 are watchmen at idle works.

b Of this amount $910 were paid two watchmen at an idle works. The amount is so small, however, that it is not subtracted in the following computations.

A somewhat similar difficulty exists in any attempt to arrive at the average rate of wages paid to persons employed in this industry. This is a most difficult fact to ascertain in connection with this or any other industry. It is very easy to give an average of the different rates of wages paid, but this is more properly termed *the average of rates of wages*, not the *real average rate*. To arrive at the average rate of wages—that is, an average that shall consider not only the several rates paid, but the number of men employed at each rate, as the average rate can only be found by the consideration of both—is very difficult.

In the following statement an attempt has been made to approximate the average rate of wages for a number of classes of employés at a portion of the coke works. These tables show:

1. The range of the rates of wages, or the highest and the lowest rate paid the different classes of labor as given in the schedules returned to this office.

2. The average rates of wages as near as can be ascertained.

These average rates are found by multiplying each rate by the number of persons employed at that rate and dividing the sum of the products by the sum of the multipliers, which represent the number of persons employed at each rate for whom rates of wages are given in the schedules. It will be observed that the tables below do not take into consideration the number of days the men were employed, or, in other words, the regularity of employment, but simply give the range of wages and the average wages, without reference to such regularity of employment:

States.	SUPERINTENDENT.		CLERK.		HAULER.	
	Range of rate of wages per month.	Average rate per month.	Range of rate of wages per day.	Average rate of wages per day.	Range of rate of wages per day.	Average rate of wages per day.
The United States	$35 00 to $125 00	$56 04	$1 50 to $4 17	$1 93	$1 00 to $2 00	$1 55
Alabama	40 00 to 100 00	63 33			1 00 to 1 25	1 17
Colorado	125 00	125 00			2 00	2 00
Illinois	55 00	55 00				
Ohio	45 00 to 62 50	50 50			1 20 to 1 50	1 29
Pennsylvania	35 00 to 105 00	53 15	1 50 to 4 17	2 03	1 15 to 1 80	1 62
Tennessee	75 00	75 00			1 40	1 40
West Virginia	50 00	50 00	1 50	1 50	1 00 to 1 10	1 07

States.	COKE-CHARGER.		ENGINEER.		COKE LABORER.	
	Range of rate of wages per day.	Average rate of wages per day.	Range of rate of wages per day.	Average rate of wages per day.	Range of rate of wages per day.	Average rate of wages per day.
The United States	$1 00 to $2 50	$1 49	$1 50 to $2 60	$1 59	$0 78 to $2 00	$1 27
Alabama	1 00 to 1 25	1 08			90 to 1 00	93
Colorado	2 00	2 00			1 50 to 2 00	1 75
Illinois			1 75	1 75	1 35	1 35
Ohio	1 20 to 1 50	1 39			1 00	1 00
Pennsylvania	1 15 to 2 50	1 65	1 50 to 2 60	1 55	78 to 1 56	1 23
Tennessee	1 10 to 1 50	1 34			1 00	1 00
West Virginia	1 00 to 2 25	1 22	1 50	1 50	1 00 to 1 10	1 06

PERIODS OF PAYMENT.

There are returns from 110 establishments showing the frequency with which labor is paid. Of these, 86 pay monthly, 14 every two weeks, 6 every week, 3 every three weeks, and 1 quarterly. This latter is an establishment in Tennessee that employs convict labor, and the state is paid quarterly for such labor. It will thus be seen that the rule as to periods of payment at coke works is monthly.

The following table gives the periods of payment at the coke works of the United States so far as reported:

States.	Total number of establishments.	Quarterly.	Monthly.	Every three weeks.	Every two weeks.	Weekly.
The United States	147	1	86	3	14	6
Alabama	4		4			
Colorado	1		1			
Georgia	1		1			
Illinois	4		1		1	
Indiana	2		1			
Ohio	15		5		4	2
Pennsylvania	104		62	3	8	3
Tennessee	4	1	1			1
West Virginia	12		10		1	

METHODS OF PAYMENT.

Returns from 118 establishments show that at 56 of them there were stores connected with the works for supplying the operatives with goods, and that 62 were without stores. This would indicate that the "truck system" was in use at a little less than half the coke works, while a little more than one-half paid cash in full. What proportion of the wages paid at those works that have stores is in cash and what proportion is "truck" we have no means of knowing.

The following table shows, so far as reports have been received, the establishments in each state that have stores connected with them and those that have not:

States.	Total number of establishments.	Number of establishments from which reports have been received.	Number of establishments that have stores connected with them.	Number of establishments that do not have stores connected with them.
The United States	147	118	56	62
Alabama	4	4	3	1
Colorado	1	1		1
Georgia	1	1	1	
Illinois	4	2	1	1
Indiana	2	1		1
Ohio	15	14	4	10
Pennsylvania	104	80	38	42
Tennessee	4	4	3	1
West Virginia	12	11	6	5

RELATIVE RANK IN PRODUCTION OF THE SEVERAL STATES AND COUNTIES.

The relative rank of the several states and the counties in the same in which coke was produced in the census year 1879–'80 is as follows:

RELATIVE RANK OF STATES.

States.	Tons of coke manufactured.	Percentage of make to total make.
The United States	2,752,475	100.00
1. Pennsylvania	2,317,149	84.18
2. Ohio	109,296	3.97
3. West Virginia	95,720	3.48
4. Tennessee	91,675	3.33
5. Georgia	70,000	2.54
6. Alabama	42,035	1.53
7. Colorado	18,000	0.65
8. Illinois	7,600	0.28
9. Indiana	1,000	0.04

RELATIVE RANK OF COUNTIES, IN ORDER OF PRODUCTION.

Counties.	Tons manufactured.	Percentage of make to total make.	Counties.	Tons manufactured.	Percentage of make to total make.
The United States	2,752,475	100.00	15. Las Animas, Colorado	18,000	0.65
			16. Marion, Tennessee	11,675	0.42
1. Fayette, Pennsylvania	1,260,440	45.79	17. Clarion, Pennsylvania	10,800	0.39
2. Westmoreland, Pennsylvania	753,501	27.38	18. Hamilton, Ohio	9,806	0.36
3. Blair, Pennsylvania	98,154	3.57	19. Williamson, Illinois	7,600	0.28
4. Allegheny, Pennsylvania	95,685	3.48	20. Armstrong, Pennsylvania	7,000	0.25
5. Dade, Georgia	70,000	2.54	21. Lawrence, Pennsylvania	3,941	0.14
6. Grundy, Tennessee	60,000	2.18	22. Marion, West Virginia	2,800	0.10
7. Fayette, West Virginia	57,943	2.10	23. Washington, Pennsylvania	1,200	0.04
8. Jefferson, Ohio	57,684	2.10	24. Ohio, West Virginia	1,200	0.04
9. Cambria, Pennsylvania	51,950	1.89	25. Mahoning, Ohio	1,017	0.04
10. Jefferson, Alabama	42,035	1.53	26. Clay, Indiana	1,000	0.04
11. Columbiana, Ohio	39,424	1.43	27. Tuscarawas, Ohio	800	0.03
12. Preston, West Virginia	33,777	1.23	28. Athens, Ohio	565	0.02
13. Tioga, Pennsylvania	33,572	1.22	29. Beaver, Pennsylvania	506	0.02
14. Roane, Tennessee	20,000	0.73	30. Butler, Pennsylvania	400	0.01

Pennsylvania in 1879–'80 is credited with 84.18 per cent. of the total product of the country. There are no figures of product given at any previous census with which to institute comparisons, but comparing by values Pennsylvania made a little less than 80 per cent. in 1879–'80, 92 per cent. in 1869–'70, and 100 per cent., or all, in both 1859–'60 and 1849–'50. Though there has been a relative decline, the amount and the value of coke actually produced in Pennsylvania have very largely increased, as will be seen from the following statement:

Value of coke produced in Pennsylvania:	
In census year 1849–'50	$15,250
In census year 1859–'60	189,844
In census year 1869–'70	1,048,716
In census year 1879–'80	4,190,136

The increase in value has been as follows:

Increase in value of coke produced in Pennsylvania in 1859–'60 over that produced in 1849–'50	$174,594
In 1869–'70 over 1859–'60	858,872
In 1879–'80 over 1869–'70	3,141,420

Ohio stands in the second rank as a coke-producing state, but far below Pennsylvania, producing but 3.97 per cent. in 1880. Making the same comparison of values with previous censuses as is made above in the case of Pennsylvania, Ohio made in 1879–'80 about 6 per cent.; in 1869–'70, 8 per cent. Prior to this no coke is reported as made in Ohio. Though in Ohio, as well as in Pennsylvania, there has been a decline in the value of product relative to the entire product, there has been an increase in total value. The value of the coke produced in Ohio in 1869–'70 was $83,675; in 1879–'80, $334,546.

None of the other states are reported as making coke at either of the censuses prior to the present. In West Virginia, Tennessee, Georgia, and Alabama, however, deposits of very good coking coal exist, and rapid advances are making in its manufacture—advances that before another census will probably place some, if not all, of these states ahead of Ohio in production, though they will hardly supplant Pennsylvania and reach the first place.

Referring to the table of "counties in order of production", it will be noted that two counties in Pennsylvania, Fayette and Westmoreland, produced, respectively, 45.79 and 27.37 per cent. of all the coke made in the country at the present census, or 73.16 per cent. of the whole. At the census of 1870 Fayette county, Pennsylvania, was the largest producer, returning $516,800 in value, Allegheny, Pennsylvania, following with $243,690, and Cambria, Pennsylvania, with $225,898. Westmoreland, which is now the second county, produced no coke, while Allegheny, formerly the second county, is now the fourth, and Cambria, formerly the third, is now the ninth; Dade county, in Georgia, Grundy, in Tennessee, Fayette, in West Virginia, and Jefferson, in Ohio, surpassing Cambria in amount of product.

YIELD OF COAL IN COKE.

The following table shows the percentage of yield in coke of the coal coked in the several states and the United States:

States.	Tons of coal used.	Tons of coke produced.	Percentage yield of coal.
The United States	4,360,110	2,752,475	63.1
Alabama	67,376	42,035	62.4
Colorado	29,500	18,000	61.0
Georgia	117,000	70,000	59.8
Illinois	15,000	7,600	50.7
Indiana	1,500	1,000	66.7
Ohio	193,848	109,296	56.4
Pennsylvania	3,608,095	2,317,149	64.2
Tennessee	179,311	91,675	51.1
West Virginia	148,480	95,720	64.5

From this table it appears that the coal coked in the United States yielded on an average 63.1 per cent. of coke. The range of the yield in the several states was from 50.7 per cent. in Illinois to 66.7 in Indiana. The high average yield, in view of the range, it being very nearly equal to the highest percentage yield, is due to the high average in Pennsylvania, 64.2 per cent., which produced 84.18 per cent. of all the coke made.

The yield of 66.7 per cent. in Indiana is an estimate. In the schedule return the amount of coke produced was given at 1,000 tons, and the statement was made that the yield was "about 66 per cent." As no record of the coal charged into the ovens was given, this estimated yield was taken, and the amount of coal used was estimated at 1,500 tons.

Neglecting this, then, as only an estimate, and considering the figures of coal used and coke produced actually reported, it will be seen that the next highest yield is in West Virginia and in Pennsylvania, which report essentially the same yield, there being a difference of only three-tenths of one per cent. As part of the coke made in Pennsylvania is made by the wasteful method of coking in pits, it may be assumed that the present investigation shows that the yield of Pennsylvania coals and that of West Virginia are about equal. This is further confirmed by the following tables. The counties in these two states of the greatest production are Fayette and Westmoreland, Pennsylvania, Fayette and Preston, West Virginia, and the coal used, coke produced, and yield of coal in coke for these four counties, which together produced 76 per cent. of all the coke made, are as follows:

Counties.	States.	Tons of coal used.	Tons of coke produced.	Percentage yield of coal.
Fayette	Pennsylvania	1,910,279	1,260,440	0.66
Westmoreland	do	1,195,824	753,501	0.63
Fayette	West Virginia	88,769	57,943	0.65
Preston	do	53,331	33,777	0.63

The low yield in some of the other states is doubtless due chiefly to two causes: First, wasteful methods of coking; and, secondly, the use of coals not well adapted to coking. It should be stated, however, that yield is not always a measure of the economic value of coal for coking purposes.

AVERAGE SELLING PRICE OF COKE.

The figures in Table I under the caption "Value of product", and in the accompanying table under "Total value", are to be regarded as the total selling price of the coke produced when loaded on cars at the ovens, or, expressed in trade language, "f. o. b. cars at ovens." The "average value" in the table given below is the "average selling price" at the ovens. Coke is rarely stocked at the place of manufacture, but when drawn from the ovens is loaded directly into cars and sent to the place of consumption, where any surplus stock, or an amount necessary to provide against delay in delivery, is stored.

It should be noticed in regard to this selling price that the census year was a period of great fluctuation greater probably than ever before in the history of the coke trade. In July, 1879, coke was selling at from $1 15 to $1 30 per ton (2,000 pounds); but during the latter part of that year it advanced quite rapidly, and sold early in 1880 in some instances as high as $5 a ton. The decline in price was equally rapid, and at the close of the census year, or early in June, 1880, it was selling at from $1 25 to $1 50 per ton.

As an important factor in determining the selling price, it should be noted that a large proportion of the total product is sold to blast-furnaces on contracts running generally for a year. The time of making these contracts in many cases was such that the coke works failed to profit by the very large increase in prices noted above; and for much of the coke supplied to blast-furnaces that were blown in to meet the great demand for iron during the census year, as well as that sold in the course of daily business or on "short-time contracts", very good prices were obtained. These amounts, however, were not sufficient to increase the average materially, and under the combined influence of the contract system and the great fluctuations in prices noted above the average selling price was low. These same influences also had a marked effect upon the relation of cost to the selling price. Contracts taken at low rates had to be filled when cost had materially advanced and coal appreciated in price, and as a result the amount of money made during the census year in proportion to the amount of coke sold was very small.

The average selling price for the census year in each state and in the United States is given in the following table:

AMOUNT AND TOTAL VALUE OF COKE PRODUCED IN EACH STATE IN CENSUS YEAR 1879-'80, AND AVERAGE VALUE OF SAME PER TON.

[Arranged by states, according to average value.]

States.	Total number of tons produced.	Total value.	Average value per ton.
The United States	2,752,475	$5,359,489	$1 95
Colorado	18,000	90,000	5 00
Alabama	42,035	148,026	3 52
Illinois	7,600	24,700	3 25
Ohio	109,296	334,546	3 06
Indiana	1,000	3,000	3 00
Tennessee	91,675	212,493	2 32
West Virginia	95,720	216,588	2 26
Georgia	70,000	140,000	2 00
Pennsylvania	2,317,149	4,190,136	1 81

The selling price, as given, should by no means be regarded as an evidence or even as an indication of the economic value of the cokes of different states. For example, the price of Pennsylvania coke, which is chiefly Connellsville, than which there is no better made in the country, averaged for the year only $1 81 per ton, while the Indiana coke, which is not equal to the Pennsylvania coke, and was indeed only experimental, is rated at $3 per ton. The difference in the selling price of cokes of the different localities is due mainly to its quality, the local demand, the amount made, and the distance from centers of supply. The Connellsville coke, which may be regarded as a typical coke, furnishing the chief fuel for the smelting of iron and other metals west of the Allegheny mountains as well as for use in founderies, virtually fixes the price for all other coke, the price at different points depending chiefly upon that at which Connellsville coke can be delivered at these points.

The very low price at which coke is sold is one of the remarkable features of this industry. To manufacture a ton of coke one and one-half tons of coal are required. This coal was handled at the ovens, burned, drawn from the ovens, and furnished, loaded into cars in the Connellsville region, for $1 81 per ton of coke, or $1 20 per ton of coal.

TABLE I.—STATISTICS OF THE MANUFACTURE OF COKE IN THE UNITED STATES, AT THE CENSUS OF 1880, BY STATES.

States.	Number of establishments.	Capital invested in coke works and employed in coke business.	NUMBER OF OVENS BUILT.					NUMBER OF OVENS BUILDING.					NUMBER OF EMPLOYÉS.					Total wages paid in manufacturing coke.
			Bee-hive.	Belgian.	Other forms.	Pits or mounds.	Total.	Bee-hive.	Belgian.	Other forms.	Pits or mounds.	Total.	Males over 16.	Females over 15.	Males under 16.	Females under 15.	Total.	
The United States	149	$5,545,058	9,728	316	30	42	10,116	2,083	......	80	......	2,163	3,068	3	71	......	3,142	$1,198,654
Alabama	4	135,500	216	......	......	......	216	206	......	......	......	206	64	......	......	......	64	38,500
Colorado	1	150,000	128	......	......	......	128	72	......	......	......	72	75	......	......	......	75	13,500
Georgia	1	80,000	140	......	......	......	140	......	......	......	......	......	107	......	......	......	107	13,837
Illinois	4	205,000	......	49	30	......	79	......	......	80	......	80	16	......	2	......	18	9,347
Indiana	2	8,000	20	25	......	......	45	......	......	......	......	......	4	......	......	......	4	300
Ohio	15	144,012	619	......	......	......	619	12	......	......	......	12	150	......	3	......	153	51,977
Pennsylvania	104	4,262,525	7,524	242	......	42	7,808	1,469	......	......	......	1,469	2,379	3	62	......	2,444	983,431
Tennessee	4	200,021	589	......	......	......	589	152	......	......	......	152	114	......	......	......	114	38,820
Virginia	2	30,000	85	......	......	......	85	21	......	......	......	21	......	......	......	......	......	......
West Virginia	12	330,000	407	......	......	......	407	151	......	......	......	151	159	......	4	......	163	48,942

States.	Value of materials other than coal.*	COAL USED.		SLACK USED.		WASHED COAL USED.		TOTAL COAL AND SLACK USED.		COAL PROPERTY.		COKE PRODUCED.	
		Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Acres.	Capital.	Tons.	Value.
The United States	$233,784	3,729,328	$2,392,449	630,782	$358,558	751,824	$533,818	4,360,110	$2,761,657	158,683	$13,060,041	2,752,475	$5,359,489
Alabama	1,304	66,376	73,814	1,000	1,500	......	......	67,376	75,314	35,860	471,000	42,035	148,026
Colorado	600	29,500	22,600	......	......	29,500	29,500	29,500	29,500	2,000	1,033,500	18,000	90,000
Georgia	4,900	117,000	120,000	......	......	......	......	117,000	120,000	15,000	220,000	70,000	140,000
Illinois	420	......	......	15,000	11,250	15,000	15,000	15,000	15,000	160	38,000	7,600	24,700
Indiana	200	1,500	2,025	......	......	......	......	1,500	2,025	260	20,000	1,000	3,000
Ohio	5,399	148,292	181,112	45,556	47,320	......	......	193,848	228,432	3,357	432,525	109,296	334,546
Pennsylvania	209,849	3,144,969	1,786,717	463,126	244,588	596,713	426,581	3,608,095	2,031,305	32,272	9,421,459	2,317,149	4,190,136
Tennessee	8,092	80,911	75,137	98,400	49,000	110,611	62,737	179,311	124,137	48,383	570,101	91,675	212,493
Virginia	......	......	......	......	......	......	......	......	......	......	......	......	......
West Virginia	3,020	140,780	131,044	7,700	4,900	......	......	148,480	135,944	21,391	853,465	95,720	216,588

* See remarks under Materials, page 7.

TABLE II.—STATISTICS OF THE MANUFACTURE OF COKE IN THE

	States and counties.	Number of establishments.	Capital invested in coke works and employed in coke business.	NUMBER OF OVENS BUILT.					NUMBER OF OVENS BUILDING.					NUMBER OF EMPLOYÉS.					Total wages paid in manufacturing coke.
				Bee-hive.	Belgian.	Other forms.	Pits or mounds.	Total.	Bee-hive.	Belgian.	Other forms.	Pits or mounds.	Total.	Males over 16.	Females over 15.	Males under 16.	Females under 15.	Total.	
	The United States.	149	$5,545,058	9,728	316	30	42	10,116	2,083	......	80	......	2,163	3,068	3	71	......	3,142	$1,198,654
	ALABAMA.																		
1	Jefferson	3	135,500	216	......	......	......	216	206	......	......	......	206	64	......	......	......	64	38,500
2	Shelby *	1	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
	Total	4	135,500	216	......	......	......	216	206	......	......	......	206	64	......	......	......	64	38,500
	COLORADO.																		
1	Las Animas	1	150,000	128	......	......	......	128	72	......	......	......	72	75	......	......	......	75	13,500
	GEORGIA.																		
1	Dade	1	80,000	140	......	......	......	140	......	......	......	......	......	107	......	......	......	107	13,837
	ILLINOIS.																		
1	Jackson	1	75,000	......	......	......	......	......	......	......	80	......	80	......	......	......	......	......	......
2	Saint Clair	1	100,000	......	24	......	......	24	......	......	......	......	......	2	......	......	......	2	910
3	Will †	1	......	......	25	......	......	25	......	......	......	......	......	......	......	......	......	......	......
4	Williamson	1	30,000	......	......	30	......	30	......	......	......	......	......	14	......	2	......	16	8,437
	Total	4	205,000	......	49	30	......	79	......	......	80	......	80	16	......	2	......	18	9,347
	INDIANA.																		
1	Clay	1	8,000	20	......	......	......	20	......	......	......	......	......	4	......	......	......	4	300
2	Fountain ‡	1	......	......	25	......	......	25	......	......	......	......	......	......	......	......	......	......	......
	Total	2	8,000	20	25	......	......	45	......	......	......	......	......	4	......	......	......	4	300
	OHIO.																		
1	Athens	1	2,000	8	......	......	......	8	12	......	......	......	12	7	......	......	......	7	375
2	Columbiana	2	57,500	195	......	......	......	195	......	......	......	......	......	27	......	......	......	27	11,965
3	Hamilton	3	14,000	22	......	......	......	22	......	......	......	......	......	13	......	......	......	13	4,012
4	Jefferson	6	61,512	344	......	......	......	344	......	......	......	......	......	96	......	3	......	99	34,645
5	Mahoning	2	2,000	10	......	......	......	10	......	......	......	......	......	3	......	......	......	3	480
6	Tuscarawas	1	7,000	40	......	......	......	40	......	......	......	......	......	4	......	......	......	4	500
	Total	15	144,012	619	......	......	......	619	12	......	......	......	12	150	......	3	......	153	51,977
	PENNSYLVANIA.																		
1	Allegheny	17	325,150	336	140	......	......	476	20	......	......	......	20	169	......	2	......	171	59,485
2	Armstrong	2	30,000	......	......	......	20	20	66	......	......	......	66	10	......	......	......	10	4,000
3	Beaver	1	400	2	......	......	......	2	......	......	......	......	......	1	......	......	......	1	280
4	Blair	4	110,000	171	......	......	19	190	......	......	......	......	......	97	......	10	......	107	38,764
5	Butler	1	200	7	......	......	......	7	......	......	......	......	......	3	......	......	......	3	509
6	Cambria	3	106,000	17	102	......	......	119	......	......	......	......	......	45	......	......	......	45	19,870
7	Clarion	2	30,200	60	......	......	......	60	......	......	......	......	......	14	......	1	......	15	7,200
8	Clearfield	1	25,000	......	......	......	......	......	60	......	......	......	60	......	......	......	......	......	......
9	Fayette	44	1,956,450	4,185	......	......	3	4,188	1,082	......	......	......	1,082	1,067	3	5	......	1,075	493,332
10	Jefferson	1	10,000	......	......	......	......	......	31	......	......	......	31	......	......	......	......	......	......
11	Lawrence	2	38,500	98	......	......	......	98	......	......	......	......	......	19	......	3	......	22	3,004
12	Tioga	1	50,000	152	......	......	......	152	......	......	......	......	......	69	......	4	......	73	25,321
13	Washington	1	2,000	8	......	......	......	8	......	......	......	......	......	4	......	......	......	4	600
14	Westmoreland	24	1,578,625	2,488	......	......	......	2,488	210	......	......	......	210	881	......	37	......	918	331,075
	Total	104	4,262,525	7,524	242	......	42	7,808	1,469	......	......	......	1,469	2,379	3	62	......	2,444	983,431
	TENNESSEE.																		
1	Grundy	1	125,000	404	......	......	......	404	102	......	......	......	102	79	......	......	......	79	24,000
2	Marion	2	56,021	118	......	......	......	118	30	......	......	......	30	18	......	......	......	18	7,820
3	Roane	1	19,000	67	......	......	......	67	20	......	......	......	20	17	......	......	......	17	7,000
	Total	4	200,021	589	......	......	......	589	152	......	......	......	152	114	......	......	......	114	38,820
	VIRGINIA.																		
1	Allegheny	1	30,000	83	......	......	......	83	21	......	......	......	21	......	......	......	......	......	......
2	Henrico	1	......	2	......	......	......	2	......	......	......	......	......	......	......	......	......	......	......
	Total	2	30,000	85	......	......	......	85	21	......	......	......	21	......	......	......	......	......	......
	WEST VIRGINIA.																		
1	Fayette	6	239,000	238	......	......	......	238	134	......	......	......	134	98	......	1	......	99	27,612
2	Marion	1	14,000	36	......	......	......	36	......	......	......	......	......	5	......	......	......	5	2,000
3	Ohio	1	3,000	3	......	......	......	3	1	......	......	......	1	2	......	......	......	2	480
4	Preston	4	74,000	130	......	......	......	130	16	......	......	......	16	54	......	3	......	57	18,850
	Total	12	330,000	407	......	......	......	407	151	......	......	......	151	159	......	4	......	163	48,942

* The report of this works is included with those in Jefferson county.

† Manufacture of coke abandoned and capital regarded as sunk.

‡ Works experimental; no returns of capital, etc.

UNITED STATES AT THE CENSUS OF 1880, BY STATES AND COUNTIES.

Value of materials other than coal.	Coal used. Tons.	Coal used. Value.	Slack used. Tons.	Slack used. Value.	Washed coal used. Tons.	Washed coal used. Value.	Total coal and slack used. Tons.	Total coal and slack used. Value.	Coal property. Acres.	Coal property. Capital.	Coke produced. Tons.	Coke produced. Value.	
$233, 784	3, 729, 328	$2, 392, 449	630, 782	$358, 558	751, 824	$533, 818	4, 360, 110	$2, 761, 657	158, 683	$13, 060, 041	2, 752, 475	$5, 359, 489	
1, 304	66, 376	73, 814	1, 000	1, 500			67, 376	75, 314	35, 860	471, 000	42, 035	148, 026	1
													2
1, 304	66, 376	73, 814	1, 000	1, 500			67, 376	75, 314	35, 860	471, 000	42, 035	148, 026	
600	29, 500	22, 600			29, 500	29, 500	29, 500	29, 500	2, 000	1, 033, 500	18, 000	90, 000	1
4, 900	117, 000	120, 000					117, 000	120, 000	15, 000	220, 000	70, 000	140, 000	1
													1
													2
													3
420			15, 000	11, 250	15, 000	15, 000	15, 000	15, 000	160	38, 000	7, 600	24, 700	4
420			15, 000	11, 250	15, 000	15, 000	15, 000	15, 000	160	38, 000	7, 600	24, 700	
200	1, 500	2, 025					1, 500	2, 025	260	20, 000	1, 000	3, 000	1
													2
200	1, 500	2, 025					1, 500	2, 025	260	20, 000	1, 000	3, 000	
	400	640	730	320			1, 130	960	287	41, 525	565	2, 097	1
1, 588	67, 646	101, 469					67, 646	101, 469	1, 530	169, 000	39, 424	125, 652	2
735			14, 922	16, 471			14, 922	16, 471			9, 806	42, 887	3
2, 992	77, 285	74, 024	29, 904	30, 529			107, 189	104, 553	1, 280	183, 000	57, 684	156, 902	4
84	1, 361	1, 779					1, 361	1, 779	180	22, 000	1, 017	3, 808	5
	1, 600	3, 200					1, 600	3, 200	80	17, 000	800	3, 200	6
5, 399	148, 292	181, 112	45, 556	47, 320			193, 848	228, 432	3, 357	432, 525	109, 296	334, 546	
7, 276	10, 618	20, 273	156, 082	99, 445	127, 261	86, 891	166, 700	119, 718			95, 685	235, 915	1
400	13, 400	6, 700					13, 400	6, 700			7, 000	13, 000	2
2			1, 012	253			1, 012	253			506	936	3
5, 366	155, 453	142, 318					155, 453	142, 318	2, 345	470, 000	98, 154	212, 102	4
30			750	100			750	100	443	15, 000	400	1, 200	5
11, 000	85, 000	78, 500					85, 000	78, 500	400	34, 500	51, 950	110, 884	6
810			16, 200	4, 050	16, 200	4, 050	16, 200	4, 050	300	26, 000	10, 800	13, 500	7
													8
127, 867	1, 907, 999	935, 654	2, 280	1, 140			1, 910, 279	936, 794	20, 856	5, 739, 450	1, 260, 440	2, 067, 876	9
									175	25, 000			10
296			7, 500	3, 750	7, 500	3, 750	7, 500	3, 750			3, 941	20, 651	11
1, 190			53, 777	67, 221	53, 777	67, 221	53, 777	67, 221			33, 572	100, 716	12
100			2, 200	550			2, 200	550			1, 200	2, 400	13
55, 512	972, 499	603, 272	223, 325	68, 079	391, 975	264, 669	1, 195, 824	671, 351	7, 753	3, 111, 500	753, 501	1, 410, 946	14
209, 849	3, 144, 969	1, 786, 717	463, 126	244, 588	596, 713	426, 581	3, 608, 095	2, 031, 305	32, 272	9, 421, 450	2, 317, 149	4, 190, 136	
4, 500	21, 600	7, 200	98, 400	49, 000	98, 400	49, 000	120, 000	56, 200	4, 000	240, 000	60, 000	120, 000	1
2, 092	19, 311	27, 937			12, 211	13, 737	19, 311	27, 937	39, 383	120, 101	11, 675	42, 493	2
1, 500	40, 000	40, 000					40, 000	40, 000	5, 000	210, 000	20, 000	50, 000	3
8, 092	80, 911	75, 137	98, 400	49, 000	110, 611	62, 737	179, 311	124, 137	48, 383	570, 101	91, 675	212, 493	
													1
													2
1, 320	88, 769	84, 444					88, 769	84, 444	16, 000	519, 715	57, 943	127, 588	1
160			4, 200	2, 100			4, 200	2, 100			2, 800	4, 000	2
90	2, 180	2, 000					2, 180	2, 000	60	13, 750	1, 200	3, 000	3
1, 450	49, 831	44, 600	3, 500	2, 800			53, 331	47, 400	5, 330	320, 000	33, 777	82, 000	4
3, 020	140, 780	131, 044	7, 700	4, 900			148, 480	135, 944	21, 391	853, 465	95, 720	216, 588	

TABLE III.—STATISTICS OF THE COKE WORKS OF THE

	States and counties.	Number of establishments.	Capital invested in coke works and employed in coke business.	Number of ovens built.					Number of ovens building.					Number of employés.					Total wages paid in manufacturing coke.
				Bee-hive.	Belgian.	Other forms.	Pits or mounds.	Total.	Bee-hive.	Belgian.	Other forms.	Pits or mounds.	Total.	Males over 16.	Females over 15.	Males under 16.	Females under 15.	Total.	
	The United States.	9	$248,700	304	49	......	......	353	21	......	......	......	21	2	......	......	......	2	$910
	ILLINOIS.																		
1	Saint Clair	1	100,000	......	24	......	......	24	......	......	......	......	......	2	......	......	......	2	910
	INDIANA.																		
1	Fountain	1	......	......	25	......	......	25	......	......	......	......	......	......	......	......	......	......	......
	PENNSYLVANIA.																		
1	Allegheny	1	20,000	24	......	......	......	24	......	......	......	......	......	......	......	......	......	......	......
2	Clarion	1	21,200	30	......	......	......	30	......	......	......	......	......	......	......	......	......	......	......
3	Fayette	1	65,000	127	......	......	......	127	......	......	......	......	......	......	......	......	......	......	......
4	Lawrence	1	2,500	18	......	......	......	18	......	......	......	......	......	......	......	......	......	......	......
5	Westmoreland	1	10,000	20	......	......	......	20	......	......	......	......	......	......	......	......	......	......	......
	Total	5	118,700	219	......	......	......	219	......	......	......	......	......	......	......	......	......	......	......
	VIRGINIA.																		
1	Alleghany	1	30,000	83	......	......	......	83	21	......	......	......	21	......	......	......	......	......	......
2	Henrico	1	......	2	......	......	......	2	......	......	......	......	......	......	......	......	......	......	......
	Total	2	30,000	85	......	......	......	85	21	......	......	......	21	......	......	......	......	......	......

TABLE IV.—STATISTICS OF THE COKE WORKS OF THE

	States and counties.	Number of establishments.	Capital invested in coke works and employed in coke business.	Number of ovens built.					Number of ovens building.					Number of employés.					Total wages paid in manufacturing coke.
				Bee-hive.	Belgian.	Other forms.	Pits or mounds.	Total.	Bee-hive.	Belgian.	Other forms.	Pits or mounds.	Total.	Males over 16.	Females over 15.	Males under 16.	Females under 15.	Total.	
	The United States.	13	$526,500	......	......	......	......	......	1,287	......	80	......	1,367	......	......	......	......	......	......
	ALABAMA.																		
1	Jefferson	1	29,000	......	......	......	......	......	100	......	......	......	100	......	......	......	......	......	......
	ILLINOIS.																		
1	Jackson	1	75,000	......	......	......	......	......	......	......	80	......	80	......	......	......	......	......	......
	PENNSYLVANIA.																		
1	Allegheny	1	14,500	......	......	......	......	......	20	......	......	......	20	......	......	......	......	......	......
2	Armstrong	1	25,000	......	......	......	......	......	66	......	......	......	66	......	......	......	......	......	......
3	Clearfield	1	25,000	......	......	......	......	......	60	......	......	......	60	......	......	......	......	......	......
4	Fayette	4	230,000	......	......	......	......	......	800	......	......	......	800	......	......	......	......	......	......
5	Jefferson	1	10,000	......	......	......	......	......	31	......	......	......	31	......	......	......	......	......	......
6	Westmoreland	2	80,000	......	......	......	......	......	150	......	......	......	150	......	......	......	......	......	......
	Total	10	384,500	......	......	......	......	......	1,127	......	......	......	1,127	......	......	......	......	......	......
	WEST VIRGINIA.																		
1	Fayette	1	38,000	......	......	......	......	......	60	......	......	......	60	......	......	......	......	......	......

UNITED STATES IDLE AT THE CENSUS OF 1880.

Value of materials other than coal.	COAL USED.		SLACK USED.		WASHED COAL USED.		TOTAL COAL AND SLACK USED.		COAL PROPERTY.		COKE PRODUCED.		
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Acres.	Capital.	Tons.	Value.	
....	....	....	....	....	....	....	....	....	1,550	$296,500	....	....	
....	....	....	....	....	....	....	....	....	....	....	....	....	1
....	....	....	....	....	....	....	....	....	....	....	....	....	1
....	....	....	....	....	....	....	....	....	....	....	....	....	1
....	....	....	....	....	....	....	....	....	300	26,000	....	....	2
....	....	....	....	....	....	....	....	....	400	55,500	....	....	3
....	....	....	....	....	....	....	....	....	....	....	....	....	4
....	....	....	....	....	....	....	....	....	850	215,000	....	....	5
....	....	....	....	....	....	....	....	....	1,550	296,500	....	....	
....	....	....	....	....	....	....	....	....	....	....	....	....	1
....	....	....	....	....	....	....	....	....	....	....	....	....	2
....	....	....	....	....	....	....	....	....	....	....	....	....	

UNITED STATES BUILDING AT THE CENSUS OF 1880.

Value of materials other than coal.	COAL USED.		SLACK USED.		WASHED COAL USED.		TOTAL COAL AND SLACK USED.		COAL PROPERTY.		COKE PRODUCED.		
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Acres.	Capital.	Tons.	Value.	
....	....	....	....	....	....	....	....	....	16,211	$1,860,000	....	....	
....	....	....	....	....	....	....	....	....	4,000	40,000	....	....	1
....	....	....	....	....	....	....	....	....	....	....	....	....	1
....	....	....	....	....	....	....	....	....	....	....	....	....	1
....	....	....	....	....	....	....	....	....	....	....	....	....	2
....	....	....	....	....	....	....	....	....	....	....	....	....	3
....	....	....	....	....	....	....	....	....	10,823	1,600,000	....	....	4
....	....	....	....	....	....	....	....	....	175	25,000	....	....	5
....	....	....	....	....	....	....	....	....	213	95,000	....	....	6
....	....	....	....	....	....	....	....	....	11,211	1,720,000	....	....	
....	....	....	....	....	....	....	....	....	1,000	100,000	....	....	1

RELATION OF COST OF COKE TO SELLING PRICE.

In the accompanying table will be found the average selling price of coke per ton in the United States and in each state, and the value of the different elements of cost so far as the data for the same have been collected and are ascertainable:

States.	Coke produced. Tons.	Coke produced. Value.	Value of coal used.	Total wages paid.	Value of materials used other than coal.	Selling price of coke. Average per ton.	Selling price of coke. Range of prices per ton.	Wages per ton of coke. Average per ton.	Wages per ton of coke. Range per ton.	Value of coal required to make a ton of coke.	Value of materials other than coal per ton of coke.
The United States	2,752,475	$5,359,489	$2,761,657	$1,198,654	$233,784	$1 95	$1 00 to $5 24	$0 44	$0 20 to $1 30	$1 00	$0 08
Alabama	42,035	148,026	75,314	38,500	1,304	3 52	3 50 to 4 00	92	56 to 93	1 79	03
Colorado	18,000	90,000	29,500	13,500	600	5 00	5 00	75	75	1 64	03
Georgia	70,000	140,000	120,000	13,837	4,900	2 00	2 00	20	20	1 71	07
Illinois	7,600	24,700	15,000	9,347	420	3 25	3 25	1 23	1 24	1 97	06
Indiana	1,000	3,000	2,025	300	200	3 00	3 00	30	30	2 03	20
Ohio	109,296	334,546	228,432	51,977	5,399	3 06	1 75 to 4 00	48	30 to 1 20	2 01	05
Pennsylvania	2,317,149	4,190,136	2,031,305	983,431	209,849	1 81	1 00 to 5 24	42	23 to 1 30	88	09
Tennessee	91,675	212,493	124,137	38,820	8,092	2 32	2 00 to 4 74	42	35 to 77	1 35	09
West Virginia	95,720	216,588	135,944	48,942	3,020	2 26	1 50 to 4 00	51	37 to 71	1 42	03

In considering these figures it should be most carefully noted that all the elements of the cost of coke are not given. No attempt was made to ascertain all these items, and my experience in other positions convinces me that any such attempt would have been an utter failure. The average business man will not give to his competitors, much less to the whole world, all the details of the cost of manufacture, nor indeed such details as will enable others to approximate, with any degree of accuracy, his cost, and therefore how much or how little profit he is making. This should not be expected.

The only elements of cost given are wages and material. Among the elements of cost of a ton of coke which are not given are interest, taxes, insurance, collections, postage, rents, general office expenses, expense of selling, bad debts, and many other items, and in most cases the hauling of coal from the pit to the ovens, washing, profit chargeable on coal, etc.

With these considerations in mind the following table should not be misleading:

States.	Average selling price of ton of coke.	Average cost of labor and material to ton of coke. Coal.	Other material.	Wages.	Total.
The United States	$1 95	$1 00	$0 08	$0 44	$1 52
Alabama	3 52	1 79	03	92	2 74
Colorado	5 00	1 64	03	75	2 42
Georgia	2 00	1 71	07	20	1 98
Illinois	3 25	1 97	06	1 23	3 26
Indiana	3 00	2 03	20	30	2 53
Ohio	3 06	2 01	05	48	2 54
Pennsylvania	1 81	88	09	42	1 39
Tennessee	2 32	1 35	09	42	1 86
West Virginia	2 26	1 42	03	51	1 96

PART II.—COKING IN THE UNITED STATES.

THE COAL-FIELDS AND COAL OF THE UNITED STATES IN THEIR RELATION TO THE MANUFACTURE OF COKE IN THE CENSUS YEAR.

A discussion at any length of the geological features of the several coal-basins of the United States, or even of the geology of the coking coal, does not lie within the scope of this report, nor will an attempt be made to establish the correlation of the different seams of coal used in coking in the several states. All of these subjects belong more properly to the report on coal, and will be referred to and discussed in this report only incidentally. Neither will it fall within the plan adopted to show, save in the most general way, the extent of the deposits of coking coal nor the character of these deposits, except of such as furnished coal for the manufacture of coke during the census year.

The coal used in the manufacture of coke at the census of 1880 represented three of the great coal-basins or coal-fields of the country, the Appalachian, the Illinois, and the Colorado. By far the larger part was derived from the measures of the great Appalachian field, less than 1 per cent. of the total coming from the Illinois and Colorado basins.

This Appalachian basin is at present the most important of the coal-fields of America. Beginning near the northern boundary of Pennsylvania, it extends for a distance of over 750 miles in a southwesterly direction, following the western line of the Allegheny mountains with a course nearly parallel to the Atlantic ocean coast line, through western Pennsylvania, West Virginia, Kentucky, Tennessee, Georgia, and Alabama, to Tuscaloosa, Alabama, where it ends. The average breadth of the field is from 80 to 90 miles, the area being fully 70,000 square miles.

The eastern escarpment of the Allegheny mountains formed, and still forms, the eastern border of this basin, while the great Cincinnati anticlinal hemmed it in on the west and separated it from the measures of the Illinois basin. The eastern line of this field is comparatively regular, following the trend of the mountains; but the western is very irregular, the basin being quite broad in its northern area, contracting through Tennessee and northern Alabama and expanding considerably at its termination in Alabama, though by no means so broad as in Pennsylvania, Ohio, and West Virginia.

In the northern part of this basin the coal is found in numerous isolated patches, the chief of which are the Blossburg, McIntyre, and Barclay. Between the eastern edge and the ocean other detached fields are found, such as the anthracite coal-fields of northeastern Pennsylvania, the Broad Top semi-bituminous coal-field of middle Pennsylvania, and the Cumberland coal-basin of Maryland. These patches are all that have been left by the denuding agencies which have swept away so much of the Devonian and Silurian rocks and cut so deeply and sharply, and at the same time so destructively, into these measures in this belt of country.

Along nearly the entire length of this great field, from Blossburg, Pennsylvania, on the north, to Birmingham, Alabama, on the south, the coke industry has been established. The ovens, following the zone of best coking coal, are generally found near the eastern limits of the field, hugging the mountains, the coal in the middle or western part of the basin being, as a rule, not so well adapted to coking as that in the eastern.

The greatest development in the manufacture of coke is in the Connellsville region of western Pennsylvania, a small trough 50 or 60 miles long by 3 miles wide. The Connellsville coke is regarded as the typical coke of this country, as the Durham is of England. Some other regions in this field may produce a coke equal to the Connellsville, but as a blast-furnace fuel especially, which is the purpose to which most coke is put, it is so well adapted, its use is so extensive, and its characteristics so well known, that it fully deserves the designation "typical". Coke is made at other points in Pennsylvania, especially in the Allegheny Mountain region, in the Ligonier valley, and near Pittsburgh. As a rule, none of these cokes equal the Connellsville. In some cases the cokes are lower in ash but inferior in physical structure, while in others washing is necessary to produce a fuel for blast-furnace uses.

In West Virginia the New River coal furnishes the most and also the best coke. Analysis shows it to be lower in ash than the Connellsville, and its producers assert that it is fully equal to it as a blast-furnace fuel; but this is by no means conceded. The Preston County beds, which are regarded as the equivalent of the Ligonier Valley coal of Pennsylvania, are also used to a considerable extent, but the coke is not equal to the New River coke.

In Ohio most of the coals are coking coals, but the deposits are much thinner than in either Pennsylvania or West Virginia, and generally, though not always, contain an objectionable amount of sulphur. The coals are coked only to a limited extent; and the manufacture of coke is not increasing as rapidly as in Pennsylvania, West Virginia, and Alabama.

In Tennessee the Sewanee seam furnishes most of the coke, while in Alabama coals from both the Warrior and the Cahaba fields were coked, furnishing a most excellent fuel. The extreme eastern outcrop of the Appalachian basin cuts the northwestern corner of the state of Georgia, furnishing a small patch of coking coal, from which some coke was made in the census year.

Two important facts regarding the character of the coal in this Appalachian field have been pointed out. These are the debituminization eastwardly of the coal and the similarity of the composition of the coals in the same basin. These laws are of considerable importance in connection with the coke industry, the one indicating generally the location of the seams of best coking coal, the other bearing on the future supply of this coal. (*a*)

The fact of the debituminization of the coals eastwardly has been pointed out by Professor Rogers. Whether this has been accomplished by the heat evolved by the dynamic crust-flexing force or by conditions in the coal flora is immaterial in this connection. Certain it is that the most abnormal condition of the coal is found in the extreme eastward coal-fields, in the natural coke or anthracite coal. From this anthracite range westward the bituminous element in the coal-beds increases gradually until the zone of full pitchy or gaseous coal is reached in the vicinity of Pittsburgh.

The following analyses exhibit these extremes:

	Per cent. of bituminous.	Per cent. of anthracite.
Fixed carbon, (MM, p. 17, No. 180) (*b*)	48.769	89.06
Volatile matter	40.995	3.45
Ash	7.020	5.81
Sulphur	2.206	0.30
Phosphorus	......	0.024
Moisture	1.010	1.35

The following table shows the increase westwardly of volatile or hydrogenous matter in the Upper Coal-Measures (McCreath):

Coal-fields.	Moisture.	Carbon.	Volatile matter.	Ash.	Sulphur.	Reports Pennsylvania Second Geological Survey.
Anthracite	1.35	89.06	3.45	5.81	0.30	L, p. 133.
Cumberland	0.893	74.289	15.522	9.296	0.714	H 3, p. 101.
Salisbury	1.665	68.774	22.35	5.965	1.246	
Connellsville	1.26	59.52	30.11	8.23	0.78	
Greensburgh	1.02	61.34	33.50	3.28	0.86	MM, pp. 23, 24.
Irwin	1.41	54.44	37.66	5.86	0.64	MM, p. 22.

This table leaves a gap of 30 miles between Salisbury and Connellsville without analysis of the great Pittsburgh bed, the Upper Coal-Measures, including the great Pittsburgh bed, having been swept away with the exception of the Salisbury and Fairfield basins, from a belt of 35 miles broad, west of the Allegheny mountains.

The following table shows the character of the Lower Coal Series in the Allegheny field (McCreath):

Coal-fields.	Moisture.	Carbon.	Volatile matter.	Ash.	Sulphur.	Reports Pennsylvania Second Geological Survey.
Anthracite	1.35	89.06	3.45	5.81	0.30	
Broad Top	0.77	73.34	18.18	6.69	1.02	
Bennington	1.40	61.84	27.23	6.93	2.60	
Johnstown	1.18	74.46	16.54	5.96	1.86	
Blairsville	0.92	62.22	24.36	7.59	4.92	H 4.
Armstrong County	0.96	52.03	38.20	5.14	3.66	M 3, p. 56.

The gradual increase of volatile matter from the Broad Top coal-field of the east to Armstrong county in the west, a distance of about 75 miles, is very marked, showing an increase of 0.267 per mile. Making a comparison of coals from the second bed in the Lower Coal-Measures, bed "B" of the *Second Geological Survey of Pennsylvania*, we find that this bed at Bennington contains 27.23 per cent. of volatile matter, which exceeds its legitimate richness westward 2.38 per cent. At Johnstown, in the second sub-basin, this bed "B" contains 16.54 per cent. of volatile matter, or 10.98 per cent. less than its westward position should afford. This is a remarkable exception to the law of general bituminization of coals westward.

So far as determinations have been made on coals in this second sub-basin north and south of Johnstown, this condition of "dryness" in the coal-bed has been found extended and uniform. How far it may reach northeast and southwest has not been determined.

Blairsville, 55 miles west from Broad Top, has coal containing 24.36 per cent. of volatile matter. This is 8.50 per cent. under its normal richness, showing the broad range of the operation of the causes that have produced these exceptional results. In fact, this Blairsville coal is lower in volatile matter than the coal at Bennington, 30 miles eastward.

a For the following statement I am indebted to Mr. John Fulton, M. E.

b These letters refer to the various reports of the *Second Geological Survey of Pennsylvania*.

Armstrong County coal attains a mature condition, and is constituted with its full share of volatile matter, 38.20 per cent. This last result unfolds a truth that has been clearly pointed out by Professor J. P. Lesley: the similarity of the elements of coals in beds in a common basin. Taking the Salisbury coal as an illustration, and its congener, the Berlin bed, below, in the same geological range, they are constituted as follows:

	Salisbury (Pittsburgh). (HHH, p. 78.) Per cent.	Berlin bed. (HHH, p. 34.) Per cent.
Moisture	1.385	2.010
Fixed carbon	69.352	68.321
Volatile matter	21.470	20.535
Ash	7.030	8.390
Sulphur	0.763	0.744

The slight increase of volatile matter in the higher beds of Salisbury and Johnstown sub-basins has been observed.

The coals in the lower and upper series in the western counties of the state show as follows:

	Pittsburgh bed (M3, p. 56). Per cent.	Kittanning coal. Per cent.
Water	0.800	0.96
Volatile matter	36.900	38.20
Fixed carbon	50.230	52.03
Sulphur	3.040	3.66
Ash	9.030	5.14

These results confirm the view of the uniformity in elementary matter in coal-beds in the same basins, with slight variations.

The importance of this law will appear when the future supply of coking coals shall be considered.

The coal-measures of the Illinois basin very nearly equal in area those of the Appalachian basin, covering about 47,188 square miles, (*a*) but they by no means equal the latter in the character of their coking coal. This basin occupies the larger part of the state of Illinois, the southwestern portion of Indiana, and the western part of Kentucky. Its eastern limit is the rocks of the Cincinnati axis, which separate it from the Appalachian basin, while its western margin is formed by the bed of the Mississippi river, which has been excavated through it and separates it from the Missouri basin. The beds of coal in the Illinois field are not as thick as in either the Appalachian or the Missouri basin, though their number is about the same as in the former. "The coals themselves are more apt to be impure," (*b*) being high in sulphur and ash. This is not uniformly the case, however, as will be evident from an inspection of the analyses of the Big Muddy and Cartersville coals of southwestern Illinois. The character of the coals of this basin, and the difficulty of adapting them to the manufacture of coke, is shown in the fact that but 8,600 tons of coke were made from them in the census year. At present (1880) the successful manufacture of coke in the Illinois basin is confined to the two localities in southwestern Illinois mentioned above: Mount Carbon and Cartersville.

In Indiana the coals of the "eastern zone" of Professor Cox's reports, or the lower measures, are non-coking, being the well-known block coal of the state, which can be used raw in smelting iron. The "western zone", or upper measures, which are much more extensiv ethan the lower, contain deposits of good coking coal, generally, however, so far as they have been tried for making coke, high in ash and sulphur.

The coals of the northern part of this basin in Illinois are too sulphurous to make good coke, but in the southwestern part of the state there are several small deposits of quite pure coal, which, although dry-burning, makes a very good coke when crushed, washed, and charged wet. The portion of this field lying in Kentucky, like that part of the Appalachian field lying in the same state, has not been utilized for the manufacture of coke.

But little is known of the extent of the coking coal in what I have termed, for want of a better name, the Colorado basin; but from the coal mines of the Trinidad region, which are the highest above the sea-level worked in the country, some coke was made in the census year. For many years it was believed that all the coals of this section were lignites or brown coal; and speaking as late as 1875 Professor Hayden says of this region:

According to Dana's classification, I should term these coals *caking or binding bituminous coal.* The term *lignite* is generally used, but speaking from the strict standpoint of a mineralogist this name is not applicable.

The term "lignite" applied to these coals has no doubt given a widespread but erroneous idea as to their character, which the success of the Colorado Coal and Iron Company in coking them has entirely removed. There are other extensive beds of coking coal in this region, but little is known of them except of the most general character.

Of the adaptability of the coals of the other basins of the country to the manufacture of coke, our information, so far as relates to actual attempts on a commercial scale, is very limited. The coal of the Rhode Island basin is anthracite, and is a natural coke. In the Missouri basin some coke has been made in Iowa, and it is rumored that

a *Statistical Atlas of the United States*, page 12. Some authorities make this 68,000. *b* *Ibid.*, page 13.

some ovens have been built to test the coal of this basin in Missouri. The coals of the Michigan basin are reported as not being adapted to coking. No trials have been made of the coals of the Texas basin, and but little is known of them. A number of trials have been made with Utah coal, and there is said to be a number of deposits of good coking coal in that territory.

In the following table will be found analyses of a number of the most important coking coals of the United States, and the oven cokes made from the same. These all appear in the remarks regarding coking in the different states, and are brought together here for convenience of reference and comparison. The cokes are supposed to be industrial cokes, unless it is stated otherwise:

Districts or localities.	Mine or seam.	COAL.					COKE.					Authorities or chemists.
		Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Moisture.	Carbon.	Ash.	Sulphur.	Moisture.	Volatile matter.	
PENNSYLVANIA.		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	
Connellsville	Broad Ford	30.107	59.616	8.233	0.784	1.260	89.576	9.113	0.821	0.030	0.460	McCreath.
Do	Coketon *	21.850	65.720	11.710	0.700	....	89.150	9.650	1.200	....	....	B. Crowther.
Irwin's	Penn Gas Coal†	38.130	54.880	6.980	0.960	....	88.240	9.414	0.962	....	1.384	Carnegie Bros. & Co.
Allegheny Mountain.	Bennington "B"	27.225	61.843	6.930	2.602	1.400	87.580	11.360	1.060	......	....	McCreath.
Do	Lilly's Station "E"	22.250	70.518	5.058	1.459	0.715	....	....	....	....	....	Do.
Blossburg	Arnot, Seymour vein ‡	21.586	71.574	4.753	0.907	1.180	84.760	13.345	0.998	0.175	0.722	Do.
Allegheny River	Lower Freeport †	35.825	54.223	7.340	1.312	1.300	85.777	11.463	2.107	0.330	0.623	Do.
Beaver county	Hulmes & Bro. ‡	38.110	54.619	4.080	0.791	2.400	84.727	12.636	1.994	0.100	0.633	Do.
WEST VIRGINIA.												
New River	Quinnimont	18.190	75.890	4.680	0.300	0.940	93.850	5.850	0.300	....	....	J. B. Britton,
Do	Fire Creek	22.340	75.020	1.470	0.560	0.610	92.180	6.680	0.618	0.110	....	Coal, Dr. Ricketts; coke, J. B. Britton.
Do	Longdale	21.380	72.320	5.270	0.270	1.030	93.000	6.730	0.270	....	....	C. E. Dwight.
Do	Nuttallburg	29.590	69.000	1.070	0.780	0.340	92.220	7.530	0.910	....	....	Do.
OHIO.												
Leetonia	Washingtonville	39.600	56.040	1.800	0.530	2.560	93.750	5.380	0.870	....	....	Professor Wormley.
Steubenville	Shaft Coal	30.900	65.900	1.800	0.980	1.400	90.630	8.380	0.270	....	....	Coal, Professor Wormley; coke, Dr. Wuth.
TENNESSEE.												
Tracy City	Sewanee	29.300	61.000	7.800	Trace	1.600	83.364	15.440	0.142	....	....	Coal, Robertson; coke. Land.
Whiteside	Kelly	21.100	74.200	2.700	0.700	1.300	94.560	4.650	0.790	....	....	Coal, Professor Shale; coke, Etna Coal Company.
Rockwood	Roane Iron Company's	26.620	63.740	7.820	0.330	1.490	84.187	14.141	0.182	....	....	Land.
ALABAMA.												
Warrior Field	Pratt seam	31.480	61.600	5.416	0.918	1.508	88.224	11.315	0.563	0.362	0.990	Professor McCalley.
Cahaba	Helena	34.370	59.580	6.050	0.660	....	84.035	15.216	0.445	0.683	0.660	Coal, Eureka Iron Company; coke, Professor McCalley.
ILLINOIS.												
Big Muddy	Mount Carbon	31.930	59.130	1.810	0.760	6.370	88.180	10.070	0.610	....	0.930	Coal, Robertson; coke, Thos. M. Williamson.
COLORADO.												
El Moro	El Moro	38.230	55.860	3.590	....	1.320	87.470	10.680	0.850	1.850		
Crested Buttes	Crested Buttes	23.200	72.600	3.100	....	1.100	92.030	6.620	....	1.350		

* Average of top and bottom of vein.
† Analysis is of washed slack and coke from same.
‡ The coal is "run of mine"; the coke is made from washed slack.

HISTORY OF THE MANUFACTURE OF COKE IN THE UNITED STATES.

The first date I have been able to find at which it is claimed that coke was used in this country is that given in French's history of the iron trade, (*a*) which states that coke was employed a few years before the Revolution in the manufacture of pig- and refined bar-iron.

While this is possible, it is hardly probable that coke was used in the blast-furnaces and refineries of this country at this early date. It was not until 1735 (*b*) that Darby used coke successfully at Coalbrookdale, in Shropshire, England, and it was not until 1750 that it came into anything like general use in that country as a blast-furnace fuel. The repeal by the British parliament in 1750 of the import duty on pig-iron from the American colonies stimulated its production in this country, but it was the scarcity of wood for fuel in Great Britain that led to this action, and it was charcoal pig-iron, not coke pig, to supply the demand of English iron works, that was sought for export. It

a *History of the Rise and Progress of the Iron Trade of the United States*, by B. F. French (New York, 1858), page 58.
b See chapter on "History of Coke in England" for difference among authorities as to this date.

is hardly probable that there would be any demand for foreign coke-iron in England at that time, especially at the price at which it could be made in America and transported to the British iron works. Even charcoal pig-iron could hardly have been exported with profit were it not for its comparatively high price in England, caused by the scarcity of wood fuel. The great abundance of wood in this country—large tracts being burned for the ashes—and the fact that coal suitable for coking, if it existed at all, was found only to a limited extent in that portion of the country in which iron was made prior to the Revolution, would seem to preclude the idea that coke was used for the manufacture of pig-iron, as stated by French. When, in addition to this, we recall the imperfect knowledge of the method of manufacture and use of coke in this country, the difficulties of transportation, and the prejudice in favor of charcoal iron, it would seem, in the absence of other and more definite information, that French's statement must be wrong.

With the close of the Revolution and the subsequent emigration from England numbers of skilled iron workers found their way to this country notwithstanding the stringent laws against such emigration and the heavy penalties imposed upon those discovered in the attempt to emigrate. Among these workers were doubtless some skilled in the manufacture and the use of coke. This supposition is borne out by an advertisement which appeared in the Pittsburgh *Mercury* of May 27, 1813, in which one of these emigrants offers his services to instruct blast-furnace managers in the method of manufacturing coal into coke. The advertisement was as follows:

To proprietors of blast-furnaces:

John Beal, lately from England, being informed that all the blast-furnaces are in the habit of melting iron ore with charcoal, and knowing the great disadvantage it is to proprietors, is induced to offer his services to instruct them in the method of converting stone coal into *coak*. The advantage of using coak will be so great that it cannot fail becoming general if put to practice. He flatters himself that he has had all the experience that is necessary in the above branch to give satisfaction to those who feel inclined to alter their mode of melting their ore. JOHN BEAL, *Iron Founder.*

N. B.—A line directed to the subscriber, postpaid, will be duly attended to.

I have been unable to learn whether Mr. Beal's proposition was accepted.

Shortly after this, however, in 1816–'17, Colonel Isaac Meason built the first rolling-mill erected west of the Allegheny mountains, to puddle iron and roll iron bars, at Plumsock, in Fayette county, Pennsylvania. At this mill, which went into operation September, 1817, coke was used in the refinery. This is the first definite statement that I have been able to find of the use of coke in this country. It is an interesting fact that it was made on Redstone creek, about midway between Connellsville and Brownsville, in Fayette county, the county that produced the largest number of tons of coke in the last census year.

This mill was built under the direction of Mr. Thomas C. Lewis, one of the English emigrant iron-workers before referred to. The next notice I have been able to find of the use of coke was at a blast-furnace built under his management, the Bear Creek furnace, situated in Armstrong county, Pennsylvania, one mile from Lawrenceburg, the present Parker's Landing. This furnace was built to use coke, and went into operation in 1819. It was unsuccessful, however, the blast being too weak, and the furnace chilled after making two or three tons of iron, and the attempt to use coke was probably abandoned.

The rapid disappearance of the forests of Pennsylvania and the abundant deposits of bituminous coal caused widespread attention to be given to the use of coke in the manufacture of pig-iron, and during the next few years attempts were made in the western part of that state to utilize bituminous coal for this purpose. In 1825 the acting committee of the Pennsylvania Society for the Promotion of Internal Improvement sent Mr. William Strickland to England as their agent to study various subjects relating to internal improvements, and also charged him with investigating the methods employed in the manufacture of iron, allowing him £100 for expenses of the iron investigation.

In their letter of instruction to Mr. Strickland the committee say: (*a*)

Attempts of the most costly kind have been made to use the coal of the western part of our state in the production of iron. Furnaces have been constructed according to the plan said to be adopted in Wales and elsewhere; persons claiming experience in the business have been employed, but all has been unsuccessful. In large sections of our state ore of the finest quality, coal in the utmost abundance, limestone of the best kind, lie in immediate contiguity, and water-power is within the shortest distance of these mines of future wealth. The prices which are obtained for iron on the western waters are double those of England, the demand is always greater than the supply, and thus nothing but knowledge of the art of using these rich possessions is wanted.

We desire your attention to the following inquiries on the subject of the manufacture of iron:

1. What is the most approved and frequent process for coking coal, and what is the expense of the process per ton or caldren?

2. In what manner are the arrangements or buildings, if any, constructed for the coking of coal, obtaining drawings and profiles thereof?

3. Are there different modes for coking coal; and if they have any differences in principle, what are they?

4. In what manner are the most approved furnaces for the smelting of ore constructed? Drawings and sections of the same to accompany the information which may be obtained upon this inquiry.

5. The mode of drawing off the pigs, the plan adopted for keeping supply of ores, if peculiar or superior to that used in this country?

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a The First Annual Report of the Acting Committee of the Society for the Promotion of Internal Improvement in the Commonwealth of Pennsylvania (Philadelphia, 1826), pages 37, 38.

The report was signed by Matthew Carey and others, who were well acquainted with the state of the iron industry at that time, and indicates that before 1825 coke had been used in the blast-furnaces of western Pennsylvania, as the reference in the first paragraph could hardly have been to the use of raw coal. This probability is strengthened by a passage referring to the investigations of their agent. In 1825 Mr. Strickland forwarded a complete statement as to the method of making coke in England. In the first annual report, before quoted, occurs the following on this subject: (*a*)

The next report received from Mr. Strickland was dated the 16th of June, 1825, which, as far as its contents are connected with railways, may be considered as a supplement to the first report. It contains "a description of the Duke of Portland's tram-road", and a very particular account of the mode of coking bituminous coal and of making cast and blister steel. The drawings, which form a part of this report, exhibit in detail the processes which are in successful use in England for the production and manufacture of the articles mentioned. To those sections of our country where bituminous coal abounds, and where no method of coking it for the purposes of smelting iron has yet been in successful operation, the plans of the ovens, by which this process is accomplished, may be essentially important; and the information communicated upon this grand desideratum in the making of iron in western Pennsylvania may be employed to remove the difficulties which have hitherto baffled all the efforts of those who have endeavored to use that coal in their smelting-furnaces.

This certainly indicates that attempts to use coke in smelting iron in western Pennsylvania had certainly been made prior to 1825, and gives color of probability to the statements made in the *History of Fayette County.*

There can be no doubt that these reports of Mr. Strickland had much to do with the experiments that shortly after their publication began to be made in the use of coke in blast-furnaces in various parts of Pennsylvania, and its advantage as a fuel for iron-smelting at last attracted the attention of the legislature of the state. In a report on coal made by a committee of the Pennsylvania senate, of which the Hon. S. J. Packer was chairman, and read in the senate March 4, 1834, it was stated that—

The coking process is now understood, and our bituminous coal is quite as susceptible of this preparation and produces as good coke as that of Great Britain. It is now used to a considerable extent by our iron manufacturers in Centre county and elsewhere.

I have not been able to learn any of the details of the use of coke in the furnaces referred to by Mr. Packer. Mr. James M. Swank (*b*), in his report on iron and steel, expresses the opinion that at the time Mr. Packer wrote his report coke could not have been used in blast-furnaces in any other way than as a mixture with charcoal, and then only experimentally; but it is probable, in view of the attention that had been given to the subject and the publication of Mr. Strickland's report, that attempts had been made to use coke alone. (*c*)

In 1835 the Franklin Institute of Pennsylvania offered a premium of a gold medal to "the person who shall manufacture in the United States the greatest quantity of iron from the ore during the year, using no other fuel than bituminous coal or coke, the quantity to be not less than 20 tons". The phraseology of this offer would lead to the belief that coke had before this been used in the manufacture of iron, as Mr. Packer states; but the best results obtained had been in connection with other fuels, as the offer of the Institute is for "iron made by the use of no other fuel than bituminous coal or coke". This would also seem to indicate that in the experiments made, if they had been made with coke only as a fuel, even so small a quantity as 20 tons of pig-iron had never been made with this fuel.

In the same year that this offer was made Mr. William Firmstone was successful in making good gray forge iron for about one month at the Mary Ann furnace, in Huntingdon county, Pennsylvania, with coke made from Broad Top coal.

Mr. Isaac Fisher, of Lewiston, Pennsylvania, who states in a pamphlet published in April, 1836, that "successful experiments have lately been tried in Pennsylvania in making pig-iron of coke", probably had Mr. Firmstone's experiment in mind. Mr. Firmstone is doubtless entitled to the honor of having been the first successful manufacturer in this country of coke pig-iron. It is also interesting to note that his blast was just one hundred years after the date usually assigned to Darby's successful use of coke in England.

In 1836 or 1837 F. H. Oliphant made at his Fairchance furnace, near Uniontown, Fayette county, Pennsylvania, a considerable quantity of coke-iron, probably more than 100 tons, and in a letter to the Franklin Institute, dated October 3, 1837, Mr. Oliphant suggests that possibly he was entitled to the premium offered by them. Accompanying his letter was a piece of pig-iron and samples of the raw material from which it was made. Mr. Oliphant, however, did not continue the manufacture of iron with coke, but returned to the use of charcoal as a fuel.

Between 1836 and 1839 other attempts were made to use coke at Pennsylvania furnaces, but they were unsuccessful or unfortunate. (*d*) The legislature of Pennsylvania, June 16, 1836, passed an act to encourage the manufacture of iron with coke or mineral coal, which gave the governor authority to charter companies, with ample

a *The First Annual Report of the Acting Committee of the Society for the Promotion of Internal Improvement in the Commonwealth of Pennsylvania*, page 20.

b *Statistics of the Iron and Steel Production of the United States*, James M. Swank (Tenth Census), p. 143.

c *The History of Fayette County, Pennsylvania*, page 242, states that coke was made and used at the Allegheny furnace, Blair county, Pennsylvania, in 1811, and speaks of this as authenticated. If this is correct, it was an earlier use of coke than that mentioned at the Plumsock refinery. The same work also states that the Howard furnace, in Blair county, put in operation in 1830, and the Elizabeth furnace, built in the same county in 1832, were constructed with a view to the use of coke, and furnaces in Clearfield, Clinton, Lycoming, and Armstrong counties, Pennsylvania, erected between 1835 and 1838, made repeated attempts at the manufacture of coke-iron, all of which resulted in failure, from the fact that cold blast was used and at a very low pressure. I have not been able to verify these statements, and give them solely on the authority of the work referred to.

d Attempts were also made in Ohio, which will be spoken of in another part of this chapter.

powers for the purpose of prosecuting this branch of industry. At Farrandsville, in Clinton county, coke was used to a considerable extent from 1837 to 1839, about 3,500 tons of pig-iron being made. The manufacture was abandoned, however, owing to the impurity of the coal and the difficulty of transportation. At Karthaus, in Clearfield county, Mr. Peter Ritner succeeded in using coke in making pig-iron as early as 1838, if not in 1834 (*a*). Coke was also used in 1839 in this furnace, but at the close of that year the enterprise was abandoned, owing to the lack of transportation facilities. In Mather's second report of the *Geology of Ohio*, published in 1838, the following statement regarding this furnace is given:

Through the enterprise and perseverance of Mr. Peter Ritner, of Karthaus, Clearfield county, Pennsylvania, the same practice has been introduced into this country, and at the last information was in most successful operation. His experiments were made in a common charcoal stack, 45 feet from the hearth to the trundle-head; diameter at the top, 6 feet; at the boshes, 13 feet; hearth 2 feet 6 inches square. Coke from Phillipsburg was used in the operation, the details of which, relative to consumption, blast, product, etc., have been freely and unreservedly given me by Mr. Ritner:

Bushels of charcoal necessary to make a ton of pig, 200; bushels of coke, 75; charge of coke, 10 bushels, weight 45 pounds per bushel; burden, about one-fourth the charge in weight; blast, 4,000 to 6,000 cubic feet per minute, under a pressure of 2¼ to 2½ pounds to the square inch; yield of furnace, 65 to 70 tons per week; ordinary yield of charcoal stack, 23 to 27. Mr. R. says, under date of August 23, 1838: "As to quality, there can be no doubt of its being as good as that made from coke in any part of the world. It has been tested by the committee appointed by the treasury department to try the strength of boiler-iron, and bore 68,869 pounds to the square inch. We have also caused it to be rolled into bars and plates, and find it an excellent article. Finished bar-iron can be made in this region at a cost not exceeding $35 per ton, and I hope to see the time when it will be.

I am informed of another furnace at Kittanning, Armstrong county, Pennsylvania, now in operation with coke as a fuel.

A furnace at Frozen Run, in Lycoming county, made some coke pig-iron in 1838, but returned to the use of charcoal in 1839.

It was in Maryland, however, that coke was first successfully used for any considerable length of time in blast-furnaces in this country. In 1837 the George's Creek Coal Company built the Lonaconing furnace, 8 miles northwest of Frostburg, Maryland, to use coke, and in June, 1839, according to Johnson, (*b*) it was making about 70 tons per week of good foundery coke-iron. This furnace was 50 feet high by 14½ in the boshes. Its highest yield in a campaign of four months was 92 tons per week; the lowest, 62. In 1840 two large blast-furnaces were built by the Mount Savage Company to use the same fuel. These furnaces were for several years successfully operated with coke. Their success, no doubt, was due to their having been constructed with sufficient blast-power and hot blasts, especially for using coke. The coke made at these furnaces was from the seam of coal known as the Mount Savage fawn-ash coal, containing about 78 per cent. of fixed carbon and 7 per cent. of ash. It also carried quite a large percentage of sulphuret of iron, which greatly injured its value both for furnace and foundery purposes. The coke was made in open pits, as was all the coke produced in Maryland so far as I have been able to learn. Both the rectangular pit and the circular mound were used. The coke produced was hard, bright, and carried a good burden in the furnace, making, it is claimed, a ton of iron with a ton and a quarter of coke. The pressure of blast used in this furnace was from 2¾ to 3½ pounds, and the temperature about the melting point of lead, 612° F. The furnaces were 14 feet boshes by 45 to 50 feet high. No doubt the success of these furnaces in making long blasts was due to their great blowing power, the greatest in the country at the time, and to their hot-blast capacity. Most of the attempts to use coke prior to this had been with the weak blasts of charcoal furnaces, blowing the air into the furnaces cold. The yield of the coal in coke was about 52 per cent. From 1840 to 1850 between 50,000 and 75,000 tons of coke were made at the Mount Savage works, most of which was used at the furnace, but some of it was used at founderies. In the next decade a portion of the coke used was from what is known as the big vein of Alleghany county, but the coke was unsatisfactory. From 1860 to 1870 all the coke made was from another portion of the big vein, which produced a good coke. These furnaces have not been in blast for some years.

In 1845 the Antietam furnace, which was built about 1730 as a charcoal furnace, and which had been several times rebuilt, was again rebuilt and blown in with half coke and half charcoal, running in this way until 1848, when all coke was used. From this time until 1857 short blasts were made, using coke entirely, the coke being chiefly from the Frostburg Coal Company's and the Cumberland Coal and Iron Company's mines, though in the last three or four years part of the coke was made at the furnace. From 1857 to 1867 there was but one short blast, when the present proprietor bought it. From this time until 1879 the coke used was made at the furnace. At its last blast, beginning in 1879, Connellsville coke was used.

As I have indicated, all of the coke made in Maryland was burned in open-air pits, and I have not been able to find the record of the existence of a single oven. During the last few years coke has only been used to utilize the fine coal from the dumps. The last company making coke at Cumberland was the Cumberland Coal and Iron Company, which made some as late as 1878 and 1879, and these were the only parties producing any for a number of years. So far as I have been able to learn, no coke is now made in Maryland.

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a Mr. John Irwin, jr., of Bellefonte, Pennsylvania, writes me that "in the year 1834 Loy & Ritner made some coke-iron at this furnace. The coke was made in pits from a superior vein of bituminous coal, six feet in thickness. I do not remember anything in regard to the quality of the coke. They, however, succeeded in making some pig-iron, but not having means to carry on the business, and being dependent altogether on the uncertain river (Susquehanna) channel to reach a market, they soon abandoned the business".

b See *Anthracite Iron*, by Walter R. Johnson, pages 7 and 8.

While these experiments were in progress in Pennsylvania and Maryland similar ones were being conducted in Ohio. In the *First Annual Report of the Geological Survey of Ohio*, page 18, published in 1838, but submitted at the close of 1837, Professor Mather says:

Coke is now manufactured in Ohio from several of the coal-beds. Hon. Daniel Upson, of Portage county, makes a coke of excellent quality from a coal of his mine in Tallmadgé. Mixed with charcoal, it is used in the high furnace at Akron, in the smelting of iron ore. Mr. Ford, of Akron, by mixing 40 bushels of coke per day with the charcoal, is stated to have increased the quantity of iron smelted 33½ per cent. The coal-bed is from 3 to 5 feet thick, and from 2 to 3 feet of the coal make excellent coke, which is found to be a perfect substitute for anthracite coal in the cupola furnaces.

An analysis of this coal and coke is given in the second report, page 35. (*a*)

In this same report (*b*) Professor Mather, after stating that most of the pig-iron produced in Ohio was smelted with charcoal, notwithstanding the inexhaustible supplies of coal fitted for the manufacture of "coke, or the charcoal of bituminous coal", says:

In my first annual report to this legislature I mentioned that coke was beginning to be used in three of our furnaces. Whether it has increased during the past season I have not been informed, but it is now extensively used for melting iron for castings. Anthracite coal was formerly brought to various parts of this state from Pennsylvania for this purpose; but in consequence of the great expense, coke has been substituted, and is equally effective. One ton of coke will melt from 5 to 10 tons of iron, but 7 tons is considered an average. This variation is due to the greater or less purity of the coal. The coal may be used raw in the furnace, where it cokes itself, or it may be previously coked in a coke oven, or in a heap in the open air. By coking it loses about one-half its weight, but increases about one-fourth its bulk.

In this second report, Mr. Whittlesey, after constantly referring to the possibility of coking the coals of Ohio, showing that the thought of this use was an ever present one, says: (*c*)

The Tallmage coal undergoes this process in the open air without any covering, but it is more economical to use close ovens, in which the refuse and inferior coal may be reduced.

Coke is already in general use in the cupolas throughout the northeastern part of the state; but the great demand for this article must soon come from the manufacture of pig-metal.

Coke, however, did not come into favor rapidly as a furnace fuel. In 1849 there was not a coke-furnace in blast in Pennsylvania. In 1856, however, according to Lesley's *Iron Manufacturers' Guide*, there were 21 furnaces in Pennsylvania and 3 in Maryland using coke, which made in that year: Pennsylvania, 39,953 tons; Maryland, 4,528 tons. The Pennsylvania furnaces were chiefly in what is known in this report as the Allegheny Mountain region. There was not a furnace using Connellsville coke unless the Valley C furnace near Ligonier is regarded as in the Connellsville region. Lesley also mentions a coke-furnace called the Potomac, at Point of Rocks, Virginia, which used charcoal until 1848, that made 60 tons a week. Coke seems also to have been used at the Clay furnaces, in Mercer county, Ohio, in the latter part of 1845, in connection with charcoal, but coke was rapidly supplanted in this section by raw coal.

It was not, however, until the development of the Connellsville region, Pennsylvania, that the use of coke as a blast-furnace fuel or the manufacture of coke itself in this country assumed any importance.

The history of the early attempts to make coke in this region are involved in considerable obscurity, though some of the parties are still living who helped build the first Connellsville coke oven. As early as 1817, as has already been stated, Colonel Meason used coke at his Plumsock refinery. It is also stated that some attempts were made in 1819 to use this coke in the blast-furnaces of the neighborhood. This early coke was all made "on the ground", and it is probable that up to 1841 no coke was made in ovens.

It was in this year, 1841, that two carpenters, Provance McCormick and James Campbell, overheard an Englishman, so the story runs, commenting on the rich deposits of coal at Connellsville and their fitness for making coke, as well as the value of coke for foundery purposes, and they determined to enter upon its manufacture. Mr. McCormick, who is still living, an old man of eighty-four, has given me an account from memory of this enterprise, which I quote:

James Campbell and myself heard, in some way that I do not now recollect, that the manufacturing of coke might be made a good business. Mr. John Taylor, a stone-mason, who owned the farm on which the Fayette coke works now stand, and who was mining coal in a small way, was spoken to regarding our enterprise, and proposed a partnership—he to build the ovens and make the coke, and Mr. Campbell and myself to build a boat and take the coke to Cincinnati, where we heard there was a good demand. This was in 1841. Mr.

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a The following is a recapitulation of the items determined in the composition of coal from D. Upson's mine, Tallmadge Portage county, Ohio:

	Per cent.
Coke containing the earthy and metallic matter of the coal	55.425
Bitumen = 39.505 volatile matter — 0.274 sulphur =	39.231
Sulphur volatilized with the bitumen	0.274
Hygrometric water	5.067
Loss	0.003

The coke in the above recapitulation is composed as follows:

Composition of coke of Hon. D. Upson's mine:	Per cent.
Carbon	96.355
Protosulphuret of iron	1.375
Earthy matter	2.270

Some of the determinations in this analysis having been made by differences, they necessarily show no loss, although a small loss was undoubtedly sustained.

b *Second Annual Report of the Geological Survey of Ohio*, page 11. This was submitted late in 1838.

c *Idem*, page 62.

Taylor built two ovens. I think they were about 10 feet in diameter. My recollection is that the charge was 80 bushels. The ovens were built in the same style as those now used, but had no iron ring at the top to prevent the brick from falling in when filling the oven with coal, nor had we any iron frames at the mouth where the coke was drawn. The top and mouth had to be repaired when they fell in.

In the spring of 1842 enough coke had been made to fill two boats 90 feet long—about 800 bushels each—and we took them to Cincinnati, down the Youghiogheny, Monongahela, and Ohio, but when we got there we could not sell. Mr. Campbell, who went with the boats, lay at the landing some two or three weeks, retailing out one boat-load and part of the other in small lots at about 8 cents a bushel. Miles Greenwood, a founderyman of that city, offered to take the balance if he would take a small patent flour-mill at $125 in pay, which Mr. Campbell did. He had it shipped here. We tried it, but it was no good, and we sold it to a man in the mountains for $30, and thus ended our coke business.

These gentlemen lost heavily in their venture. Mr. Greenwood sent part of his coke to Dayton, to Judge Gebhart, who was formerly a resident of Connellsville, and who owned a foundery at Dayton. He was so much pleased with the fuel that he visited Connellsville, and, as Mr. McCormick states—

Wanted us to continue to make coke, and he would take two boat-loads a year, delivered at Cincinnati, and pay the cash on delivery; also that he would insure us sale for all the coke we could make and deliver at Cincinnati at 8 cents per bushel; but we had gone into other business, and refused to do anything more with the coke.

This was the beginning of the coke business in the Connellsville region. (*a*) For some years but little coke was made, though a few ovens were built, and that knowledge acquired which was necessary for the coming development of the trade. In 1843 the ovens built by Taylor were leased to three gentlemen named Cochran, a name that from that time to the present has been connected with coke-making in this region. They made 13,000 bushels and floated it down to Cincinnati, where it was sold to Miles Greenwood, at 7 cents a bushel. Between this date and 1850 three or four ovens were built by Stewart Strickler, who sold his product to the Cochrans. In 1851 improved ovens were built, and the trade increased somewhat, but in 1855 it is stated there were but 26 coke ovens above Pittsburgh. It was not until the Baltimore and Ohio railroad was completed to Pittsburgh, and Connellsville coke had been used successfully in the Clinton furnace of Graff, Bennett & Co., at Pittsburgh, that its value as a furnace fuel was thoroughly demonstrated and the foundation laid for the demand that has resulted in such a development of coke manufacture in the Connellsville region. This furnace was blown in in the fall of 1859, to make pig-iron from coke. The coke was at first made from Pittsburgh coal near the furnace on the south side of the Monongahela river, nearly opposite the Point, at Pittsburgh. The furnace was run for about three months, when, the coke made in this way not proving satisfactory, it was blown out, and arrangements made to secure a supply from the Connellsville region. The furnace blew in again early in the spring of 1860, the coke used being from the Fayette coke works on the Baltimore and Ohio railroad, made at first on the ground in pits. The result was so satisfactory that 30 ovens were built in 1860 and arrangements were made to secure a continued supply. When it is remembered that this was only twenty years ago, the development of this industry, as shown in this report, is remarkable.

Though there have been many attempts to coke Indiana coals, some of which were at quite an early date, this industry has never prospered in this state. Before the building of railroads made it possible to procure coke from Pennsylvania at a reasonable cost Indiana founderies were compelled to depend for their supplies upon the coal of the state, and at a number of coal-banks coke was made in small quantities for melting iron. In the *Report of the Geological Survey of Indiana for* 1872 (page 364) is the following statement, which assigns the earliest date to the manufacture of coke in this state I have been able to find: "Coke Oven Hollow is named from the business conducted in it by William G. Coffin about thirty-five years ago. He had a foundery at Mount Etna, near by, and procured his pig-iron from Cincinnati, Hanging Rock, and Pittsburgh. It was transported by wagons from Cincinnati, and in order to have loading economically both ways he mined and coked coal in this hollow, which reaches Sugar Creek just below the Feeder Dam, and would make sale of it either in Indianapolis, Richmond, or Cincinnati."

If this statement is correct, it would appear that coke was made in Indiana as early as 1837, only two years after Firmstone's successful experiments in Huntingdon county, Pennsylvania, and four years before the first coke oven was built in the Connellsville region.

The *Geological Report* for 1870 (page 224) refers to the production of coke in Sullivan county as early as 1845, for the supply of the Terre Haute founderies. Some fragments of the coke were found in 1870 by Professor Collett "after an exposure to the elements of a quarter of a century as bright and lustrous as if fresh from the oven". Some time prior to 1873 further attempts were made to coke the Sullivan county coals, a bee-hive oven being erected by Mr. Charles R. Peddle, at the instance of Mr. Chauncey Rose, to test the adaptability of the coal to coke-making. Mr. Peddle writes regarding this attempt:

I built the oven and coked some of the coal, and, though it came out of the oven all right in appearance, there was evidently more or less sulphur or some other ingredient that hardened the iron and rendered the coke unfit for foundery purposes. The coke was lighter than Connellsville, weighing about 37 pounds to the bushel. The founderyman who tried it reported that it required 561 pounds of Connellsville coke to melt 3,000 pounds of iron and 609 pounds of the Shelburn coke to do the same work. The coke did not swell in burning, so that the bulk of the coke was about the same as of the coal charged.

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a In the *History of Fayette County*, elsewhere mentioned, a statement is made that some coke ovens were built between 1830 and 1836, at or near the mouth of Furnace run. While making the statement and indorsing the credibility of the informant, the *History* seems to imply that there may be a mistake of dates.

Some time about 1849, so Mr. W. B. Seward, of Bloomington, Indiana, writes me, his father built two coke ovens at Arney's coal-bank, in Owen county, Indiana, and one at Bloomington for the purpose of coking the Arney coal, for use in his foundery at Bloomington. These ovens he describes as being "very much like the old Dutch bake-oven", evidently "bee-hive ovens". For a number of years, and until the building of a railroad to Bloomington enabled him to procure it from Pennsylvania, all the coke used in Mr. Seward's foundery was made in these ovens. In speaking of the coke Mr. Seward writes:

With proper care in managing the ovens a good article of coke was made, but it was not equal in quality to that made from what is known here as "Pittsburgh coal". The Arney coal runs together better than any other Indiana coal I have seen, but not enough to make large coke from fine coal. We always used the large lumps for coking. It was as free from sulphur as Pittsburgh coke, and, when properly made, melted iron about as well. We discontinued its use some twenty years since, when we got a railroad, as we had to transport the Arney coke 30 miles in wagons. I have examined all the specimens of Indiana coal I have been able to procure from time to time with a view to testing their coking qualities, but have not as yet found any that is superior to the Arney coal.

In 1868 Wilson, Ostrander & Co. began the manufacture of coke in mounds at Washington, Daviess county, and made some 25,000 or 30,000 bushels, but they were so far from market that it was difficult to dispose of it, and its manufacture was abandoned. In 1879 Cabel Wilson & Co., the successors of the before-mentioned firm, erected two ovens to make coke out of slack, but as no arrangements were made to wash the slack the enterprise was a failure.

Coke has also been made in other counties. Of the Fountain county attempt some account is given in another part of this report. Some years since coke was made in Parke county, near Clinton, by the Indiana Furnace Company, but with what success has not been learned. A number of attempts have also been made in Clay and other counties, but I have received no details of importance concerning them.

But little has been learned regarding the history of coke in other states, and that of a most fragmentary character. The location of the coal mines and the slight preparation and expense necessary in experimental coking in pits or "on the ground" are not conducive to the preservation of the records of early trials, and it is not until ovens are built that a permanent record is made. Even then in many cases the location of these ovens is such that information about them is only found in the books of the coke-maker or in his memory.

In Virginia coke was made many years ago at the mines in the neighborhood of Richmond, but it was not of a very good quality, and during the war of the rebellion coke was also made for use in the founderies of the state. In the northwestern part of the state some furnaces were run on coke between 1840 and 1850, but it is supposed the fuel came from Maryland.

In West Virginia the first ovens in the New River region were built in 1874. In this year the Quinnimont furnace was put in blast, using, with most gratifying success, the New River coke. The opening of the Chesapeake and Ohio railroad through this region in 1873 aided largely in its development, and made it possible to bring the coke and iron ores along its route together and furnish an outlet for the product. As is elsewhere stated, the development of this section since this date has been very rapid.

Coke to some extent was made in Alabama during the late war, being mainly used in the manufacture of cannon at the Selma (Alabama) foundery of the confederate government, and many openings were made along the veins in the immediate vicinity of the Cahaba river. On Pine Island branch, on what is known as the Gholson seam, coke was made in the open air, and was hauled over the hills to the railroad for shipment to Selma. Considerable quantities were also made at the opening in township 22 of sections 12 and 13, known as the "coke seam", and at various other places in the Cahaba coal-field. Some time in 1866 or 1867 the Glasgow Coal Company opened a mine on what is known as the Gould seam and made some coke, but after a while the work was discontinued, partly on account of the small demand for the coal and coke. In the Coosa fields some coke was made in 1863 and 1864 by Captain Schultz for the confederate army, and was floated down the river.

Though no coke was made in Kentucky in the census year, (*a*) some years ago attempts were made to run a number of charcoal furnaces in this state on coke, in some instances using coke entirely, and in others part charcoal and part coke. The old Airdrie was thus run, and in volume one, new series, *Kentucky Geological Survey*, page 147, is an analysis of coke made at this furnace, which has been weathered sixteen years. This analysis shows 82.90 per cent. fixed carbon, 5.40 per cent. ash, 11.70 per cent. moisture and volatile matter. I am also informed that some ovens were erected in Carter county for testing the Coalton coal, but the percentage of sulphur was too high at the particular trial made, being 2.026 per cent.

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a I am informed while this report is going through the press that good coke is made at Earlington, Hopkins county, Kentucky, by the Saint Bernard Coal Company. Recent investigations show the existence of a coal in southeastern Kentucky remarkable for thickness, purity, and its high percentage of carbon, which has been named by Mr. John R. Proctor, the director of the Kentucky geological survey, to whom I am indebted for the information, the "Elk horncoking coal". These coals were coked by officers of the geological survey by building ricks on the ground, and were also sent to coke ovens at Cincinnati and in Connellsville, Pennsylvania. Analyses of these cokes by Dr. Peter gives the following results, selecting those highest and lowest in carbons:

	Per cent.	Per cent.
Moisture	0.06	2.86
Fixed carbon	94.34	88.44
Ash	5.60	8.70
Sulphur	0.788	0.844

The cokes are firm, bright, and, as will be seen, quite pure.

As to the early history of coke in the other states, the information in my possession is given in connection with the paragraphs on the coke industries of these states.

THE COKE INDUSTRY IN PENNSYLVANIA.

In any statement concerning the coke industry of this country Pennsylvania must occupy the first place. It was in this state, so far as the record remains, that coke was first manufactured, and it is here that the development of this industry has been the greatest, its production being largely in excess of that of any other state.

Coke was produced in western Pennsylvania commercially at least sixty years ago, but it has only been within the last decade that its manufacture has attained to a magnitude and an importance that entitle it to separate consideration. Its magnitude is shown in the statistical tables of this report, and its importance is evidenced by the fact that not only has it built up a large pig-iron industry in a section where there are no ores, but it is used in the smelting of much of the iron ore of the country from the Hudson to the Mississippi. Indeed, the commercial success attained in the smelting of these ores west of the Allegheny mountains with mineral fuel is due to this coke. In addition to the ores of iron, it smelts most of the ores of the precious metals of the Rocky Mountain region, its value for this purpose being so great that it is carried to points where the freight in many cases exceeds the cost of the coke at the oven 1,000 per cent.

There were produced in Pennsylvania in the census year 2,317,149 tons of coke, all west of the Allegheny mountains. This was valued at $4,190,136, or $1 80 per ton. In its manufacture 3,608,095 tons of coal, valued at $2,031,305, or 56.3 cents a ton, were consumed. This would make the yield 64.2 per cent. At the close of the census year there were 7,808 ovens built, of which 7,524 were bee-hive. In addition to this 1,469 were building June 1, 1880, all bee-hive; 2,444 persons were employed in its manufacture, to whom $983,431 wages were paid.

The following table, condensed from Table I, will show the chief statistical items concerning the manufacture of this coke:

Counties.	No. of estab-lish-ments.	Capital.	OVENS.		Number of employés.	Wages paid.	COAL.		COKE.	
			Number built.	Number building.			Tons used.	Value.	Tons produced.	Value.
Total	104	$4,262,525	7,808	1,469	2,444	$983,431	3,608,095	$2,031,305	2,317,149	$4,190,136
Allegheny	17	325,150	476	29	171	59,485	166,700	119,718	95,685	235,915
Armstrong	2	30,000	20	66	10	4,000	13,400	6,700	7,000	13,000
Beaver	1	400	2	....	1	280	1,012	253	506	936
Blair	4	110,000	190	....	107	38,764	155,453	142,318	98,154	212,102
Butler	1	200	7	....	3	500	750	100	400	1,200
Cambria	3	106,000	119	....	45	19,870	85,000	78,500	51,950	110,894
Clarion	2	30,200	60	....	15	7,200	16,200	4,050	10,800	13,500
Clearfield*	1	25,000	....	60	....	....	....	....	....	....
Fayette	44	1,956,450	4,188	1,082	1,075	493,332	1,910,279	936,794	1,260,440	2,067,876
Jefferson*	1	10,000	....	31	....	....	....	....	....	....
Lawrence	2	38,500	98	....	22	3,004	7,500	3,750	3,941	20,651
Tioga	1	50,000	152	....	73	25,321	53,777	67,221	33,572	100,716
Washington	1	2,000	8	....	4	600	2,200	550	1,200	2,400
Westmoreland	24	1,578,625	2,488	210	918	331,075	1,195,824	671,351	753,501	1,410,946

* Building, and not in operation during any part of the census year.

The bituminous coal regions of western Pennsylvania were divided by Professor Rogers, in his report of the *First Geological Survey of Pennsylvania*, into six principal basins, numbered from the Allegheny mountains on the east to the Ohio river on the west. Five great anticlinal waves of remarkable persistence and regularity separate these basins, one of these, the anticlinal that bounds the Connellsville basin on the west, running from the Virginia state line to Elk county, a distance of 100 miles, in an absolutely straight line. (*a*) Some of these basins coincide with the physical division of the surface. The first basin, for example, lies between Laurel Hill and the Allegheny mountains, and the second between Chestnut Ridge and Laurel Hill. Other basins, however, are only geological, and have no strongly marked corresponding surface depressions. (*b*)

In all of these basins coke was made during the census year. The bulk of the product, however, was from the Allegheny Mountain and the Connellsville regions. Most of the coke was made from the coal of the great Pittsburgh seam, which is, on the whole, the most extensive and economically important coal-bed in the Appalachian basin. It is the main seam worked at Pittsburgh, on the Monongahela and Youghiogheny rivers, at Connellsville, Wheeling, and many other places, and is estimated to underlie, in the states of Pennsylvania, Ohio, and West Virginia, 14,000 square miles. In southwestern Pennsylvania Professor Lesley estimates that this bed, after all the erosion it has

a See Report H, *Second Geological Survey of Pennsylvania*, page 16.

b For a discussion of these basins, their extent and subdivision, more thorough than can be given here, the reader is referred to the different publications of the *Second Geological Survey of Pennsylvania*, particularly reports H and KK. It will of course be understood that in this report we are speaking only in general terms regarding these basins.

undergone, is found over an area of somewhat less than 3,000 square miles, so situated that every square yard of it can be reached. He also states that the present British coal trade could be supplied for twenty centuries from this single coal-bed, as developed in western Pennsylvania. (*a*) This bed does not everywhere show the same thickness as in western Pennsylvania, where it is generally about 8 feet, gradually increasing eastwardly to the Cumberland (Maryland) region, where it is 14 feet; nor does it always make as good a coke as that of the Connellsville region, where it is seen at its best.

This Connellsville region, or basin, the great coke-producing center of the country, is situated in the southwestern part of the state of Pennsylvania, in the counties of Westmoreland and Fayette, some 50 or 60 miles from Pittsburgh. It is a slender prong, separated from the Upper Coal-Measures, and may be regarded as extending from near Latrobe, on the Pennsylvania railroad, in a southwesterly direction, to the Virginia state line, forming a basin some 3 miles wide and 50 miles long, almost without a fault, the beds yielding from 8 to 10 feet of workable coal. The same trough that contains the Connellsville coal extends northwesterly from Latrobe through the remainder of Westmoreland county, and through Indiana and Clearfield counties, but the Connellsville region is regarded as extending no farther north than the vicinity of Latrobe. The coal in the northern part is inferior as a coking material to that in the southern part, though both physically and chemically the coal of this basin on the Conemaugh seems the same as that on the Youghiogheny. The latter, however, produces the typical Connellsville coke, compact, silvery, and lustrous, while the coke from the coal on the Conemaugh, or in any locality north from the Pennsylvania railroad, is tender, dull, and soon loses what little luster it has. Even in some portions of what is known as the Connellsville region proper the coal and coke is not of equal value. Coal at Coketon, in the northern part of the immediate Connellsville basin, just south of the Pennsylvania railroad, produced wretched coke when coked as it came from the mines, but when washed it produced a coke regarded as fully equal to the Connellsville. The coal at Latrobe and at Loyalhanna, in the same locality, must also be washed before coking to produce the best results.

As showing the character of the coal in this part of the Connellsville basin and the coke made from it I give the following analyses, which have been furnished by Mr. Benj. Crowther, of the Isabella Furnace Company:

ANALYSES OF COKETON (PENNSYLVANIA) COAL.

	Top of vein. Per cent.	Bottom of vein. Per cent.
Bituminous matter	25.52	18.18
Fixed carbon	70.91	60.57
Ash	3.34	20.08
Sulphur	0.23	1.17

ANALYSES OF COKETON (PENNSYLVANIA) COKE.

Constituents.	Unwashed.	WASHED.	
		No. 1.	No. 2.
	Per cent.	*Per cent.*	*Per cent.*
Moisture and volatile matter	1.26		
Fixed carbon	86.58	89.15	83.93
Ash	10.67	9.65	14.80
Sulphur	1.49	1.20	1.27
Silica in ash		4.67	6.12

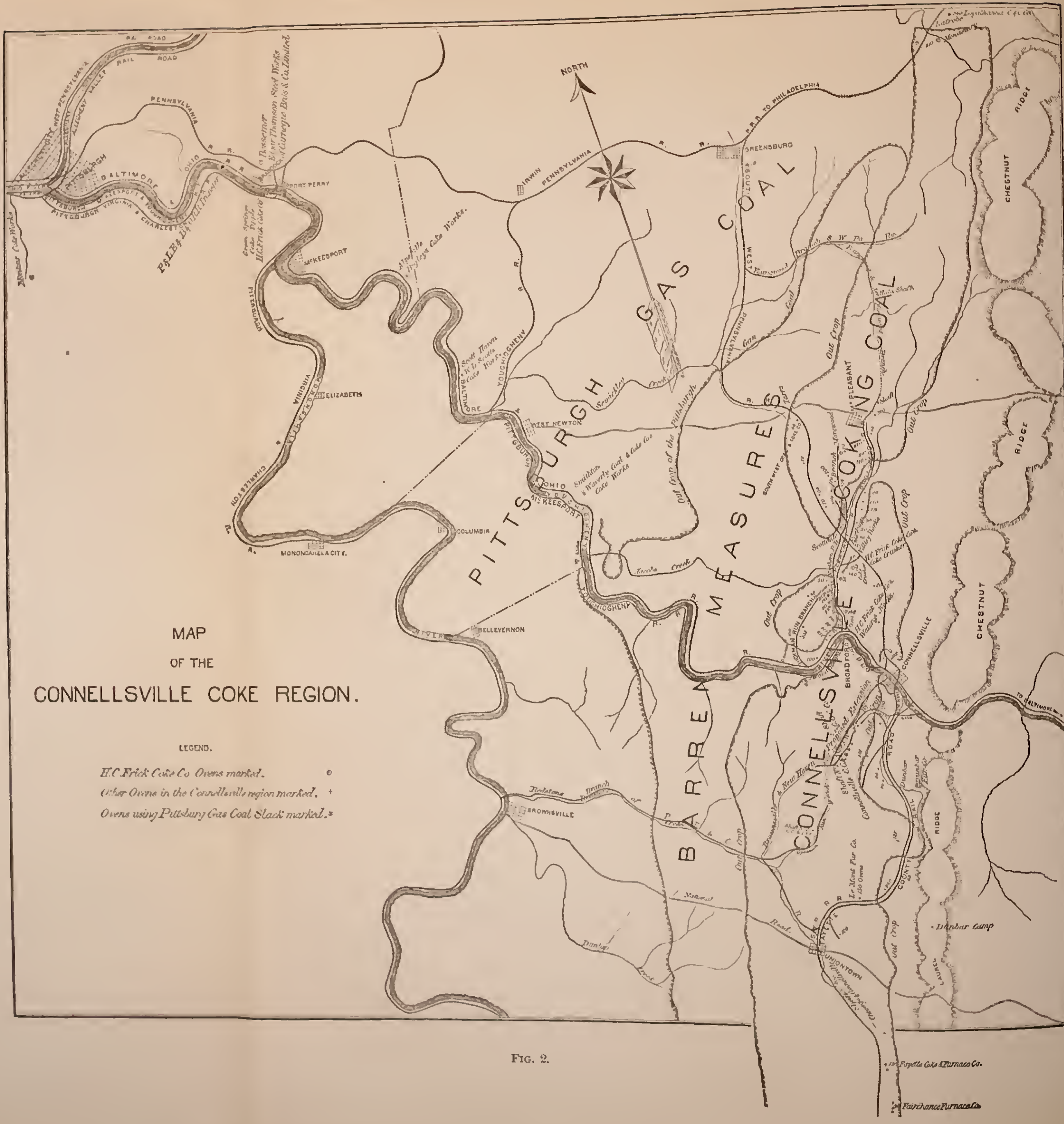
Mr. Crowther states that No. 1 coke from washed coal is about the average result when the washer is working right.

A comparison of the above analyses with those of the Connellsville coal and coke from the neighborhood of Broad Ford will show the difference in the character of the coal and the similarity of the coke from the washed coal.

This variation in the Connellsville coal seems to have been discovered at an early day in the history of coke manufacture, for the coke-making area is confined to that portion of the trough which lies south from Sewickley creek, and the works are by no means important until one comes near to Jacob's creek. Thence southward to near Uniontown, in Fayette county, the eastern outcrop of the bed is lined with coke ovens. There appears to be prejudice in favor of the eastern outcrop; and although several manufacturers have told me that the coal on the western outcrop is somewhat inferior, facts do not seem to justify this prejudice. The extensive coke works near Dawson, on the Youghiogheny river, are upon the extreme western outcrop, but the coke made there is not inferior to any made along the eastern outcrop from Mount Pleasant to Lemont furnace. (*b*)

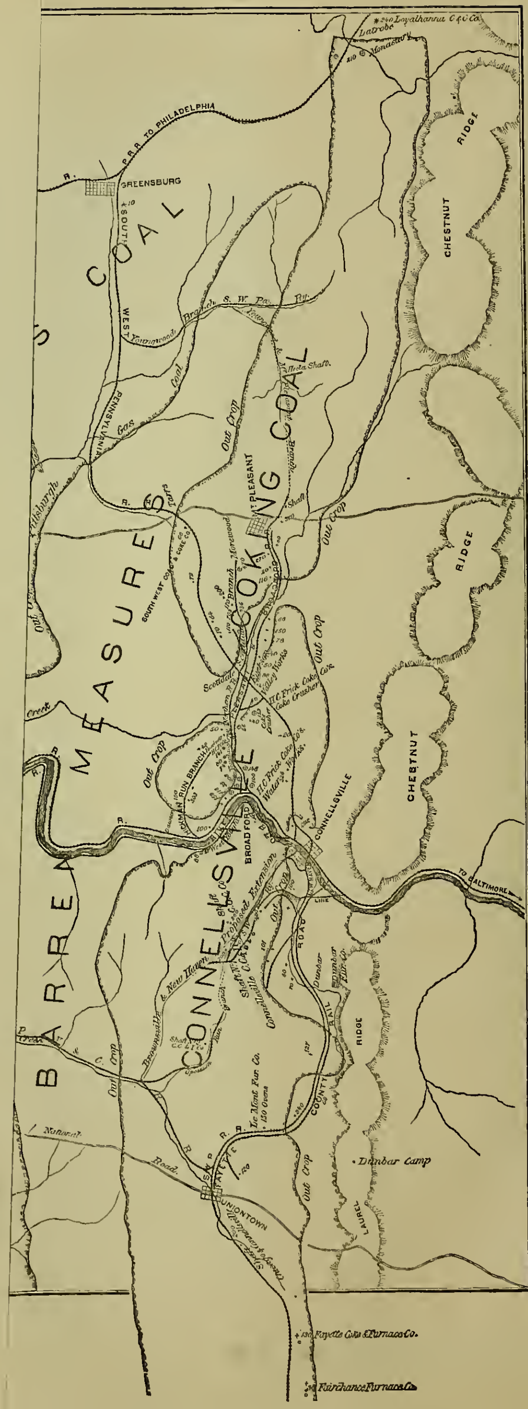
Regarding the Connellsville region proper as including all the ovens in the basin from Latrobe and vicinity south, there were built in this region at the close of the census year, May 31, 1880, 6,264 ovens, all of which were of the bee-hive pattern. There were also three pits or mounds. At the same time there were actually 1,242 ovens

a *Atlas of Pennsylvania*, with description (Philadelphia, 1872), page 17.
b *Second Geological Survey*, Report KKK, by J. J. Stevenson, page 200.



MAP
OF THE
CONNELLSVILLE COKE REGION.
LEGEND.
H.C.Frick Coke Co Ovens marked.
Other Ovens in the Connellsville region marked.
Ovens using Pittsburg Gas Coal Slack marked.
PITTSBURGH GAS COAL
BARREN MEASURES
CONNELLSVILLE COKING COAL
NORTH
PITTSBURGH
McKEESPORT
ELIZABETH
WEST NEWTON
COLUMBIA
MONONGAHELA CITY
BELLEVERNON
BROWNSVILLE
GREENSBURG
IRWIN
PORT PERRY
MT. PLEASANT
BROADFORD
CONNELLSVILLE
UNIONTOWN
CHESTNUT RIDGE
LAUREL RIDGE
YOUGHIOGHENY
P.R.R. TO PHILADELPHIA
PENNSYLVANIA R. R.
TO BALTIMORE
Dunbar Camp
Fayette Coke & Furnace Co.
Fairchance Furnace Co.

FIG. 2.



Loyalhanna C. & C. Co.
Latrobe
P.R.R. TO PHILADELPHIA
GREENSBURG
SOUTH WEST PENNSYLVANIA
Youngwood
S. W. Pa. Ry.
Gas Coal
Alice Shaft
CHESTNUT RIDGE
CHESTNUT RIDGE
CHESTNUT
MT PLEASANT
Morewood
SOUTH WEST COAL & COKE CO.
BARREN MEASURES
CONNELLSVILLE COKING COAL
Out Crop
Scottdale
Valley Works
H.C. Frick Coke Co.'s Coke Crusher
H.C. Frick Coke Co.'s Water Works
HICKMAN RUN BRANCH
BROADFORD
CONNELLSVILLE
TO BALTIMORE
Proposed Extension
Brownsville & New Haven
Connellsville C. Co.
Dunbar
Dunbar Fur. Co.
COUNTY
RAIL ROAD
RIDGE
Le Mont Fur. Co. 150 Ovens
National Road
UNIONTOWN
Dunbar Camp
LAUREL
Fayette Coke & Furnace Co.
Fairchance Furnace Co.

in process of construction in this region, all bee-hive. Deducting from the totals for Fayette and Westmoreland counties, as given in the table on page 29, the totals for those establishments that cannot properly be regarded as in the Connellsville basin, we have the following statistics for the Connellsville region:

Counties.	No. of establishments.	Capital.	Ovens.		Number of employés.	Wages paid.	Coal.		Coke.	
			Number built.	Number building.			Tons used.	Value.	Tons produced.	Value.
Fayette	42	$1, 930, 450	4, 109	1, 082	1, 030	$489, 882	1, 898, 709	$920, 454	1, 253, 743	$2, 051, 126
Westmoreland	19	1, 295, 500	2, 158	160	826	284, 573	984, 499	600, 872	639, 457	1, 149, 772
Total	61	3, 234, 050	6, 267	1, 242	1, 856	774, 455	2, 883, 208	1, 533, 326	1, 893, 200	3, 200, 898

From this table it appears that about 62 per cent. of all the ovens in the United States at the close of the census year were in the Connellsville region, and that 69 per cent. of all the coke made that year was made in the same district. Of the extensions in progress June 1, 1880, judging by the number of ovens building, about 58 per cent. were in the Connellsville region. Since the census year its development has been remarkable, large tracts of land, in which the coal lies at a considerable depth below the surface, being now utilized, and the number of ovens has increased, until it is estimated that there are now 9,000. The accompanying map, showing the extent of the Connellsville region, the localities of the ovens, and their relation to Pittsburgh, is based on a map furnished by H. C. Frick & Co.

The coal-bed from which all the so-called Connellsville coke is made is the Pittsburgh bed of Professor Rogers' report of the *First Geological Survey of Pennsylvania of* 1842, and is described in the second volume of the final report of 1858. The continuation of the Pittsburgh area of this bed with the Connellsville area is broken off by the Youghiogheny river, the bed taking an upward course and descending again, the intermediate portion being swept away. This has led to a popular belief that the bed at Connellsville is different from that at Pittsburgh, but careful surveys have established their identity. It is a fact, however, that at Pittsburgh this bed is not in its best condition, while at Connellsville it is at its greatest thickness and is of the finest quality. It is also true that the coke made from the bed at Pittsburgh is not as good as that made at Connellsville. In the Connellsville basin the coal ranges from 8 to 11 feet in thickness, with one small slate parting, the "bearing-in slate", (*a*) 18 inches above the floor. The roof is only passable; the rooms can only be run 12 feet wide, and the pillars will average 10 feet, a large amount of which is lost in drawing. The floor is even and quiet, the coal is of a remarkably good and uniform character, and is soft and easily mined. On wagers, 23 wagons (57,684 pounds) have been dug and loaded inside of 10 hours by a man and a boy. The greater portion of this work is to shovel the coal into wagons, the digging or mining being the easiest part. Very little outside labor is required, and the average output per man per day is from 8 to 10 wagons, the cost of digging being about 25 cents per ton.

It is this ease of mining which, next to its chemical and physical characteristics, gives the Connellsville coal so much value as a material for coke, and has enabled the latter to compete in such distant markets with other cokes and fuels. Mr. Fulton has pointed out in a letter that this ease of mining is also a distinguishing peculiarity in the Connellsville basin. East or west from this narrow strip the cost of mining increases; westward the coal hardens, eastward the beds become thinner.

The coal is bituminous, with generally a dull, resinous luster, alternating with seams of bright, shining, crystalline coal, coated with a yellowish silt. It contains numerous particles of slate and some crystals of pyrites; is compact, with a tendency to break up into cubes; is a very tender coal, and is ill adapted for shipping. Such a coal from the mines of the H. C. Frick Coke Company, at Broad Ford, is taken by the Pennsylvania geological survey as the typical coal of the Connellsville basin. Its analysis, as determined by Mr. McCreath, chemist of the survey, is:

	Per cent.
Water	1. 260
Volatile matter	30. 107
Fixed carbon	59. 616
Sulphur	0. 784
Ash	8. 233

Color of ash, reddish gray; coke, per cent., 68.633; sulphur left in coke, 0.512.

	Per cent.
Percentage of sulphur in coke	0. 746
Percentage of ash in coke	11. 995
Percentage of carbon in coke	87. 25

The coke from this region is of silvery luster, cellular, with a metallic ring, tenacious, comparatively free from impurities, and is capable of bearing a heavy burden in the furnace. Its porosity and ability to "stand up" in the

a The present or *Second Geological Survey* is devoting a great deal of labor to this coal-field, and the reports that have been published contain much valuable information. I am greatly indebted to these reports, especially reports L and KK, for data.

furnace are what have given it such a reputation as a blast-furnace fuel, and have created such a demand for it for mixing with anthracite and bituminous coal in the east and west, especially where an open iron, such as is used in the Bessemer process, is needed. Mr. John Fulton has conducted a series of very elaborate and ingenious experiments on the physical properties of coke for furnace use, embracing the typical coking coals of Pennsylvania. Some of these results are given in a table in connection with the remarks on the Allegheny Mountain region, and will be referred to at further length in the chapter on "Coke as a Blast-furnace Fuel".

In coking the Connellsville coal, the bee-hive oven is in universal use in the Connellsville region, these ovens varying at the different works from 11 to 12 feet in diameter, and from 5 to 6 feet in height. (*a*) The working is very simple. The coal is dumped through an opening in the crown of the furnace and spread evenly on the floor to the average depth of 2 feet for 48-hour coke and 2½ feet for 72-hour. The front opening, through which the coke is discharged, is at first nearly closed with brick, luted with loam. The heat of the oven from the previous coking fires the charge, and as the coking progresses the air is more and more shut off by luting the openings and finally closing the roof openings. The average charge is 100 bushels (76 pounds each) of coal, and the yield in coke is from 63 per cent. to 65 per cent. The average time of coking is 48 hours, with 72 hours for that burned over Sunday; 24-hour coke is sometimes made. The 72-hour coke is a firmer coke than either of the others, but it is questionable whether it is a better furnace coke. When the coke is thoroughly burned, the door is removed, and the coke is cooled by water, thrown in from a hose, and then drawn.

We have given an analysis of what was regarded as the typical coal from this region from the mines of the H. C. Frick Coke Company at Broad Ford. The analysis also gave the results of coke in the laboratory. A sample of the coke from these mines made in the ovens of the firm, analyzed by Mr. McCreath, gave the following results. This coke is exceedingly coherent and compact, with a silvery luster, and contains some slate:

	Per cent.
Water	0.030
Volatile matter	0.460
Fixed carbon	89.576
Sulphur	0.821
Ash	9.113

Mr. Platt, of the Pennsylvania geological survey, in his report on coke, takes this as the typical coke, "as being thoroughly burned and as well made as can be produced in the Connellsville basin." Probably the most thorough analyses of the coke from this region were made by Mr. J. Blodgett Britton, of Philadelphia. It is the average of a large number of analyses of all sorts of Connellsville coke, and cannot, therefore, be regarded as a fair analyses of good coke:

	Per cent.
Moisture	0.490
Ash	11.332
Sulphur	0.693
Phosphoric acid	0.029
Carbon, by difference	87.456

Mr. E. C. Pechin gives a typical verified analysis of this coke as follows:

	Per cent.
Volatile matter	1.296
Carbon, hydrogen, and nitrogen	89.147
Ash	9.523
Water	0.032
Sulphur	0.084
Ash ignited:	
Silica	5.413
Alumina	3.262
Sesquioxide	0.479
Lime	0.243
Magnesia	0.007
Phosphoric acid	0.912
Potash and soda	traces.

In commenting on this analysis, Mr. Pechin, who has had considerable experience with Connellsville coke, says:

A large number of analyses of Connellsville coke have been made, showing less carbon and more sulphur. As regards carbon, I have had a number of analyses made at different times out of different lots, showing somewhat more carbon than the above.

It will be noted that Mr. Pechin's analysis corresponds very closely with that given above from the Pennsylvania geological survey, and from the best evidence I have been able to obtain I regard these two as fairly representing the average of good Connellsville coke. At the Edgar Thomson steel works, near Pittsburgh, a large amount of coke is used from the works of the H. C. Frick Coke Company, and frequent analyses for ash are made. The average of a large number of these analyses, covering the deliveries of 150,000 tons, extending from May 25 to November 18, 1882, gives 9.75 per cent. of ash, the range being from 9.11 to 10.91 per cent.; 9.75 may therefore be regarded as the average ash in good Connellsville coke.

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a Drawings of these ovens are given in the chapter on "Bee-hive Ovens".

It is almost impossible to arrive at the average detailed cost of making coke in this region, as the mines and facilities for manufacture greatly differ.

When engaging in the manufacture of coke, no one should have less than 200 acres of coal to 100 ovens. Coal advantageously located cannot on the average be had for less than $400 per acre, and the ovens, with all the necessary plant, cannot be built for less than $40,000. Then we have:

200 acres of coal, at $400 per acre	$80,000
100 ovens complete	40,000
Total cost	120,000

At least 8 per cent. per annum interest should be expected on an investment of this character, which gives us:

Interest	$9,600
100 ovens use per annum fully 7 acres of coal, $400	2,800
Total cost	12,400

So it will be seen that at least $12,400 should be first made yearly out of an investment of this kind to pay interest and make up depleted capital. It is not possible to make on an average more than 39,000 tons of 2,000 pounds each of good coke yearly with 100 ovens, and by the above figures it will be seen that it will require about 32 cents per ton to cover interest and replace capital.

At the best arranged works in the Connellsville region, and at the present prices of labor, the cost of manufacturing a ton of 2,000 pounds of coke is about as follows:

Mining coal for 1 ton of coke	$0 38
Drawing coke	25
Loading, hauling, and incidentals	10
Repairs	10
Total	83

For the total we have:

Interest on capital, and allowance for coal used, per ton, say	$0 32
Cost of manufacture, per ton	83
Total, per ton	1 15

The above calculation is, if anything, too low, as the investment in ovens, etc., is lost when the coal is all gone, and the cost of manufacture will increase as the front coal is used up. This calculation is based on coal that will drain itself, as the cost will exceed this when drainage is added. Until recently most of the coal was brought out through entries, but now a number of shafts are employed, the great increase of ovens necessitating the mining of coal at points where the coal-measures are from 300 to 500 feet below the surface.

A statement furnished by Mr. John Fulton as to the cost of a plant of 400 ovens erected by the Cambria Iron Company at Morrell, Pennsylvania, and also as to the cost of producing coke, differs considerably from that given above. The cost of the plant at Morrell was as follows:

Water-works	$29,113 80
Houses	30,598 48
Slope	50,000 00
400 ovens	118,673 46
Total	228,385 74

This would make the cost of a hundred ovens $57,096 43½. Taking the cost of workmen's houses, $30,598 48, from the above, the cost of the 400 ovens, not including such houses, would be $197,787 26, and of 100 ovens $49,446 81½, or very nearly $50,000. This Mr. Fulton regards as the cost of 100 ovens where the coal is worked by slope or shaft, the estimate being based on a slope 2,000 feet long or a shaft 300 feet deep. Of course when a simple adit is run the expense would be less, but adits are exceptional. This is 25 per cent. less than the estimate above given, but is based on the actual cost of a bank of 400 ovens recently built.

The actual cost of making coke at the works of the Cambria Iron Company, at Morrell and Wheeler, near Connellsville, is given on page 34, the mining of coal being based on 25 cents per ton for mining the room coal and 32 cents per ton (2,000 pounds) for heading coal.

MINING COAL.

Mining coal, per ton (2,000 pounds)	$0 27.6
Hauling	07.3
Hoisting and dumping	03.8
Superintendent, foreman, and clerk	01.6
Lumber, ties, and props	02.9
Repairs and supplies	06.8
Cost of coal per ton, delivered at ovens	50.0

COKING.

1.6 tons of coal, at 50 cents	$0 80.0
Labor (drawing, loading, charging, superintendent, and clerk)	41.2
Supplies	02.6
Repairs	05.2
Cost of coke per ton	1 29.0

It is estimated that at these works 20 cents per ton on all coke made should be added to this to pay for real estate and interest on improvements. This would make:

Cost of improvements and allowance for coal used per ton of coke	$0 20
Cost of manufacturing coke per ton	1 29
Total	1 49

It will be noted that this estimate of the cost of manufacturing coke is considerably in excess of that first given. These two estimates, from two reliable manufacturers, are given for the purpose of showing how difficult it is to arrive at exact figures.

The result of a careful survey lately made puts the amount of coal yet remaining in this region at 72,000 acres. As each acre furnishes 5,500 tons of coke, this would furnish, say, 400,000,000 tons, which will supply the present output, say, 200 years. This only applies to the Pittsburgh bed. Other seams in this same field not now worked will no doubt, when needed, furnish a supply of coking coal.

Before speaking of the Allegheny Mountain region, the next most important coking district in western Pennsylvania, it may be well to refer to those coke works in Fayette and Westmoreland counties not properly belonging to the Connellsville region. In these counties are two coal-basins, or, more properly, sub-basins or troughs, in addition to the Connellsville, one the Greensburgh, of small extent and lying only in Westmoreland county, the other the Lisbon or Irwin, which is much larger than the Connellsville, extending from near the northern boundary of Westmoreland county in a southwesterly direction, through Fayette and Greene counties, into West Virginia. In both of these troughs the Pittsburgh bed remains, from which considerable coke was made in the census year, mainly from slack.

Following the line of the Pennsylvania railroad, the first of these troughs (the Greensburgh) lies west of the northern extremity of the Connellsville basin, and some five or six miles from Latrobe. It is of but little importance as a coking-field, only 4,154 tons of coke from unwashed slack being made in its limits in the census year.

The second of these troughs, still following the line of the Pennsylvania railroad westward, the Irwin, is less than 10 miles distant from the Greensburgh, and includes the mines of the Penn Gas Coal Company and the Westmoreland Coal Company, so well known for the production of coal of excellent gas-making qualities. The coal from the Pittsburgh bed in this portion of the Irwin trough makes an excellent coke, and contains, except in very rare cases, but little sulphur and a very low percentage of ash. The coal, however, is much harder than the Connellsville, and will bear shipping, which the Connellsville, as a rule, will not, being too friable. The coal of this trough also contains a large proportion of volatile combustible matter, and consequently the percentage of coke per ton of coal is much less than in the Connellsville region. For these two reasons, and to utilize what would otherwise be not only a waste product but one very inconvenient to dispose of, but little lump coal is used in coking, most of the coke being made from slack, 9,200 tons only out of 215,045 tons used being lump coal or "run of the mine".

The largest works in this trough is that of Carnegie Brothers & Co., limited, who have a large number of ovens, with necessary washers, near Larimer station, on the Pennsylvania railroad, washed slack chiefly from the mines of the Westmoreland Coal Company and the Penn Gas Coal Company being used. This coke is of good quality, in some respects equal to the Connellsville and lower in ash, and has been used in Pittsburgh furnaces with good results. An average of three analyses of the Penn Gas Company's coal, made by Mr. A. S. McCreath, chemist of the Pennsylvania geological survey, is as follows:

	Per cent.
Water	1.427
Volatile matter	37.980
Fixed carbon	54.598
Sulphur	0.638
Ash	5.357

From Messrs. Carnegie Brothers & Co., limited, we have the following analyses of the slack, both washed and unwashed, and the coke made from the same. It will be noted, on comparing the analysis of the unwashed slack with that of the coal above given, that the amount of sulphur and ash are both very much higher in the unwashed slack than in the coal, while the volatile matter is somewhat lower. By washing, the slack is made to very nearly equal in purity and contents the unwashed coal:

Constituents.	SLACK.		Coke.
	Unwashed coal.	Washed coal.	
	Per cent.	*Per cent.*	*Per cent.*
Fixed carbon	56.57	54.88	88.240
Volatile matter	31.68	38.13	1.384
Ash	11.08	6.98	9.414
Sulphur	1.26	0.96	0.962

Southwesterly from the Pennsylvania railroad, on the Youghiogheny and Monongahela rivers, several banks of ovens have been erected to utilize the slack from various mines. This slack, however, contains, when unwashed, fragments of slate, which interfere with the reputation and the use of coke made from it. At Cat's run, on the Monongahela, near the Virginia state line, where ovens and washers have been erected, an analysis of the coal is as follows:

Water	1.040
Volatile matter	32.815
Fixed carbon	60.214
Sulphur	1.249
Ash	4.655

The slates of this coal are somewhat thicker than in the Connellsville basin, and the coke is not apt to find a ready market, owing to the injury caused by projecting bits of slack.

We give below a statement showing the manufacture of coke in these two counties outside of the Connellsville region:

Troughs.	No. of establishments.	Capital.	OVENS.		Number of employés.	Wages paid.	COAL.		COKE.	
			Number built.	Number building.			Tons used.	Value.	Tons produced.	Value.
Greensburgh	1	$3,125	10	....	4	$1,653	7,750	$3,410	4,154	$6,231
Irwin	6	297,000	399	50	133	48,299	215,055	71,409	116,590	271,693
Total	7	300,125	409	50	137	49,952	222,805	74,819	120,744	277,924

The most important coking district in western Pennsylvania, next to the Connellsville, is the Allegheny Mountain, which district includes that part of Blair and Cambria counties that lie in the first bituminous basin along the sides and near the summit of the Allegheny mountains. This basin extends both north and south of these counties, but the coke made from its coal in the census year was all made in the counties named.

The coal in the different sub-basins of this district differs widely in its coking qualities. In the eastern portion of the region, on the eastern slope of the mountains, near the summit, it cokes readily in the bee-hive oven, forming a hard, silvery coke, but little, if any, inferior to the Connellsville; but west of the summit, on the slope, bee-hive ovens are also used, and the coke, which is from a different bed of coal, is not as good as that at Bennington and other localities in Blair county. Still west of this a few miles, at East Conemaugh, pits were used and a good coke made, while a short distance farther west the coal is so dry-burning that the Belgian oven is employed. This distance, say, from Altoona to Johnstown, less than 40 miles, thus becomes one of the most interesting coking districts in the country. The coal varies from a true coking coal, making in the bee-hive oven an admirable blast-furnace coke, to a dry-burning coal that cannot be coked to advantage in the bee-hive oven, requiring the heat of the Belgian to coke it properly. In this same district could be studied in the census year the three typical methods of coking: in pits, in bee-hive ovens, and in Belgian ovens. The experiments made for the Cambria Iron Company by Mr. John Fulton, their mining engineer, in the use of different coals and methods of coking, as well as those relating to the value of cokes, have been the most careful and thorough of any made in this country. They have already been of great value, and must be of increasing importance.

The coal most extensively used for coke, as well as that making the best coke in the district, is bed "B" of the geological survey. An analysis of this coal as it is mined at Bennington, in Blair county, where it is called the Miller seam, and the coke from it, is as follows: (*a*)

	Coal. Per cent.	Coke. Per cent.
Water	1.400	......
Volatile matter	27.225	......
Fixed carbon	61.843	87.58
Ash	6.930	11.36
Sulphur	2.602	1.06

a From *Report Second Pennsylvania Geological Survey*, HH, page 16.

This coal is semi-bituminous, and has a shining luster, contains considerable pyrites, and in the vicinity of Bennington the bed is about 3½ feet thick. All of the coke made in Blair county (bee-hive ovens being used) is from this seam, and closely resembles the Connellsville, is sonorous, cellular, and tenacious, reasonably pure, and has great calorific vigor.

On the western side of the summit of the Alleghenies, at Lilly's station, in Cambria county, coal from bed E, commonly known as the Upper Freeport bed, is coked. An average analysis of this coal at this point is as follows: (a)

	Per cent.
Water	0.715
Volatile matter	22.250
Fixed carbon	70.518
Sulphur	1.459
Ash	5.058

This coal has a bright, shining luster, is rather friable, and contains numerous thin partings of mineral charcoal and pyrites. Coke was made from this coal in open ricks until December, 1879, when some bee-hive ovens were put in operation.

The Lilly's Station mine is in the Wilmot sub-basin of the first bituminous basin. A short distance west an anticlinal rises, which separates this sub-basin from the Johnstown sub-basin, where bed E is again used at the East Conemaugh ovens. This coal is reasonably pure, is low in ash but high in sulphur, and makes a dense coke. It is also low in volatile matter.

Though this coal was coked in open ricks during the census year, Belgian ovens are now (1882) being erected to use it.

At Johnstown, bed E, or the Upper Freeport, the same bed as is coked at Lilly's station and East Conemaugh, is coked in Belgian ovens. An analysis of this coal by T. T. Morrell, chemist, is as follows:

	Per cent.
Moisture	0.160
Volatile matter	18.630
Fixed carbon	74.950
Ash	4.860
Sulphur	1.400
Phosphorus	0.011

Mr. John Fulton has prepared for this report the following statement as to the coals and cokes of this region:

The Allegheny section affords three types of coking coals: Connellsville, Allegheny-Bennington, and Portage.

Connellsville and Bennington types are coked in bee-hive ovens, and make excellent coke.

The dry coals approaching Johnstown basin would require to be coked in Belgian ovens, as they do not inherit sufficient pitchy matter to fuse in the slow heat of a bee-hive oven.

The following table exhibits the typical coals of the Allegheny region for coking:

Constituents.	Connellsville (Pittsburgh coal).	Bennington (Miller, bed B).	Portage (Upper Freeport, bed E).
	Per cent.	*Per cent.*	*Per cent.*
Moisture	1.260	1.400	....
Volatile matter	30.107	27.225	22.24
Fixed carbon	59.616	61.843	68.94
Ash	8.233	6.930	8.82
Sulphur	0.784	2.602	....

These three types of coking coals embrace the main supply of the eastern section of the Allegheny region.

The Connellsville (Pittsburgh bed) is 8 feet thick, with soft, easily-mined coal; Bennington (Miller bed B) 3 feet thick, affording also a soft coal, and the Lemon bed, or Upper Freeport (bed E), 4 feet thick, gives a very desirable coal for coking.

The detached Broad Top coal-field in Huntingdon and Bedford counties affords coking coal which produces a hard, bright, cellular coke, second only to Connellsville. The Kemble Coal and Iron Company coke for two blast-furnaces at Riddlesburg from the Kelly or "E" bed in bee-hive ovens. Robert Hare Powell, esq., is coking the "A" or Fulton bed in Belgian ovens.

The East Broad Top Railroad and Coal and Iron Company coke a dry coal in Belgian ovens with indifferent success.

The three types submitted, which embrace Broad Top and Clearfield coals, can be coked to good advantage, and the cokes take a first rank for metallurgical uses. Outside of these there are two extremes that will require special treatment to produce a moderate quality of coke: the very dry coals of the east, holding from 16 to 18 per cent. of hydrogenous matter, and the very fat coals of the west, holding from 30 to 50 per cent. of volatile matter. The first requires to be charged into a hot oven to fix its small percentage of fusing matter; the latter requires to be coked slowly under pressure to repress an excessive cell development.

a *Report of the Pennsylvania Geological Survey*. HH, page 33 (McCreath).

The following table exhibits the physical character of the cokes of the Allegheny border, taking the Connellsville as a standard:

Localities.	Grams in one cubic inch.		Pounds in one cubic foot.		Percentage.		Compressive strength per cubic inch (¼) ultimate strength.	Height of furnace charge supported without crushing.	Order in cellular space.	Hardness.	Specific gravity.	Chemical analysis.						Remarks.
	Dry.	Wet.	Dry.	Wet.	Coke.	Cells.						Fixed carbon.	Moisture.	Ash.	Sulphur.	Phosphorus.	Volatile matter.	
												Pr. ct.	Pr. ct.	Pr. ct.	P. ct.	Pr. ct.	Pr. ct.	
Standard coke, Connellsville.	12.46	20.25	47.47	77.15	61.53	38.47	284	114	1	3.5	1.500	87.46	0.490	11.32	0.69	0.029	0.011	
No. 1 big vein, Salisbury.	12.98	23.33	49.52	89.01	56.07	44.93	162	65	1	3.25	1.501	89.31	0.420	9.45	0.82	0.019	....	Almost equal to Connellsville.
No. 2, over big vein.	12.73	22.94	48.50	87.39	55.49	44.51	171	69	1	3.00	1.645	84.42	0.030	12.92	1.63	0.100	....	Little high in sulphur and phosphorus.
No. 3, under big vein.	12.65	22.78	45.92	86.05	52.49	47.51	127	51	1	3.00	1.644	86.27	0.010	11.68	2.02	0.020	....	Little high in sulphur.
No. 4, under big vein.	13.71	22.35	85.15	85.15	60.88	39.12	167	67	1	2.75	1.546	91.59	0.150	7.08	1.16	0.020	....	Very good coke.
Blair Coal and Iron Co., Bennington.	13.19	20.80	50.25	79.25	63.41	36.59	......	......	1	3.30	......	87.58	....	11.36	1.06	....	....	
Kemble Coal and Iron Co., Broad Top.	11.76	20.18	44.81	76.88	58.27	41.73	240	96	1	3.20	....	89.28	.....	9.66	1.06	....	....	Washed coal.
Clearfield Coal Co., Clearfield.	14.79	19.86	56.35	76.69	74.43	25.57	319	128	1	3.60	1.560	89.87	0.005	9.41	......	....	0.667	T. T. Morrell, chemist.
Munson coke, Clearfield.	14.09	19.37	53.71	72.30	72.23	27.77	180	70	1½	3.00	1.186	84.30	0.520	13.74	1.41	0.022	....	Do.
Hon. Hy. Rawle, Butler county.	13.35	21.11	50.66	80.46	58.68	41.32	266	107	1	3.30	1.300	92.04	......	7.18	0.78	....	....	Do.

From the above table it will be seen that the Allegheny coal region affords a wide area for coke-making, and it is remarkable that, so far as disclosed in the practice hitherto, economy of production and good quality of coke are closely allied. It also affords a wide field for the application of ovens adapted to the peculiar wants of each family of coking coals.

It may be urged that the Connellsville and Allegheny Mountain belts may become exhausted. To this it may be shown that the law of similarity of composition of coals in each basin would afford a large additional supply of coking coal. The lower productive coal-measures in the Connellsville basin must produce at least twice as much coking coal as the great upper bed, and the belt of coals between the Johnstown sub-basin and the Connellsville basin should also afford a very extensive supply of coking coals. It would appear, therefore, that the present demands the utilization of the best coking coals with the utmost economy in the production of coke.

Though no coke was made in Somerset county in the census year, I am informed that there are 30 bee-hive ovens at Ursina, built about 1868 or 1870, but as the coal failed to make a marketable coke these ovens were abandoned, and have not been in operation for some years. The company has recently been reorganized, and the ovens will be repaired and put in operation. Coking is also now being done at other places in this county.

The Appalachian coal-field, at its northern extremity, breaks into a number of small detached coal-basins. From the coal of one of these, the Blossburg, in Tioga county, 33,572 tons of coke were made in the census year, all from washed slack, 53,777 tons being consumed. Slack both from the Bloss bed (Upper Kittanning) and the Seymour bed, which lies some 150 feet above, is used, but the Seymour-bed slack furnishes much the larger proportion. This bed is from 3 to 3½ feet thick. The coal is semi-bituminous, bright and shining, and is very tender, carrying numerous thin partings of iron pyrites and a large amount of mineral charcoal. An average specimen of the coal from this bed, as analyzed by A. S. McCreath, gave the following result:

	Per cent.
Water	1.180
Volatile matter	21.586
Fixed carbon	71.574
Sulphur	0.907
Ash	4.753

I have no analysis of the slack, washed or unwashed, but an analysis of the washed coke is given in report MM of the *Pennsylvania Geological Survey*, page 110, as follows:

	Per cent.
Water	0.175
Volatile matter	0.722
Fixed carbon	84.760
Sulphur	0.998
Ash	13.345

The screenings are thoroughly washed and coked in bee-hive ovens, the yield being about 62 per cent. of the washed slack. The ovens are burned from 48 to 72 hours, and the coke is watered in the oven. When properly burned, it is an open, porous, cellular, ringing, and strongly coherent coke, and its physical structure is very good. From its location the manufacture of coke at this point is commercially of considerable importance, a large portion of New York state being supplied with this fuel. Two ovens were erected at McIntyre, in Lycoming county, during the census year, and experiments looking to the utilization of this so-called McIntyre coal were made.

But little coke is made from the coal of the Pittsburgh bed at or near Pittsburgh. There are two reasons for this. In the first place the coal does not make as good a coke for smelting iron as that from the same bed at Connellsville, which is only some 60 miles distant. While the coke is as pure, indeed somewhat purer, the coal contains so much volatile matter that the coke is generally too porous for blast-furnace purposes when the lump or run of the mine is used. In addition to this, the coal at Pittsburgh is more valuable for other purposes than for coke, and by using an oven adapted to coking this coal, good coke could be made, but under present circumstances it would not pay.

Notwithstanding these facts, Allegheny county ranked fourth in order of production among the counties of Pennsylvania in the census year. It also made more coke than any of the states except Pennsylvania, Ohio, and West Virginia, its production being only 35 tons less than that of the latter state. There were produced in this county 95,685 tons of coke from 166,700 tons of coal, all but 10,618 tons of which were slack. Most of the slack was washed. It will be noted that while the larger number of ovens were bee-hive, 140 were Belgian, nearly half of those in the United States. Considerable success has been reached in coking Pittsburgh slack in this oven, and it is a curious fact that in western Pennsylvania, where the bee-hive oven is used so extensively, and, indeed, where it is the best oven for most of the coal now coked, the Belgian oven has also been used the most successfully, these Pittsburgh ovens and those at Johnstown showing the best results of any flue ovens in this country. It is also worthy of note that the coke is watered inside the Belgian ovens at Pittsburgh. Probably this practice obtains nowhere else.

A noticeable feature of the manufacture of coke in Pittsburgh and vicinity is that it is chiefly to utilize what would otherwise be a waste product. Slack is used in other sections, but nowhere to the extent that it is used at Pittsburgh. In what is sometimes called the Pittsburgh district, which includes Allegheny county and those portions of Fayette and Westmoreland counties outside of the Connellsville region, in which 216,429 tons of coke were made in the census year from 389,505 tons of coal used, only about 25,000 tons, or 6 per cent. of the whole amount, was lump coal or run of the mine, and more than half of this was used, as has already been explained, in bee-hive ovens for the purpose of manufacturing gas, the coke being a by-product, so that of the entire amount of coal used in this Pittsburgh district directly for the manufacture of coke about 2½ per cent. only was lump coal.

The following table gives the chief statistical items concerning the make of coke in Allegheny county in the census year:

County.	No. of establishments.	Capital.	Ovens.		Number of employées.	Wages paid.	Coal.		Coke.	
			Number built.	Number building.			Tons used.	Value.	Tons produced.	Value.
Allegheny	17	$325,150	476	20	171	$59,485	166,700	$119,718	95,685	$235,915

Outside of the districts already mentioned the manufacture of coke in the state of Pennsylvania was of comparatively small importance, although the total make of these counties is much greater than the entire make of a number of the states. The coke, however, is either produced for the purpose of utilizing screenings, which would otherwise be wasted, or to supply some local blast-furnace with fuel.

In the Allegheny River region, which may be regarded as including the ovens in the valleys of the Allegheny and Redbank rivers above Pittsburgh, coke was made in Armstrong, Butler, and Clarion counties in the census year. But 7,000 tons were made in Armstrong county, all in pits or mounds. This coke was made from Upper Freeport coal, Mr. McCreath's analysis of a fair average specimen being as follows:

	Per cent.
Water	1.700
Volatile matter	35.520
Fixed carbon	55.545
Sulphur	0.835
Ash	6.630
Yield of coal in coke	63.0100
Phosphorus in coal	0.0684
Phosphorus in coke	0.1085

The coking is badly done in open-air ricks, requiring from 8 to 10 days in the operation, according to the state of the weather. The coke is very tender, and is an inferior fuel; crushing and washing the coal before coking would improve it. It is used in a local blast-furnace. Another works was in course of construction. (*a*)

a At this works, which is now (1882) in operation, the coal is washed, and a very good blast-furnace fuel is made.

In Butler county coke (400 tons) was made at one small works for the purpose of utilizing slack from the mine.

In Clarion county there are two coke works, but one of which was in operation in the census year. The idle works, when in operation, supply coke to a blast-furnace which was idle during the entire year. The coke made is from the Upper Freeport coal, the bed ranging from 2 feet 6 inches to 4 feet 3 inches, the coke showing the following analysis:

Water	0.230
Volatile matter	1.106
Fixed carbon	88.360
Sulphur	1.076
Ash	9.228

At the works which were in operation in this county coke was only made for the utilization of slack, the coal in this case being the Lower Freeport, and the yield in coke being 67 per cent. The coal is from 5½ to 6½ feet thick. The slack is mixed with considerable slate and fire-clay, necessitating careful washing, which is done by a Stutz washer. The following analyses show the effect of washing on the coal and coke:

	Unwashed slack. Per cent.	Washed slack. Per cent.
Water	1.260	1.300
Volatile matter	35.130	35.825
Fixed carbon	51.397	54.223
Sulphur	1.988	1.312
Ash	10.225	7.340

COKE FROM WASHED SLACK.

Water	0.033
Volatile matter	0.623
Fixed carbon	85.777
Sulphur	2.107
Ash	11.463

The cost of washing is about 12 cents a ton, but on a large scale it would be somewhat less. The coke is bright, silvery, of rather an open structure, with small masses of slate included.

In Washington county 1,200 tons of coke were made in the census year; but like most of the other coke made on the Pan-Handle railroad near Pittsburgh, it was only made to utilize a portion of the slack at the mine, as at times it is more profitable to sell the slack.

In Beaver county there was one small works, making altogether but 506 tons of coke from slack produced at a small mine. The coal used is from the Kittanning bed. This bed is in two benches, the upper a hard, dull, open-burning coal, with some pyrites, and the lower a bright, oily, soft coking coal. Much of the lower part comes out as slack and nut coal, and is coked. The coke is firm and porous, has a bright silvery luster, and is used in the steel cutlery and other works at Beaver Falls. The analysis of this coal and coke is as follows:

	Coal. Per cent.	Coke. Per cent.
Water	2.400	0.010
Volatile matter	38.110	0.633
Fixed carbon	54.619	84.727
Sulphur	0.791	1.994
Ash	4.080	12.636

It is evident that the coal is a picked specimen, and that the slack from which the coke was made contained a larger proportion of slate than coal.

In Lawrence county 3,941 tons of coke were made in the census year, washed slack from the mines in the vicinity of New Castle being used. These works had been idle for some years, but owing to the increased demand for coke that sprung up in the census year the works were repaired and run. There are also some coke-ovens connected with the Wampum furnace, but these were idle the entire year. When running, they make coke from the Darlington or Upper Kittanning coal. The coke is mixed with Connellsville and is used in the furnace.

THE COKE INDUSTRY IN WEST VIRGINIA.

Coke to the amount of 95,720 tons was made in four counties of West Virginia in the census year. The following table, condensed from Table I of this report, gives the chief statistical items concerning its manufacture:

Counties.	No. of establishments.	Capital.	Ovens.		Number of employés.	Wages paid.	Coal.		Coke.	
			Number built.	Number building.			Tons used.	Value.	Tons produced.	Value.
Fayette	6	$239,000	238	134	99	$27,612	88,769	$84,444	57,943	$127,588
Marion	1	14,000	36	....	5	2,000	4,200	2,100	2,800	4,000
Ohio	1	3,000	3	1	2	480	2,180	2,000	1,200	3,000
Preston	4	74,000	130	16	57	18,850	53,331	47,400	33,777	82,000
Total	12	330,000	407	151	163	48,942	148,480	135,944	95,720	216,588

In order of production West Virginia ranked third among the states, producing 3.48 per cent. of the entire make. In yield of coal in coke the returns contained in the table on page 11 show that Indiana coal surpassed that of West Virginia; and, disregarding the Indiana manufacture as little more than experimental, West Virginia, in this respect, stands first, closely followed by Pennsylvania. Indeed, the yield in coke of the coal of these two states may be regarded as the same.

The most important, as well as the best known, of the coking coal-fields of this state is the New River field, which lies principally in Fayette and Raleigh counties, extending along the course of the New river (*a*) and its tributaries about 40 miles. Reports of recent investigations include the Flat Top coal-field in the New River district, which would extend this district to Mercer county, and make its total length 80 miles. The relations of these fields to the New river and the Chesapeake and Ohio railway and the Norfolk and Western railroad will be seen by an inspection of the accompanying map, prepared specially for this report, by Major Jed. Hotchkiss.

Along the sides of the escarpment of these mountains, fronting on the cañon of New river and its many tributaries, the outcroppings of several veins of bituminous and semi-bituminous coal are exposed, varying in thickness from a few inches to over seven feet, (*b*) five of them being workable, containing 3 feet of coal and upward. The coking property of these coals, in view of their relations to extensive deposits of iron ore, makes them very valuable, the coke made from them being an admirable blast-furnace fuel, second to none in the country. It "stands up" well in the furnace, has a high percentage of carbon and low percentage of ash, sulphur, and phosphorus, and in the practical test of furnace work has shown results that have not been surpassed by any other coke in the country. At the Longdale furnace, with 72-hour coke and an ore with 50 per cent. metallic iron, 5 per cent. silica, and of an aluminous nature, a ton of pig-iron has been made with a ton of coke, and this not for a day at a time, but for some weeks in succession. The average consumption for the entire blast would be in excess of this. As a result of this excellent character, coke is rapidly coming into use in the iron furnaces of Virginia and the Ohio valley, and the number of ovens has largely increased since the census year. (*c*)

The bee-hive oven was the only form of oven used in this region in the census year, but ovens on the Coppée system are being constructed in Virginia to coke the New River coal. The charge of coal to each oven is three tons; the time of coking is 48 hours, except on Fridays and Saturdays, when the charge is increased and the coking continued for 72 hours. The coal yields about 64 per cent. of coke. This is to be understood as the average, not the uniform yield. The yield at Sewell in 1879 was 65⅝ per cent.; at Quinnimont, for five months, 66.7 per cent. The chief points in New River region at which coke was manufactured during the census year, following the line of the Chesapeake and Ohio railway, are Quinnimont, Fire Creek, Sewell (Longdale Iron Company), Nuttallburg, and Hawk's Nest. Below we give analyses of the coals of this region, and the furnace cokes made from them:

Constituents.	Quinnimont coal.			Fire Creek coal.		Longdale coal.§	Nuttallburg coal.		Hawk's Nest coal.‖	Anstead coal.
	No. 1.*	No. 2, lump coal.†	No. 3, slack.†	No. 1.‡	No. 2.		No. 1.§	No. 2.†		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Fixed carbon	75.89	79.26	79.40	75.02	75.499	72.32	69.00	70.67	75.37	63.10
Volatile matter	18.19	18.65	17.57	22.34	22.425	21.38	29.59	25.35	21.83	32.61
Ash	4.68	1.11	1.92	1.47	0.805	5.27	1.07	2.10	1.87	2.15
Sulphur	0.30	0.23	0.28	0.56	0.536	0.27	0.78	0.57	0.26	0.74
Water	0.94	0.76	0.83	0.61	0.735	1.03	0.34	1.35	0.93	1.49
Phosphorus								0.08		
Total	100.00	100.01	100.00	100.00	100.000	100.27	100.78	100.12	100.26	100.00

* Analyst: J. B. Britton. † Analyst: Professor Egleston. ‡ Analyst: Dr. Ricketts. § Analyst: C. E. Dwight. ‖ Analyst: J. W. Mallet.

As the Flat Top coal is now (1882) included in the New River region, and is rapidly assuming importance as a coking coal, we give the following analysis by A. S. McCreath:

	Per cent.
Water	0.932
Volatile matter	20.738
Fixed carbon	73.728
Sulphur	0.618
Ash	3.984
Laboratory coke	78.3300
Phosphorus	0.0013

a The upper part of the Kanawha is called the New river.

b Four feet is the generally-stated maximum thickness of any of these seams, but a letter from Major Hotchkiss puts it at 12 feet. This probably refers to the Flat Top region, and not to that section where coke was produced in the census year. In Professor McCreath's section of this coal at Pocahontas, published in *Mineral Wealth of Virginia*, 4 feet 8 inches of the 11 feet 8 inches is described as "coal with irregular thin slate streaks". With such a coal, if it is included, an analysis showing but 3.984 per cent. of ash is remarkable.

c Mr. Jed. Hotchkiss, in the October (1882) number of his journal, *The Virginias*, published at Staunton, Virginia, gives the number of coke ovens in operation on the line of the Chesapeake and Ohio railway as 731, very nearly double the entire number of ovens in the state in 1879–'80, and more than three times the number in the New River region at that date.

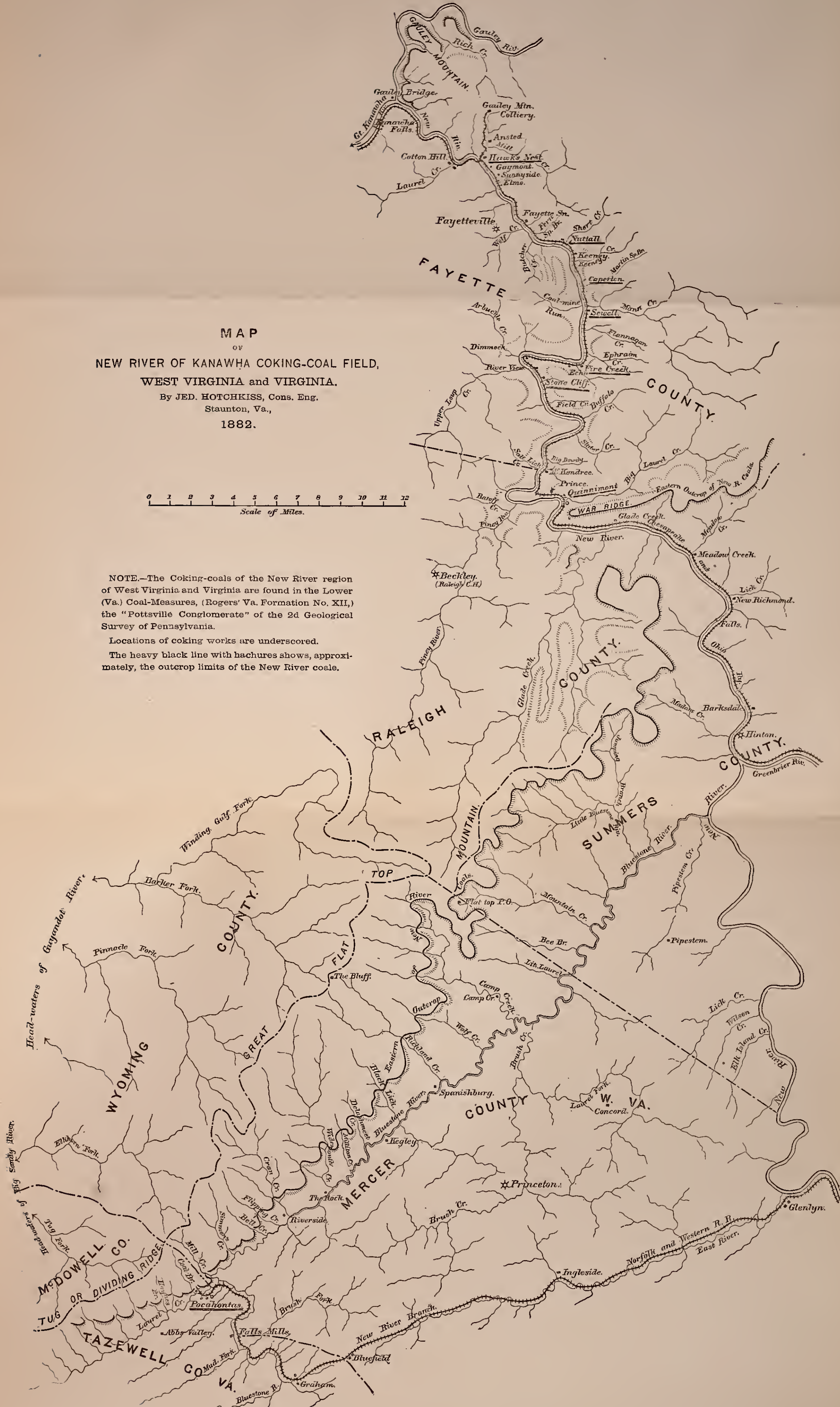
Gauley Mountain.
Gauley Riv.
Rich Cr.
Gauley Bridge.
Gt. Kanawha Riv.
Kanawha Falls.
New Riv.
Gauley Mtn. Colliery.
Ansted.
Mill
Hawks Nest.
Cr.
Cotton Hill.
Gaymont.
Sunnyside.
Elmo.
Laurel Cr.
Fayetteville.
Fayette Sn.
Ferry
Sp. Br.
Short Cr.
Wolf Cr.
Nuttall.
Butcher Cr.
Keeney.
Keeney's Cr.
Martin Sp. Br.
Caperton.
Coal
FAYETTE
TAZEWELL CO. VA.
Mud. Fork.
Bluefield
Graham.
Bluestone R.

MAP

OF

NEW RIVER OF KANAWHA COKING-COAL FIELD, WEST VIRGINIA and VIRGINIA.

By JED. HOTCHKISS, Cons. Eng.
Staunton, Va.,
1882.



NOTE.—The Coking-coals of the New River region of West Virginia and Virginia are found in the Lower (Va.) Coal-Measures, (Rogers' Va. Formation No. XII,) the "Pottsville Conglomerate" of the 2d Geological Survey of Pennsylvania.

Locations of coking works are underscored.

The heavy black line with hachures shows, approximately, the outcrop limits of the New River coals.

The following are analyses of industrial coke made from New River coals:

Constituents.	QUINNIMONT.		FIRE CREEK.		Longdale.‡	Nuttallburg.‡
	No. 1.*	No. 2.†	No. 1.*	No. 2.		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Volatile matter				0.492		
Carbon	93.85	93.11	92.180	91.940	93.00	92.22
Ash	5.85	5.94	6.680	6.928	6.73	7.53
Sulphur	0 30	0.82	0.618	0.538	0.27	0.92
Moisture			0.110	0.102		
Total	100.00	99.87	99.588	100.00	100.00	100.67

* Analyst: J. B. Britton. † Analyst: Professor Egleston. ‡ Analyst: C. E. Dwight.

The relation between the ash in the coals and cokes of which analyses are given will not fail to be noted. In but two of these analyses (Quinnimont No. 1. and Longdale) is the per cent. of ash in the coal and coke near what it should be theoretically. In all of the others the ash in the coke is much in excess of that which should be found in cokes made from coals of which the analyses are given. The ash in these cokes, however, is very low, but the cokes could not have been made from coal containing no more ash than the analyses show.

There are now (December, 1882) 200 coke ovens in the Flat Top region in process of construction. The coal-beds are reached at railway level, so that no inclines are needed. Of the large vein opened at Pocahontas Major Hotchkiss writes:

I have been into it over half a mile, and have had it fully proved for miles to the northeast, along the Bluestone slope of Flat Top. The New River coal-beds begin to thicken as soon as you cross New river from the Chesapeake and Ohio railway, and, from what we now know, attain their greatest thickness in the Flat Top region. No coal was coked from this particular bed during the census year.

The only other county in which coke was made to any considerable amount in the census year was Preston, all in bee-hive ovens, and most, if not all of it, for use in the local blast-furnaces, generally by the owners or lessees of the furnaces. Professor Maury, in *The Resources of West Virginia*, describes the Preston County coal-basin as bounded on the east by the Briery mountains, on the west by Laurel ridge, and is the southerly continuation of the Ligonier valley of the Pennsylvania survey. At the Irondale furnace a seam 4 feet thick is worked, giving a coke, which is used in the furnace, with the following analysis:

	Per cent.
Fixed carbon	89.30
Volatile matter	0.54
Moisture	0.16
Sulphur	0.70
Ash	9.30

The coke made in Marion and Ohio counties is commercially of but little importance, that of the former county being only made to utilize the waste coal from a gas-coal mine. The ovens were operated but seven months, and during that time sometimes 5 and at other times 10 of the 36 ovens were operated, and at no one time were more than 15 ovens burning. The Ohio County ovens were run to supply a glass-works with coke, Wheeling coal being used.

THE COKE INDUSTRY IN VIRGINIA.

During the census year no coke was made in Virginia. A number of attempts have been made to coke the coal from the mines near Richmond, and some coke was made in this vicinity during the recent war for cupola use, but it was very poor stuff, and could only be used under the exceptional circumstances then existing. At the present time Virginia coke cannot compete in quality with that from New river or from Connellsville; indeed there is little or no coal in Virginia that has as yet been developed that can be adapted to the manufacture of coke. The Lowmoor Iron Company, at Lowmoor, Virginia, were building ovens during the census year, but made no coke. Their supplies of coal are to be drawn from the New river, in West Virginia. The Iron and Steel Works Company of Virginia, limited, have since the census year begun the building of 80 Coppée ovens at Goshen Bridge, Virginia, but in this case also the coal will be brought from the New River region of West Virginia.

THE COKE INDUSTRY IN OHIO.

Ohio held the second rank among the states in the production of coke in the census year, producing 109,296 tons, or 3.98 per cent. of the entire amount. The following table, condensed from Table I of this report, gives the chief statistical items concerning its manufacture:

Counties.	No. of establishments.	Capital.	OVENS.		Number of employés.	Wages paid.	COAL.		COKE.	
			Number built.	Number building.			Tons used.	Value.	Tons produced.	Value.
Athens	1	$2,000	8	12	7	$375	1,130	$960	565	$2,097
Columbiana	2	57,500	195		27	11,965	67,646	101,469	39,424	125,652
Hamilton	3	14,000	22		13	4,012	14,922	16,471	0,806	42,887
Jefferson	6	61,512	344		99	34,645	107,189	104,553	57,684	156,902
Mahoning	2	2,000	10		3	480	1,361	1,779	1,017	3,808
Tuscarawas	1	7,000	40		4	500	1,600	3,200	800	3,200
Total	15	144,012	619	12	153	51,977	193,848	228,432	109,296	334,540

While much of the coal of this state is excellent for many purposes, there is but little as well adapted to the manufacture of coke as some of the coals of Pennsylvania, West Virginia, and Alabama, though most of the seams of coking coal are geologically the same as those of the former. They appear, however, at their best as they approach the mountains. Much of the coal used in Ohio gives a coke that is soft and brittle, and often high in sulphur and ash. This is not true of all the cokes, however, some being remarkably pure. The yield in coke is not as great as that of the coal of the same seams in the states mentioned above, being on an average only 58.64 per cent., one of the lowest yields in the country, Tennessee and Illinois only showing a lower yield.

The chief localities in which coke was made in Ohio in the census year were Columbiana and Jefferson counties, which produced 97,108 tons of the 109,296 tons made in the state, or about 89 per cent. Most, if not all, of this was consumed in the blast-furnaces located at or near the ovens, the Columbiana coke being used at the Leetonia furnaces and the Jefferson County coke at the Steubenville furnaces.

Of the coal from which the Columbiana County coke is made Professor Newberry says: "It is remarkably pure, and makes a coke of superior quality."(*a*) A portion of the coke reported as made in Columbiana county was made in Mahoning county, the Cherry Valley iron works, which are situated in the former, having ovens in the latter and finding it impossible to separate the product of the two. Mr. J. C. Chamberlain, of this works, writes me regarding their coal and coke as follows:

We have a mine and coke ovens on the Mahoning county side, another mine and coke ovens on the Columbiana county side, and a mile and a half south, at Leetonia, we have still another mine and coke ovens. All three of these mines are working the same seam of coal; this is positive, and there is no material difference in the coke; if anything the middle mine produces coal a little freer from sulphur. It is from this mine that the "Washingtonville coke" received its name. We call all our coke by that name. The coal is, according to Professor Newberry's classification, "No. 4," but further and later examinations will place it one if not two veins higher in the series. The greatest thickness of the seam is 3 feet, the average is 30 inches, of which from 4 to 6 inches of the top of the seam we do not coke, but use in the furnace in its raw state. This upper 6 inches is very hard and a little slaty. The bottom 2 feet we coke, using slack and lump coal or slack only, just as circumstances require. Generally we run the coal over a 2-inch screen and sell or use the lump coal at the furnace or rolling-mill, coking only the screenings. The coal is remarkably pure, is free from sulphur, and has a very low per cent. of ash.

The following is an analysis of No. 4 seam coal, Leetonia, Ohio, thickness 2 feet 6 inches:

	Per cent.
Water	2.56
Volatile combustible matter	39.60
Fixed carbon	56.04
Ash	1.80
Sulphur	0.53
Specific gravity	1.213

Coke compact; ash white.

Two analyses of oven coke made at Leetonia are as follows:

	Per cent.	Per cent.
Carbon	93.75	95.50
Ash	5.38	3.30
Sulphur	0.87	1.20
Silica in ash		3.02

Mr. Chamberlain writes me that the analysis of 1.20 of sulphur is the only one he has ever seen of this coke that showed over 1 per cent. This coke is not so compact as that at Connellsville, and will not stand transportation so well, but it is used in the Leetonia furnace, and is regarded as better than Connellsville for the native ores. It is also claimed that it will carry as much burden by weight as Connellsville coke.

This coal, when coked in bee-hive ovens, yields from 55 to 58 per cent. in coke, and is mined, paying for slack and "top" coal at 69 cents per ton of 2,100 pounds. The miners keep the top coal separate.

An analysis of picked samples of the coal used for coking at Steubenville, Jefferson county, shows a very pure coal, containing less than 2 per cent of ash. As this coal is somewhat slaty, the samples from which the analysis was made must have been a very good selection. Mr. William H. Wallace, president of the Jefferson iron works at Steubenville, which was the largest producer of coke in Ohio in the census year, writes regarding Steubenville coke as follows:

In reply to your inquiries in regard to Steubenville coke I would say: It is soft and brittle; it breaks very easily, and a large proportion of it becomes fine and like dust, even in transporting it from the ovens to our blast-furnaces, a few hundred yards distant. As compared with Connellsville coke, it is difficult to give more than an approximate statement. We have not used the Connellsville coke alone, but usually in the proportion of one-half Connellsville and one-half Steubenville coke. We find that it not only increases the output of the furnaces from 25 to 35 per cent. when used in this way, but the amount consumed per ton of pig-iron is less, being 85 to 90 bushels of Steubenville, and but 77½ bushels when mixed half and half. The Connellsville coke does not improve the quality of the iron when mixed with the Steubenville coke, and our forge manager, a practical boiler of many years' experience, has said that the iron is deteriorated in quality by the admixture. As we use a large proportion of good lump coal in making our coke, it costs us not far from 4½ cents per bushel, or $2 25 per ton. The Connellsville coke costs us from $1 25 to $1 75 per ton at the ovens; freight to Pittsburgh $1 16⅝, and freight from Pittsburgh to Steubenville $1; making it cost here from $3 41⅝ to $3 91⅝ per ton. If we could get the

a *Geology of Ohio*, vol. iii, page 124.

Connellsville coke at $2 75 per ton it would not pay us to make our own coke, as the superior quality of the Connellsville coke would overcome the difference in the cost. Our coal contains considerable slate, to which is ascribed, by some, the brittle character of the coke; but it also contains a large amount of charcoal, and it is believed that in crushing and washing the coal to remove the slate this charcoal would be wasted. We use the bee-hive oven, and the views above expressed are the result of opinions formed from experience with coke made in this way. What difference a different process for its manufacture would make, and what improvement in quality might result therefrom, we have no means of ascertaining at present.

The seams of coal at Steubenville are from 3 feet 9 inches to 5 feet thick. The following analyses by Wormley are of shaft coal No. 6 and of coke made from the same in the Steubenville Furnace and Iron Company's ovens:

	Per cent.
Fixed carbon	65.90
Volatile combustible matter	30.90
Ash	1.80
Sulphur	0.98
Water	1.40
Specific gravity	1.308

Coke from this coal analyzed by Wuth as follows:

	Per cent.
Fixed carbon	90.63
Ash	8.38
Sulphur	0.27
Hydrogen	0.72

All of the ovens used at Steubenville are of the bee-hive pattern, and vary somewhat in their dimensions, some being 11 feet in diameter by 5 feet high in the clear, and arched from the bottom, others 10½ feet in diameter with 36-inch spring of arch above wall, 5½ feet high in the clear. In some cases, with a charge of 100 bushels of coal, 72-hour coke is made, and in others, with 75 bushels of coal to the charge, 48-hour coke.

But little coke was made in the great Hocking Valley coal-field during the census year, the single establishment reported as in existence having been built during the year and operated from March only. While much of the coal in this region is adapted to use in the blast-furnace raw, and therefore does not need to be coked, other coals are well adapted to the manufacture of coke. Dr. T. Sterry Hunt (a) thinks that coal No. 7 will yield a good coke, while the lower four feet of the great Pittsburgh seam, so fully developed in Big Run, gives a coke of superior appearance. Mr. E. C. Pechin, whose long experience in the manufacture of iron in the Connellsville region gives his views special weight, says: (b)

In coal No. 7 the district possesses a coal for making an admirable coke which will shortly play a most important part in the metallurgical operations of the district.

Mr. Pechin, in the same article, refers to a peculiar product of one of the coals of this valley, which he calls "charred coal", which has many of the properties and can be put to many of the uses to which coke is put. He says:

I inspected the oven at XX furnace, which had been experimenting on various coals. The attempt at coking the small coal and slack was not successful, as the heat of the oven was not sufficient to agglutinate the slack; but in charging the slack several large pieces of the coal had gone in with it and had been drawn unbroken. They had retained their original shape, and were extremely hard, resonant, and lustrous. The use of this charred coal will prove of special importance in those districts where coal No. 7 is either not found or becomes too impure for smelting purposes.

But little coke is reported as made in Mahoning county. A part of that reported in Columbiana county, however, was made in that county, and all information received is to the effect that some very good seams of exceedingly pure coking coal exist there. At Washingtonville there is one of the purest coals in the state, containing very little sulphur and not more that 2 per cent. of ash. The vein is 2½ feet thick, and some little coke was made from it at this point. The coke made in Columbiana county was nearly, if not quite, all from the same seam. Formerly this Washingtonville seam is reported to have been extensively coked, and to have furnished a fuel regarded as excellent for blast-furnace purposes. One reason probably why this coal has not been more extensively used is that Mahoning county furnishes the well-known Brier Hill or Mahoning coal, called locally "block coal", used largely for iron-smelting. Though this coal has more bitumen and less carbon than well-known coking coals, it is non-coking, and can be used raw in the furnace.

It will also be noticed from the table on page 41 that some little coke was made in Tuscarawas county; but though this county contains some coal fairly well adapted to coking, and though many attempts have been made to establish the manufacture of coke on a commercial scale within its limits, they have up to this time been unsuccessful, the failures arising chiefly from unskillful management and the necessity of thoroughly washing the coal to remove the ash and sulphur. There is no doubt that some of the coals of Tuscarawas county, especially coal No. 5 and coal No. 6 of the geological survey, by proper washing will give good coke. That already made is generally strong, adhesive, has a high heating power, and is capable of bearing a heavy burden; but its high percentage of ash and sulphur precludes its use unless thoroughly and carefully washed, which has not yet been done.

a *Coal and Iron of Southern Ohio*, T. Sterry Hunt, Salem, Massachusetts, 1874, page 78.
b *Metallurgical Review*, vol. i, page 107.

The attempts to use the coal of Tuscarawas county at the Glasgow-Port Washington furnaces resulted in the loss of large amounts of capital invested in iron and coal land plant and operations by a company of Scotch capitalists. (*a*)

All of the coke in Hamilton county was made from the screenings of Pittsburgh and other coals gathered from the coal-boats and coal-yards.

Some attempts have also been made to use the Vinton County coals, and others of the Hanging Rock region, for the manufacture of coke, but with little success so far, though with proper methods and care a fair coke can no doubt be produced. A block of Belgian ovens are standing at the Vinton furnace, but they have been idle for some years, and there was no coke made in the census year.

THE COKE INDUSTRY IN TENNESSEE.

Coke to the amount of 91,675 tons was made in Tennessee in the census year at four works located in three counties. The following statement, condensed from Table I, will give the chief statistical items concerning its manufacture:

Counties.	No. of establishments.	Capital.	Ovens.		Number of employés.	Wages paid.	Coal.		Coke.	
			Number built.	Number building.			Tons used.	Value.	Tons produced.	Value.
Grundy	1	$125,000	404	102	79	$24,000	120,000	$56,200	60,000	$120,000
Marion	2	56,021	118	30	18	7,820	19,311	27,937	11,675	42,493
Roane	1	19,000	67	20	17	7,000	40,000	40,000	20,000	50,000
Total	4	200,021	589	152	114	38,820	179,311	124,137	91,675	212,493

As a coke-producing state Tennessee holds the fourth rank, supplying 3.33 per cent. of the entire product. In no other state, however, was the average output so great as in Tennessee, the average for each of the four works being 22,919 tons, Pennsylvania, which was the next, averaging 22,280 tons.

The coal-fields of Tennessee, which are a continuation of the great bituminous deposits of western Pennsylvania and West Virginia, are computed to cover an area of 5,100 square miles. These fields extend through the state from northeast to southwest, are coextensive with the Cumberland table, about one-half the area being in middle Tennessee and the other in eastern Tennessee, and form an irregular quadrilateral, 71 miles wide at the northern border and 50 at the southern. In the southern portion of the field, on the eastern side, is a deep gorge, canoe-shaped, with sharp escarpments rising from 800 to 2,000 feet above the valley, through which the Sequatchie river flows. The Sequatchie valley or trough thus formed is 160 miles long, the Tennessee part being 60 and the Alabama 100 miles in length. It was in this valley, and that of its feeder, the Little Sequatchie, that most of the coke produced in the census year was burned.

The most important as well as the best known of the coke-producing localities of Tennessee are the Sewanee mines, in Grundy county, in the Little Sequatchie coal-field, sometimes called the Tracy City mines. This coal-seam is in the Upper Measures, is supposed to correspond to bed B of the Pennsylvania geological survey, and is to the state of Tennessee what the Pittsburgh seam is to the state of Pennsylvania. It will average 4½ feet in thickness, its largest development being 10 feet 4 inches, its smallest 2 feet, and varies somewhat in its characteristics and constituents in different localities. The Sewanee coal, as mined at Tracy City, is semi-bituminous, conchoidal in fracture, reasonably low in ash, and almost wanting in sulphur. The cohesion of this coke is slight, having the same tendency to disintegrate on exposure to the atmosphere that the Connellsville coke has. For this reason, and from the fact that it is an excellent coking coal, it is more largely used for coke than it otherwise would be. The coke is made in part from the slack, which contains, of course, a larger amount of slate than the coal, and accounts for the large percentage of ash in the coke as compared with the ash in the coal. Analyses of the Sewanee coal and coke are as follows:

ANALYSIS OF THE SEWANEE (TENNESSEE) COAL.

Constituents.	No. 1.*	No. 2.†	No. 3.‡
	Per cent.	*Per cent.*	*Per cent.*
Water			1.6
Volatile matter	29.9	29.0	29.3
Fixed carbon	63.5	65.5	61.0
Ash	6.6	5.5	7.8
Sulphur	Trace.		Trace.

* Analyst: H. T. Yaran. † Analyst: F. Zwicke. ‡ Analyst: Robertson.

a Report for 1882 of Mr. Andrew Roy, mine inspector of Ohio.

ANALYSIS OF SEWANEE (TENNESSEE) COKE.

[Analyst, W. S. Land.]

	Per cent.
Fixed carbon	83.364
Ash	15.440
Sulphur	0.142
Undetermined	1.054

The coke made at Tracy City was all burned in bee-hive ovens, of which 404 were built at the close of the census year and 102 were being built. The ovens at these works vary in size and shape, the old ones of the regular bee-hive pattern being 10 feet in diameter and 4½ feet high inside, while the latest built are 11 feet in diameter and 8 feet high. The larger ovens seem to work the best, making the most compact and the densest coke. From 100 to 120 bushels of coal are charged into each of these ovens, and the coke is burned 48 hours. The yield is about 58 per cent. At the Rattlesnake mines of this company the ovens are oval or egg-shaped, 9½ by 14 feet and 5½ feet high inside; eighty bushels are charged. The labor at these mines and works is largely done by convicts, 306 convicts and 300 free hands being employed at the close of 1880.

In Marion county, which joins Grundy county, there were two coke works in the census year, the Etna and the Southern States Coal and Iron Company. At the Etna works two veins, called the Kelly and the Oak Hill, are worked. From the Kelly mine a coke is made for foundery use exclusively, while from the Oak Hill coke for blast-furnace use is made. The Kelly seam is frequently regarded as the equivalent of the Sewanee at Tracy City, and J. B. Killebrew, the commissioner of mines of Tennessee, shares in this opinion. It is asserted, however, by the Etna Coal Company, who mine the Kelly coal, that in appearance and general characteristics these coals are as different as two coals of the same formation can well be, and samples of both seem to bear out this claim. In Professor Safford's *Geology of Tennessee* (pages 369–382) the difference between the two measures can be readily distinguished. The impression as to the identity of these two coals probably arises from the fact that both lie in the upper plateau of their respective regions. The Etna Coal Company claim, however, that the "Kelly", the "Oak Hill", and the "Slate" veins do not appear at any other point in this region. At Tracy City only eight veins are shown, while the Etna Coal Company claim eleven at their mines. A section at the Kelly mines shows two conglomerates, while at the Sewanee mines there is only one.

About one-fourth of the product of the mines is coked, all in bee-hive ovens. The coke from the Kelly seam is sent all over the South, where it has an especially enviable reputation for foundery purposes, commanding at the present time for this use $6 25 per ton on cars at the mines. This coal is not washed before coking. Below will be found analyses of the Kelly coal and of the Kelly and the Oak Hill cokes:

ANALYSIS OF KELLY COAL.

[Analyst, Professor Shale, New York.]

	Per cent.
Water	1.30
Volatile matter	21.10
Fixed carbon	74.20
Ash	2.70
Sulphur	0.70

ANALYSIS OF KELLY AND OAK HILL COKES.

Constituents.	Kelly.*	Oak Hill.*
	Per cent.	*Per cent.*
Fixed carbon	94.56	83.05
Ash	4.65	16.95
Sulphur	0.79	....

* Analyst: William Manthey.

The coke at these works is made in bee-hive ovens ranging from 9 feet in diameter and 5 feet high to 11 feet in diameter and 6 feet high. In the smaller ovens 80 bushels of coal are charged, and in the larger from 100 to 120 bushels. The Oak Hill (blast-furnace) coke is burned from 48 to 60 hours, and the Kelly (foundery) coke 72 hours.

The other works in Marion county is that of the Southern States Coal and Iron Company. The coal from these mines resembles the Sewanee in structure, but contains a large quantity of sulphur in balls and plates from the size of a pea to pieces 8 or 10 inches long and from 1 to 1½ inches thick. For manufacture into coke it is therefore all crushed and washed. The ovens are of the usual bee-hive pattern, and are from 10 to 11 feet in diameter and 6 feet high to the crown of the arch.

In Roane county, toward the eastern part of the coal-field, the Roane Iron Company makes coke for its blast-furnaces from a seam of coal nearly identical with the Sewanee vein. The average thickness of this seam is about 5 feet. The coal is easily mined, and makes a dense and valuable coke. Nearly the entire product is converted into coke and used at the works of the company at Rockwood, where the mines and furnaces are located. On page 46 will be found and analysis of the coal and coke at Rockwood.

ANALYSIS OF ROCKWOOD COAL.

[Chemist, W. S. Land.]

	Per cent.
Moisture	1.49
Sulphur	0.33
Volatile matter	26.62
Fixed carbon	63.74
Ash	7.82

ANALYSIS OF ROCKWOOD COKE.

[Chemist, W. S. Land.]

	Per cent.
Fixed carbon	84.187
Ash	14.141
Sulphur	.182
Undetermined	1.490

The coke at these works is made in the ordinary bee-hive oven, from 9 to 11 feet in diameter and from 4½ to 6 feet in height. Forty-eight hours are allowed for coking. The coke is taken in bogies hot directly to the furnaces, which are situated contiguous to the ovens. Since the close of the census year the works at this point have been largely increased.

THE COKE INDUSTRY IN ALABAMA.

Alabama possesses three distinct coal-fields or basins, in all of which coking coal is found in abundance. These are the Coosa, which is the most easterly, containing some 300 square miles; (*a*) the Cahaba, with some 230 square miles; and the Warrior, which is the southern end of the great Appalachian coal-field, and which is much the largest of the Alabama basins, covering nearly 4,700 square miles. As in other states, these basins are divided into a number of sub-basins, but little is known of them, owing to the incompleteness of the geological survey, except of a most general character. It is estimated, however, that the Alabama coal-fields underlie more than 5,000 square miles, divided as stated.

The coke made from some of the seams of coal in these fields, especially in the Warrior and the Cahaba fields, the Coosa not being so well known, is an excellent fuel for blast-furnace and foundery purposes, and was largely used by the confederate government at their cannon foundery at Selma, one of the officers pronouncing it "to equal the very best English cokes". Its value has become so manifest that large investments have been made, both during and since the census year, in iron and coal properties, and several blast-furnaces to use coke are either building or have recently been completed.

Alabama ranked sixth as a coke-producing state during the census year, producing 42,035 tons, or 1.53 per cent. of the entire amount, from 67,376 tons of coal, a yield of 62.1 per cent. All of this was made in bee-hive ovens, of which there were 216 built May 31, 1880, and 206 were building. The capital invested in coke works was $135,500; 64 persons were employed, to whom $38,500 of wages were paid.

The coke made during the census year was made in the Warrior and the Cahaba fields. These coal-fields lie very near each other. Below Birmingham, in the vicinity of which are situated the blast-furnaces which consume most of the coke made, they are never more than 7 or 8 miles apart. In the Warrior field coke was made at the Pratt mines and at New Castle, and in the Cahaba field at Helena, by the same company that operates the ovens at the Pratt mines. Both at Pratt and at Helena the works are quite extensive, but at New Castle but little is made.

The Pratt seam is economically the most important of the coals of Alabama, supplying not only a large proportion of the coal used for railroads, mills, and for all general purposes, but nearly all of the coal made into coke. (*b*) The Pratt Company coke a large amount in its own ovens, and sell a still larger amount to furnaces, to be coked at the furnace ovens. The seam at the Pratt mines is 4½ feet thick. The coke is made from unwashed screenings from a 3-inch screen, which accounts for the large amount of ash in the coke as compared with that in the coal, as shown in the analyses.

At New Castle, in this same (Warrior) field, as is stated, but little coke was made, the ovens having been built to use up the slack from the mines at this point. The coke was too high in sulphur for use in smelting iron. A small vein, called the Black Creek, in the Warrior field, has also been used to some extent in coking, and it is stated the coke was superior as a blast-furnace fuel to any other made in the state. The vein, however, is so small, only 2 feet, that it cannot be worked economically.

The first coke made for blast-furnace use in Alabama was from coal of the Cahaba field at Helena, and a portion of the coke used at the blast-furnaces in the state in the census year was supplied from this field, but it is so high in ash, due probably to careless mining, that the Pratt coke is now used in its stead. The only veins in

a I am informed by Prof. Cook, state geologist, that recent investigations make this field some 300 square miles in extent, but 100 square miles will probably include the productive portion of the field.

b At the present time (December, 1882) most of the coke used in the blast-furnaces of Alabama is made from the coal of this seam as mined by the Pratt Coal and Coke Company. This seam has also been opened at another point, at which some coke is now being made.

this Cahaba field that have been used for coke are the Wadsworth and the Helena. Both make a fair coke, but that from the Pratt seam is so much better that it has entirely displaced the Helena for furnace use.

Attempts have been made to use the "Black Shale" seam, of which an analysis is given below, but it was found to have some iron pyrites which carried arsenic, and though its analysis showed it to be a "pure" coal, low in sulphur and ash, it would not make satisfactory metal in the furnace.

Below is given analyses of the coals used in coking in this state, with cokes made from the same:

ANALYSES OF COALS USED IN COKING IN THE WARRIOR FIELD.

Constituents.	PRATT SEAM.		NEW CASTLE OR MILNER SEAM.		BLACK CREEK.	
	No. 1.*	No. 2.†	No. 1.‡	No. 2.†	No. 1.	No. 2.§
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Specific gravity	1.300	1.29	1.38	1.30	1.36	....
Fixed carbon	61.600	64.30	59.69	55.18	71.64	63.12
Volatile matter	31.480	32.08	28.24	36.17	28.24	31.25
Sulphur	0.918	0.47	0.64	1.38	0.64	0.89
Ash	5.416	2.08	10.92	7.83	2.03	5.63
Water	1.508	1.07	0.50	1.12	0.12	....
Yield of coal in coke	....	....	....	....	73.67	68.75

* Analyst: Professor McCalley. † Analyst: N. T. Lupton. ‡ Analyst: Otto Wuth. § Analyst: Eureka Iron Company.

ANALYSES OF COKES MADE FROM COALS OF THE WARRIOR FIELD.

Constituents.	FROM PRATT COAL.						
	No. 1.*	No. 2.†	No. 3.†	No. 4.†	No. 5.†	No. 6.‡	No. 7.‡
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Fixed carbon	93.01	88.15	86.090	83.27	85.81	88.224	84.653
Volatile matter	0.16	0.60	0.910	0.93	0.78	0.990	1.329
Ash	6.83	11.25	13.000	15.06	12.80	11.315	13.317
Sulphur	....	0.70	0.721	0.74	0.61	0.563	0.897
Water	....	....	....	....	....	0.362	0.671

* Analyst: Fred. P. Dewey. † Analyst: Eureka Iron Company. ‡ Analyst: Professor McCalley.

The analyses No. 2 of Pratt coal and No. 1 of coke were furnished by the Pratt Coal and Coke Company.

ANALYSES OF COALS USED IN COKING IN THE CAHABA FIELD.

Constituents.	HELENA SEAM.			Wadsworth.‡	Black Shale.‡
	No. 1.*	No. 2.†	No. 3.‡		
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Specific gravity	1.12	1.32	....	....	....
Fixed carbon	66.81	58.69	59.59	60.53	70.00
Volatile matter	12.44	35.48	34.37	34.60	27.01
Sulphur	....	0.90	0.66	0.68	0.79
Ash	1.21	3.82	6.05	4.87	2.99
Water	2.54	1.74	....	....	....
Yield in coke	....	....	65.63	65.40	....

* Analyst: R. P. Rothwell. † Analyst: Lupton. ‡ Analyst: Eureka Iron Company.

ANALYSES OF COKES MADE FROM THE COALS OF THE CAHABA FIELD.

Constituents.	Helena.*	Wadsworth.*	Not stated.†
	Per cent.	*Per cent.*	*Per cent.*
Specific gravity	1.659	1.693	....
Fixed carbon	84.035	88.903	93.252
Volatile matter	0.066	0.413	0.730
Sulphur	0.445	0.342	0.601
Ash	15.216	10.144	5.380
Water	0.683	0.540	0.300

* Analyst: Professor McCalley. † Analyst: Professor McCreath.

The first ovens built in this state for furnace-coke were Belgian, on the Coppée system, but they were not successful, and were abandoned and bee-hive ovens were erected in their stead, and since that time no others have been used.

THE COKE INDUSTRY IN GEORGIA.

But one coke works was reported in existence in Georgia in the census year, at which 70,000 tons of coke were made from 117,000 tons of coal, a yield of 59.8 per cent. No information has been received as to the extent of the coal-fields or the character of the coal or the coke made from the same. All of the labor at these ovens, of which there were 140, was performed by convicts, the superintendent, mining overseer, and the guards being the only labor not convict. Most of the coke is used at the Rising Fawn furnace, in the same county, and gives fairly good satisfaction. It has considerable ash, but it is thought to be more economical to flux this out in the furnace than to wash it out before coking. (*a*)

THE COKE INDUSTRY IN INDIANA.

Though the *Geological Survey of Indiana* reports that "the seams of coking coal in Indiana are locally not less than fifteen in number", (*b*) some of which are 7 or 8 feet thick, the manufacture of coke can hardly be said to have existed as an industry in this state in the census year, but 1,000 tons being made. The coking coals of this state, according to the various reports of the geological survey, are found in fourteen counties, and some of the seams are said to be "rich-looking and pure". The percentage yield of coke in the laboratory ranges from 52 to 64.50 per cent., and the ash from 0.50 to 7. (*c*)

Notwithstanding this asserted abundance of coking coals and their purity, the manufacture of coke up to and during the census year had not been, in a commercial sense, a success, though repeated attempts to make it so are recorded. Possibly one reason has been that Indiana has not been a large iron-producing state, and for the little iron ore that has been smelted the block coal furnished an excellent fuel. It is also possible that the physical constitution of the coke made from Indiana coals is not such to justify its use as a blast-furnace fuel. Professor Cox, in the *Report of the Indiana Geological Survey*, published in 1879, page 12, states:

> The coking coals of Indiana swell and fuse to a pasty mass when burning, but the coke which is made from them is not strong, and is filled with large cells, that give it a sort of honey-comb appearance.

Probably the most thorough and careful attempt yet made to coke Indiana coal was that of the North Chicago Rolling Mill Company, made since the census year. The coal used was screenings of Coal Creek coal from Fountain county. These screenings contained from 15 to 20 per cent. of ash, which was reduced by washing, so that the coke contained only from 10 to 12 per cent. The sulphur, however, was from $\frac{3}{4}$ to $1\frac{1}{4}$ per cent. Belgian ovens with Endres' modifications were used. The coke, beside being high in sulphur, was spongy and soft, and would not carry a burden in the furnace; but when mixed in the proportion of from 10 to 15 per cent. with Connellsville coke fairly good results were obtained. Mr. O. W. Potter, president of the company making the experiments, writes:

> We are not sure but further experiments in using lump and nut coal and crushing to remove the slate may give us better results than we have had up to this time.

Some attention has been given to charring or coking the block coal of this state. (*d*) The block coal found at Brazil differs but little in chemical composition from the coking coals of western Pennsylvania. The physical difference is, however, quite marked, the latter having a cuboid structure made up of bituminous particles lying against each other, so that, under the action of heat, fusion throughout the mass readily takes place, while block coal is formed of alternate layers of rich bituminous matter and a charcoal-like substance, which is not only very slow of combustion, but so retards the transmission of heat that agglutination is prevented and the coal burns away, layer by layer, retaining its form until consumed. The experiments in charring the coke above referred to arose out of a failure to coke the slack. The lumps as they came from the mine were charged into a hot bee-hive oven, and after a proper interval were drawn, not materially changed in size or shape, but greatly changed in character, being hard, compact, and silvery, like coke. This product was charged into the furnace instead of Connellsville coke (350 pounds of charred coal in the place of 385 pounds of Connellsville coke) with the most satisfactory results, the quantity of iron produced remaining about the same, but of a somewhat higher grade.

Professor Cox has also made some extended experiments on coking Indiana coals under pressure, and is of the opinion that the dry-burning or block coals of Indiana can be made under pressure into a remarkably strong and dense coke.

THE COKE INDUSTRY IN ILLINOIS.

Of the four coke works reported in existence in Illinois in the census year, but one was in operation during any part of the time, and this made 7,600 tons of coke, the entire production of the state, from washed slack. One of the works resumed operations June 1, 1880, one of the others is still idle, and the ovens and machinery at the fourth have been wrecked and a portion of the materials and machinery removed to another point in the state. (*e*)

Much of the coal of Illinois is coking coal, but its chemical and physical nature is such that as yet no coke has

a The company, in December, 1882, were constructing 140 additional ovens.

b *Seventh Annual Report of the Geological Survey of Indiana*, Professor E. T. Cox (Indianapolis, Indiana, 1876), page 11.

c *Second Annual Report Geological Survey*, (Indianapolis, 1871), page 180.

d In vol. iv, page 99, *Transactions of the American Institute of Mining Engineers*, will be found a paper on "Coking Indiana Block Coal", contributed by Mr. John Alexander.

e Since the census year, however, two of the existing works have been enlarged and others built, and the product of coke at present (1882) in this state is much greater than during the time covered by this report.

been made from it equal to the Connellsville as a furnace fuel. The deposits, however, are so large and so near the rich and abundant iron-ore fields of Missouri and lake Superior that the efforts to utilize Illinois coal for the manufacture of coke for metallurgical purposes have been unceasing during the past ten years. Much of this experimenting has been to ascertain what form of oven was best adapted to coking. The bee-hive has not answered the purpose, and not one was in use in the state in the census year. The coals that are low in sulphur and ash are, as a rule, too dry-burning, and the bee-hive is too cold an oven for them. Modifications of the bee-hive, similar in plan to the Welsh ovens, have to a considerable extent been used with fairly good results in southwestern Illinois, though equally good results are obtained with the Big Muddy coal in bee-hive ovens that have been erected as a trial plant. The tendency, however, is to the use of some form of the Belgian oven, and from the results of experiments with the different forms it is manifest that this oven is not in all cases a corrective of all the evils that gather about coke-making in Illinois.

Many of the Illinois coals which are not dry-burning are high in sulphur and ash, that of the northern part of the state being especially sulphurous, and for this evil even the Belgian oven is not a cure. It requires careful and thorough washing, and even then, in many cases, the result is not satisfactory. In one case the washing was so thorough that 60 per cent. of the coal was washed away, and still there was an excess of ash and sulphur in the coke. Some of the coals also show no tendency to coke until crushed and washed, and a washing plant is generally a necessary part of a coking plant in this state.

The coal of the Big Muddy region, in the southwestern part of the state, is a marked exception in purity to most Illinois coal, the coke from it being reasonably low in sulphur and ash. Previous to 1876, at which time the furnaces were torn down, the Grand Tower Mining, Manufacturing and Transportation Company made Bessemer pig from Iron mountain and Missouri hematite ores, using four-fifths raw Big Muddy coal and one-fifth coke made from washed screenings of the same in small Welsh ovens. The furnace was 16 by 72 feet. The iron exhibited at the Centennial was awarded the medal for purity and structure. This field, or pocket, occupies an area of about 4,000 acres, of which 250 have been worked out. The coal is not as well adapted to coking as that of the fields that bound it on the north and east, but these latter coals are too high in sulphur to produce a coke for smelting iron, with the exception of a pocket of limited extent at Cartersville. The Big Muddy seam lies almost horizontal, with a slight dip to the north, and varies from 5 to 7 feet in thickness, with a thin slate between the bottom and top coal. The coal is a hard, semi-bituminous, free-burning fuel, showing no inclination to run together, even under extreme heat, unless ground fine and wet. The following analyses of the coal and coke, with the exception of No. 3 coke, are furnished by Mr. Thomas M. Williamson, the superintendent of the Saint Louis Ore and Steel Company's works at Grand Tower and vicinity, where they coke this coal:

ANALYSIS OF MOUNT CARBON BIG MUDDY COAL.

	Per cent.	Per cent.
Water	6.37	6.02
Volatile matter	31.93	33.71
Fixed carbon	59.13	57.06
Ash	1.81	3.21
Sulphur (separately determined)	0.76	1.19

ANALYSIS OF MOUNT CARBON BIG MUDDY COKE.

Constituents.	No. 1.	No. 2.	No. 3.
	Per cent.	*Per cent.*	*Per cent.*
Hydroscopic moisture			0.28
Volatile matter	0.83	0.93	1.46
Fixed carbon	87.32	88.18	88.74
Ash	11.85	10.07	9.71
Sulphur (separately determined)	1.08	0.61	0.97
Silica in ash			47.00

Another analysis shows 1.17 per cent. hydroscopic moisture and 46.33 silica in ash.

As has been stated, this coal is much too dry-burning to allow of the successful use of the ordinary bee-hive oven. The Saint Louis Ore and Steel Company coke it in ovens known as the "English drag". This oven is 36 feet long, 7 feet wide, and 3½ feet high, with a capacity of 300 bushels of coal. It is a solid wall oven, discharged by a drag laid on the oven floor prior to the beginning of the operation, the drag being operated by a windlass. The coal is crushed as fine as beans, the screenings also being crushed, and both are washed. The charge of each oven is 11 tons; the time of burning, 96 hours. The yield is only about 55 per cent., as much of the carbon is necessarily wasted in furnishing the heat necessary to coke the coal. These ovens have not worked entirely satisfactorily, though they have been in use for some years, and the company expect to erect Belgian ovens.

The Carbondale Coal and Coke Company, at Cartersville, produced the only coke made in this state in the census year from one of the comparatively pure coals of southwestern Illinois, found near the Big Muddy deposit, before described. This coal is slightly more bituminous than the Big Muddy, and contains more sulphur and ash, and the seam is 9 feet thick. I have no analysis of the coal, but an analysis of the coke is as follows:

ANALYSIS OF CARBONDALE COKE.

[Analyst, Chauvenet.]

	Per cent.	Per cent.
Water	2.48	------
Volatile matter	2.42	1.58
Fixed carbon	86.79	80.14
Ash	8.31	18.28
Sulphur	0.88	2.03

The coal is washed before being coked, and the ovens used are called "tunnel ovens", and are of the same general plan as those used at Mount Carbon, except that they are smaller, being only 15 feet long, 7 feet wide, and 32 inches deep below the arch, and 3½ feet from the bottom of oven to top of arch. The charge is 6 tons, and the time of burning 72 hours, and the yield of coke was 50.7 per cent.

At East Saint Louis the Meir Iron Company have made careful and expensive experiments in using the slack and nut of the Belleville coal, which is high in sulphur and ash, for the manufacture of coke. The analysis of this nut and slack is as follows:

	No. 1. Per cent.	No. 2. Per cent.
Moisture and gas	15.35	15.09
Condensed volatile matter	10.59	15.74
Fixed carbon	53.62	52.62
Ash	20.44	16.55

These represent the slacks; the coals are much better. No. 1 was slack of ordinary quality; No. 2 slack from Duquoin. The slacks used when these works were in operation contained from 16.55 to 23.35 per cent. of ash, but by careful washing and preparation the ash in the coal was reduced to 6 per cent., and in the coke to 10 or 11 per cent. In the ovens used, which were Belgian of the old François pattern, modified by the Messrs. Meir, washed slack yielded 65 per cent. of coke. Mr. Adolphus Meir, who has been so persistent in his efforts to utilize this coal for coking, writes me: "Good coke has been, and will be, made from Illinois coals. A strong prejudice exists against such coke, but we have proof of melting from 7 to 8½ pounds of iron per pound of our coke in cupola furnaces in Saint Louis."

In northern Illinois all attempts to utilize the coal for coke have so far ended in failure, for while it contains more bituminous matter than that of the Big Muddy region, and is a truer coking coal, it is, however, very sulphurous and high in ash. Washing has reduced the percentage both of ash and sulphur somewhat, but not sufficiently low, in view of other characteristics, to make it desirable as a metallurgical fuel. In the experiments at the Joliet steel works, the ovens used being Belgian or a modification of the Belgian, the resulting coke, while not exceedingly high in ash or sulphur, was too porous for the blast-furnace.

Mr. H. S. Smith, the general superintendent of the Joliet Steel Company, at my request, and in view of the fact that the record of a failure is often as valuable as of a success, has furnished a statement of the experiments at these works, from which the following facts are derived.

The first experiments made were in 1872. The ovens used, of which there were twenty, were known as Belgian, and were 22 feet long and 20 inches wide on the inside, and 8 feet high to the top of the arch. The flues in the sides were horizontal, and from a pencil sketch accompanying Mr. Smith's letter I should judge they were either Smet or Dulait ovens; at least they were the earlier forms of the Belgian, and not the latter, like the Coppée or Appolt. These ovens were charged through openings on the top, and the gases escaped through short chimneys. The ovens were discharged by a ram, and the coke was watered outside. The coal used was chiefly slack from the northern Illinois mines, which was crushed and washed to reduce the percentage of ash and sulphur, which was quite large. The experiments were quite extensive, several thousand tons of coke being made, and the results were the same in all cases. The sulphur was reduced so much that, considering its content of sulphur alone, the coke could have been used for smelting iron, but it was still too high in ash and was too porous and weak to carry a proper burden in the furnace.

In 1879 still further experiments were made, Mr. J. J. Endres' modification of the Belgian oven being adopted, the width of the old ovens reduced to 16 inches, and flues put in the walls and bottom approaching the later Belgian ovens in plan. This experiment was a most thorough one, and was participated in by the steel company, the mines, and railroads. It was continued several months, the coal being carefully and thoroughly washed, and was then coked under Mr. Endres' supervision, but the result was no better than before. The washing removed considerable of the ash and a large percentage of the sulphur. In some cases the sulphur and ash were low enough to make a good coke, that from the Diamond mine having but 7.05 per cent. of ash and 1 per cent. of sulphur, but the coke was weak and porous, and was not adapted to carrying the burden in a furnace. Mr. Smith has kindly furnished a table (see page 51) showing the percentage of ash and sulphur in the coal, washed coal, and coke from a number of mines.

CHEMICAL RESULTS OF EXPERIMENTS ON COKING ILLINOIS COAL MADE BY MR. ENDRES IN 1879.

Name of coal.	PERCENTAGE OF ASH.			PERCENTAGE OF SULPHUR.		
	Crushed coal.	Washed coal.	Coke.	Crushed coal.	Washed coal.	Coke.
H shaft	....	....	8.11	....	....	1.10
G shaft	10.95	4.51	7.21	3.66	2.16	1.11
Diamond	5.51	4.57	7.05	1.70	1.71	1.00
Coal City	8.22	5.67	8.96	2.37	2.23	1.26
Eureka	7.27	4.99	8.60	2.83	1.93	1.21
Do	6.95	4.83	7.75	2.27	1.67	1.05
Streator	9.07	7.32	12.68	4.42	3.59	2.55
Do	8.23	5.77	9.42	4.70	2.62	1.32
Pontiac	....	12.71	21.01	....	2.25	1.27
Braidwood	7.10	6.20	8.11	3.12	2.55	1.30
Springfield	11.53	9.96	16.10	3.56	3.22	1.90
Indiana	10.21	8.02	13.34	2.37	1.77	1.33
Grape Creek	6.66	4.49	....	1.08	0.84	....

These experiments have been entirely abandoned, the ovens wrecked, and a portion of the machinery was used in building another bank of ovens in another section of the state; and the Joliet Steel Company have erected ovens in the Connellsville region. The result of these experiments, however, was to indicate that certain of the coals tried might, with proper manipulation, make a fair coke, and ovens are being erected to test these coals still further.

The Illinois Central Iron and Coal Mining Company have erected at Saint John's since the census year a number of Thomas Pettral ovens for using the Paradise coal, which they mine. The following table, for which I am indebted to Mr. M. C. Wright, of the Saint John's coke works, gives the physical and chemical properties of certain Illinois coal:

TABLE EXHIBITING PHYSICAL AND CHEMICAL PROPERTIES OF CERTAIN ILLINOIS COAL.

[Chemist, T. T. Morrell.]

	GRAMS IN ONE CUBIC INCH.		POUNDS IN ONE CUBIC FOOT.		PERCENTAGE.		Compressive strength per cubic inch (¼), ultimate strength.	Height* of furnace charge supported without crushing.	Order in cellular space.	Hardness.	Specific gravity.	CHEMICAL ANALYSIS.					
	Dry.	Wet.	Dry.	Wet.	Coke.	Cells.						Fixed carbon.	Moisture.	Ash.	Sulphur.	Phosphorus.	Volatile matter.
												Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Paradise	11.00	17.86	41.91	68.15	61.59	38.41	204	78	1	3.0	....	90.44	....	8.76	0.80	0.01	....
Jackson	12.80	21.10	48.77	80.39	60.66	39.34	206	81	1¼	3.0	....	89.68	....	9.38	0.94	0.067	....
Do	10.39	16.25	39.59	61.91	63.93	36.06	130	52	1	2.0	....	87.56	....	11.30	1.14	0.014	....
Saline	10.99	19.14	41.87	72.92	57.41	42.59	129	51	1	2.5	....	81.63	....	16.02	2.35	0.01	....
Jackson	11.80	18.49	44.96	70.44	63.87	36.13	150	62	1	3.0	....	81.98	....	15.78	2.24	0.011	....

THE COKE INDUSTRY IN COLORADO.

The manufacture of coke in Colorado, which has been but recently undertaken on a commercial scale, has been of the utmost importance to the industries and the development of that state, and has made possible the utilization of its valuable iron resources. The production of pig-iron from native ores has been successfully established, one furnace being in blast and another building, and with this has come the manufacture of nails and Bessemer steel rails. In addition to this, much of the coke used for smelting the ores of the precious metals in this region is now produced in the state, and the long and expensive transportation from the Connellsville region of Pennsylvania is avoided.

The only point at which coke is reported as made during the census year is some 6 miles south of El Moro, in Las Animas county, near the boundary-line of New Mexico, in what is known as the Trinidad or El Moro coal-field. The coke was made from the coal of one of a number of small and isolated basins into which this field is divided. The El Moro field lies along the eastern foot of the Rocky mountains, beginning at the Huerfano river, south of Pueblo, in Colorado, and extending southward into New Mexico as far as the Cimarron river, the basin being about 80 miles long and perhaps 10 miles broad. The beds are Upper Cretaceous or Lower Tertiary. The field is worked near its northern extremity by the Colorado Coal and Iron Company at Walsenburg, on the main line of the Denver and Rio Grande railroad. At this point there are three beds, respectively 4, 7, and 6 feet thick, producing a very good quality of steam coal, which, however, does not coke. These beds are distinctly traceable to the southern boundary of Colorado. From a thickness of 4 feet at Walsenburg, they increase to 11 feet in the neighborhood of Trinidad, the quality changing from a non-coking coal to an excellent coking coal. South of El Moro, in Las Animas county, at the Colorado Coal and Iron Company's works, where the coke made in the census year was produced, a horizontal vein 10 to 12 feet thick is worked, and at Starkville, in the same county, the Trinidad Coal and Coking Company is mining coal, both companies making coke. (*a*) Some 25 miles farther south, in New Mexico, near Raton, the field is worked by the Raton Coal and Coking Company, the veins being from 5 to 7 feet thick. The coal at this point is an excellent steam coal, and will coke, but there is made from it.

a There are now (1882) 250 coke ovens near El Moro, and between 40 and 50 at Starkville.

The seam from which coke was made during the census year is, according to Professor W. H. Chandler, who made an examination in 1877, 14 feet 2 inches thick, with 12 feet 9 inches of coal, the coal being separated by three small layers of slate from 2 inches to 1 foot thick. Analyses of these four strata of coal are given as follows:

Constituents.	No. 1.	No. 2.	No. 3.	No. 4.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Water	1.32	1.36	1.34	1.66
Volatile matter	38.23	36.77	35.79	34.48
Fixed carbon	55.86	56.37	54.75	60.08
Ash	3.59	5.50	8.12	3.78

In Hayden's *Report of the Geological Survey of Colorado* for 1875 an analysis of this coal is given, which is as follows:

	Per cent.
Water	0.26
Volatile matter	29.66
Fixed carbon	65.76
Ash	4.32
Sulphur	0.85

These analyses show the coal to be quite pure, but on coking it from 16 to 23 per cent. of ash was found, the large percentage of ash being due to the presence of a large amount of bony coal, which did not show in the coal analysis. A car-load of the same coal was sent to Pennsylvania to be crushed, washed, and coked, and the coke produced, after being thus treated, analyzed as follows:

	Per cent.
Water and volatile matter	1.85
Fixed carbon	87.47
Ash	10.65
Sulphur	0.85

This indicated the necessity of a crushing and washing apparatus, and machinery designed by Mr. S. Stutz, of Pittsburgh, was erected. The result is a coke answering all the purposes of a metallurgical fuel, being cellular, of a silvery appearance, and having a physical structure to fit it for furnace use. Its content of ash is from 2 to 3 per cent. more than that in Connellsville coke. The coke is made in bee-hive ovens, only 70 of which were completed at the beginning of the census year, but at its close there were 128, with 72 more in process of construction. The El Moro mines are worked through drifts, and the coal is of a remarkably uniform character. The price paid for digging in 1881 was 50 cents per ton of 2,240 pounds, and the actual cost of the coal loaded on the cars at the mines 73 cents. The product of coke in the census year was but 18,000 tons; in 1881 it was 47,186 tons.

Though no coke was made at any other locality in the census year, there are other deposits of excellent coking coal that have since been utilized for this purpose, and still others at which preparations are in progress for its manufacture. At Crested Buttes, north of Gunnison, on the Denver and Rio Grande railroad, some coke of a most excellent quality, very low in ash, was made in 1881 in open pits from two seams of coal 5 and 6 feet respectively. Analyses of this coal and coke are as follows:

ANALYSES OF CRESTED BUTTES (COLORADO) BITUMINOUS COAL.

	Per cent.	Per cent.
Water	1.10	0.44
Volatile matter	23.20	24.17
Fixed carbon	72.60	72.30
Ash	3.10	3.09
Theoretical yield of coke	75.70	75.39

ANALYSES OF CRESTED BUTTES (COLORADO) COKE.

	Per cent.	Per cent.	Per cent.
Water and volatile matter	1.35	0.42	0.41
Fixed carbon	92.03	90.71	92.44
Ash	6.62	8.87	7.15
Sulphur		0.58	0.37

At the close of 1881, 484 tons of coke only had been made, but yards were being prepared for making 200 tons per day. All the slack and fine coal which passes through the shute-screens is used in the coke-yards, and the coke made is of good quality and runs low in ash. This coke commands $7 per ton on cars at the works.

THE COKE INDUSTRY IN UTAH.

There have been for some time past in the Sanpete district, in Utah, a number of coke ovens, but no coke has been made in them recently. Most of the coke used in Utah comes either from Connellsville, Pennsylvania, or from England, the English coke being delivered at San Francisco, or some point on the Pacific coast, and sent by rail to Utah. A line of railroad is now building from Salt Lake City to connect with the Denver and Rio Grande railroad, which will enable El Moro and Gunnison coke to be delivered at the Utah smelting works.

THE COKE INDUSTRY IN NEW MEXICO.

In central New Mexico, 9 miles east from San Antonio station, on the Atchison, Topeka and Santa Fé railroad, is the San Pedro coal-mine, where there is a bed of coking coal 6 feet thick. (*a*)

a Ovens are now (1882) being erected at San Antonio station, on the Rio Grande river, for coking this coal.

Part III.—COKING IN EUROPE.

HISTORY OF COKE IN ENGLAND.

But little is known concerning the history and the uses of coke in England until the beginning of the seventeenth century; but as it would be impossible to burn pit or mineral coal for domestic or any other purposes by the methods in use in early days in Great Britain without producing coke as cinders, in the same way that cinders were produced in burning wood, it is very probable that coke in the form of coal cinders was known at a very early day. It is proved beyond doubt that coal was used by the Romans during their occupation, and cinders of the Roman period are frequently met with. This view of the early use of coke is strengthened by the extract from M. Jars' work on metallurgy, quoted in the chapter on bee-hive ovens.

While it is probable that coke was not unknown at an early period in Britain, it by no means follows that it was made for use in the arts, either domestic or manufacturing, as the immense forests at that time would make it unnecessary to seek for a substitute for wood. The method of charring wood was well known in these early times, and the charred wood was a better fuel than the charred coal, so that there would be no inducement to use coke until charcoal should become scarce and high-priced. It is also well known that for many years a prejudice existed against burning "stones", as the coal was called, and in ignorant minds it was coupled with a species of witchcraft.

As the wood failed, however, the outcrop of the seams of coal would naturally be used, especially in the manufacture of iron, in which such large amounts of fuel were consumed, and it would be but natural to subject the coal, which was well known as a fuel, to the same treatment as wood, and coking in pits or mounds would be the result.

One of the earliest references to the coking of coal is in a patent granted to Thomas Proctor and William Peterson, in 1589, for making iron and steel and melting lead "with earth-coal, sea-coal, turf, and peat". The scheme proved a failure, two tons only having been made, so report says, at an iron works in Yorkshire, at a cost of 200 marks (£66 13*s.* 4*d.*) per ton. The chronicler quaintly remarks, "It is deere iron." In this patent is a distinct allusion to a preparatory treatment of the coal by "cooking". A short time after this, in 1590, a patent was granted to the Dean of York "to purify pit coal and free it from offensive smell". In 1620 a patent was granted to a company composed of Sir William St. John and other knights, esquires, and gentlemen, with a Hugh Grundy, who was the "practical" man, for "charking" sea-coal, pit-coal, stone-coal, turf, peat, etc., and employing the same for smelting ores and manufacturing metals and other purposes. The project originated with Grundy, and referred specially to the making of coke by a process invented by him some time before.

About this time considerable attention began to be paid to the charring or coking of coal, not only in connection with the smelting experiments which were going on, but with a view to its employment for other purposes as well. In 1627 a patent was granted to Sir John Hacket and one Octavius de Strada (who two years before had been making attempts to smelt with coal in Hainaut) for a method of rendering sea-coal and pit-coal as useful as charcoal for burning in houses, without offense by the smell or smoke. A few years afterward (1633) another patent was granted to a company consisting of Sir Abraham Williams and others for a new way of "charking" sea-coal and other earth-coal, and for "preparing, dressing, and qualifying them so as to make them fit for the melting and making of iron and other metals and many other good uses".

During the next three or four years some eight or nine patents were granted for the employment of smokeless preparations of coal; and though the application of coke to the smelting of minerals was not successfully accomplished till long afterward, it came into use at this time for several other purposes, particularly for making malt. Houghton tells us that up to about 1640 the malt was made with straw fuel in Derbyshire, but that it then came to be made with coke, which occasioned an improvement in the quality of the brewings, "and brought about that alteration which all England admired."

A little later an attempt to substitute coke for coal in house fires was made by Sir John Winter. The project is referred to by Evelyn in his diary under date of 11th of July, 1656, in the following terms:

> Came home by Greenwich Ferry, where I saw Sir John Winter's new project of charring sea-coale to burne out the sulphure and render it sweete. He did it by burning the coals in such earthen pots as the glasse men mealt their mettal, so firing them without consuming them, using a barr of yron in each crucible or pot, which bar has a hook at one end, that so the coales, being mealted in a furnace with other crude sea-coals under them, may be drawn out of the pots sticking to the yron, whence they are beaten off in greate halfe-exhausted cinders, which being rekindled make a cleare pleasant chamber fire, deprived of their sulphur and arsenic malignity. What success it may have, time will discover.

Sir John sent some of his "cooked coal", together with a new-fashioned grate, to several great men for a trial, but his project did not succeed.

In 1662 Dr. Fuller wrote:

> It is to be hoped that a way may be found out to charke sea-coal in such manner as to render it useful for the making of iron. All things are not found out in one age, as reserved for future discovery; and that perchance may be easy for the next which seems impossible to this generation. (*a*)

a For many of these details I am indebted to the *History of Coal Mining*. R. C. Galloway. London, 1882.

Dr. Plot, in his *Natural History of Staffordshire*, published in 1686, states:

They have a way of charring the coal, in all particulars the same as they do wood, whence the coal is freed from those noxious steams that would otherwise give the malt an ill odor. The coal thus prepared they call "cokes", which conceives as strong a heat, almost, as charcoal itself, and is as fit for most other uses, but for melting, fining, or refining of iron, which it cannot be brought to do, though attempted by the most skillful and curious of artists.

Swedenborg, who was an able metallurgist, in his book on the *Subterranean Kingdom*, published in 1734, states that in certain districts in England coke was employed in smelting iron, and that cinders and coke were synonymous terms. This would indicate that the date (1735) usually given as that of the successful introduction of the smelting of iron with coke is erroneous.

Jars' statement, made in 1769, that coke was made in England, not only in heaps, but also in closed ovens, is elsewhere mentioned. His statement would lead to the belief that the method of coking in heaps was in use on the continent of Europe; a belief that is confirmed by the fact that the iron manufacturers of Liége, a short time after this publication, adopted with success the method of coking in closed ovens.

About the same time, according to Horne, (*a*) coking in ovens was carried on in the villages around London, the coke being prepared for the use of maltsters and for some other purposes. He gives the following description of the process:

These ovens being from time to time charged with a proper quantity of coals, they set them on fire. Near the front or opening of these ovens the chimneys are placed, at which outlets, when the coals become sufficiently ignited, the flames which play round the interior parts of the oven make their exit, carrying along with them a very considerable part of crude sulphur. The workmen employed at these ovens, when they imagine the coals are sufficiently burnt, draw them out with an iron raker upon the ground before the oven, where they endeavor to stifle the yet remaining part of the sulphur by quenching them with a deluge of water. Thus they go on charging, discharging, and suffocating till they have completed their intended quantity.

An experimental coke oven, on a plan proposed by Horne, was erected in Staffordshire, and, it is stated, with a successful result. The details of the plan are not given. It appears, however, that the oven consisted of a closed arched chamber, and that on trial it was found to be desirable to leave some outlet "in the top of the crown" for the escape of vapor, in order to prevent the blowing up of the oven. In 1781, according to Bishop Watson, the application of coke to the smelting of iron had become general in England, and coke ovens were in operation at Newcastle-on-Tyne, and even at Cambridge, where the coke was used for drying malt. (*b*)

It was this extension of the use of coke in the smelting of iron that gave its manufacture prominence. Up to early in the seventeenth century charcoal was the only fuel used in iron-smelting; but during the reign of James I several patents were granted for the exclusive right to manufacture iron with pit-coal, none of which were successful until 1619, when Dud Dudley succeeded and obtained a patent for fourteen years.

At this time many of the iron works were idle from want of wood. Remarking on the rapid exhaustion of the forests of England, Mr. David Mushet (*c*) estimates that the amount of charcoal necessary for the manufacture of iron alone in the year 1615 would be 28,063,000 cubic feet. Supposing an acre of ground to afford 2,000 cubic feet of timber, he estimates that 14,031 acres of land were annually stripped to supply the iron manufactories. Though pit-coal had been mined at Newcastle prior to 1272, and vast quantities of it had been annually exported to Holland and the low countries for the use of the smithies and other manufactories requiring an intense and continued heat, yet in England prejudice was very strong against its application to the manufacture of cast or malleable iron, and smithies and nail forges and manufactories of every sort were still carried on by means of charcoal. As a result of this the price of iron advanced, and those manufacturers whose supply of wood was undiminished were, of course, hostile to any improvements by which other fuels could be used.

Dudley continued his experiments with pit-coal with varying success and under many discouragements for a number of years. Other patents were also taken out for the manufacture of iron with coal, in one of which, that of Captain Buck, it is believed Cromwell was a partner. In 1663 Dudley applied for his last patent, setting forth in his application that at one time he was able to produce 7 tons of pig-iron weekly. His uncommon success produced combinations against him, which terminated in hostile attacks upon his works. This rivalry in the business, and his attachment to the royal cause during the civil war, brought successive misfortunes upon him, and interfered with the use of his improvements, and the refusal of a new patent after the restoration prevented him from again entering into the business.

Mr. I. Lowthian Bell, the well-known authority on blast-furnace phenomena, believes that if Dudley had met with encouragement instead of persecution he would ultimately have been led to treat mineral fuel as they had previously done the vegetable, viz, char it. (*d*)

Though Dudley's last application for a patent was in 1663, his experiments really ceased in 1657, and from that time for nearly eighty years the art of making iron with pit-coal was lost. Abraham Darby's invention of the use of coke in blast-furnaces completed the work of his unfortunate predecessor, though in the meantime efforts

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a *Essays concerning Iron and Steel*, by Henry Horne. London, 1773.

b See *Percy's Metallurgy*, London, 1875, page 416.

c *Papers on Iron and Steel, Practical and Experimental*, by David Mushet. London, 1840.

d See *Chemical Phenomena of Iron Smelting*. London, 1872.

to use coal had not entirely ceased, and in some cases even coke was used in the blast-furnace. Leigh tells us in his *Natural History of Lancashire* that shortly before 1700 iron was being made "by means of cakes of pit-coal" (*i. e.*, coke).

It is generally conceded that the credit of the first successful and continued use of coke in the blast-furnace is due to Abraham Darby. The date of Darby's invention seems in doubt, (*a*) some authorities placing it as early as 1713, others about 1735, and still others at 1750. The statement of Swedenborg, before referred to, would indicate that it must have been at least as early as 1735, and this is the date usually assigned.

Percy thus describes his experiments: (*b*)

Young Abraham Darby entered upon the management of the Coalbrookdale Iron Works about 1730. As the supply of charcoal was fast failing, Abraham Darby attempted to smelt with a mixture of raw coal and charcoal, but did not succeed. Between 1730 and 1735 he determined to treat pit-coal as his charcoal-burners treated wood. He built a fire-proof hearth in the open air, piled upon it a circular mound of coal, and covered it with clay and cinders, leaving access to just sufficient air to maintain slow combustion. Having thus made a good stock of coke, he proceeded to experiment upon it as a substitute for charcoal. He himself watched the filling of his furnace during six days and nights, having no regular sleep, and taking his meals at the furnace-top. On the sixth evening, after many disappointments, the experiment succeeded, and the iron ran out well. He then fell asleep in the bridge-house at the top of his old-fashioned furnace, so soundly that his men could not wake him, and was carried to his house, a quarter of a mile distant.

While the change in fuel from charcoal to coke was being brought about the manufacture of iron in England declined so rapidly that in 1740 the number of furnaces was only 59, a reduction of 25 per cent., and the make of pig-iron only 17,350 tons. The production rapidly advanced, however, under the stimulus of Darby's discovery, until 1788, when of 61,300 tons of pig made 48,200 were smelted with coke and but 13,100 with charcoal. It is also but just to state that Watt's improvements in the steam-engine, and the great changes that took place about this time in the form and construction of furnaces, contributed to this advance. At the present time little or no charcoal iron is made in Great Britain.

We have entered thus fully into the history of the progress of the manufacture of pig-iron with coke, as this industry and that of coke-making are so closely identified that it is almost impossible to state the history of one without making it also a history of the other. Outside of the use of coke in the iron industries its consumption is but comparatively small. In all attempted improvements in ovens and methods of manufacture of coke the ruling question as to their adoption is, "What kind of a blast-furnace fuel is the resulting coke?" and as the coke is improved or injured for this purpose by the new methods the improvements have been adopted or rejected.

As has been already stated, the earlier method of making coke in heaps or mounds soon gave place, as the demand for coke for iron-smelting increased, to the bee-hive oven, and this in turn, in some countries, though to no great extent in England, to the improved form of ovens commonly known as the "Belgian". These changes and improvements will be treated of under their appropriate heads.

In addition to these changes methods have been adopted for utilizing the waste heat of the ovens for raising steam, and, as is stated in the chapter on the utilization of waste products, for utilizing the ammonia and tar from the waste products of combustion. In at least one case, also, these waste gases, having first been enriched, are used for lighting purposes.

Outside of the improvements already noted but very few changes have been made in the methods of operating the ovens, and these mostly in the line of greater economy in charging the coal, discharging the coke and watering it, and loading it upon cars. "Hoppers," "trolleys," and "larries" have been substituted for charging the ovens, instead of the old plan of throwing the coal through the door by means of shovels, drags and mechanical rams for discharging the ovens have taken the place of hand-labor and a hook, and the coke is quenched with a hose and nozzle instead of the primitive bucket. In the management of the oven, also, practically three levels are used, the first or highest containing the track on which the charging larries are run, the second on a line a little below the bottom of the oven, called the "coke-wharf" in this country, upon which the product of the ovens is discharged, while the third level, a little lower still, is occupied by the railroad, the top of the cars being on a line with the wharf, thereby giving greater facility for loading. It is impossible to follow chronologically the course and the development of these improvements; the best that can be done is to indicate their results.

COKING IN GREAT BRITAIN AND IRELAND.

No complete statement of the present condition and extent of the manufacture of coke in the United Kingdom has been obtained; indeed, it is doubtful if such a statement exists in any form accessible to the public. Coke is generally regarded as a form of coal, and its statistics are included with those of coal, the coke sometimes being reduced to its supposed equivalent in coal and sometimes not. Even the *Mineral Statistics of the United Kingdom* furnish no complete statistics, nor do they give data from which even the make of coke can be estimated. Coal and coke are usually reported together, but the exports of coke are given separately. It is possible to

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a See *Jevon's Coal Question*; also Scrivenor's *History of the Coal Trade*, which puts it at 1713. Mr. M. M. Johnson, of the Kingswood colliery, England, in a lecture delivered before the Bristol Mining School, published in the *Colliery Guardian* of February 2, 1877, page 161, also gives the date as 1713.

b *Percy's Metallurgy*, "Iron and Steel," page 888.

estimate the consumption of coke in the blast-furnaces of certain districts, and some of the railroads distinguish between the coal and coke carried over their lines, but in the tables of total production coke disappears. Statements as to the amount of coke consumed in certain industries are sometimes published, but all such statements, as well as those professing to give the output for certain districts, are only estimates more or less accurate, while statements showing even the estimated total production of the United Kingdom for recent years are almost, if not quite, wanting.

Notwithstanding this dearth of positive information regarding English coke, sufficient is known to warrant the classification of its manufacture among the important industries of Great Britain; important, not only by reason of the aggregate tonnage produced, which must be considerably in excess of 6,000,000 tons gross annually, but also because of the wonderful development of the British iron trade which its manufacture has made possible. The pre-eminence of Great Britain in the manufacture of iron is due to its possession of abundant deposits of coal. When the kingdom had been well-nigh stripped of its forests to furnish charcoal to smelt its iron ores, and the high price of pig so smelted promised to send this manufacture at least to countries having abundant supplies of charcoal, it was Darby's invention or rediscovery of the use of coke for smelting that gave to its blast-furnaces a new life, reduced the cost of pig-iron, and retained its manufacture in Great Britain. As other countries have advanced in the manufacture of iron, there can be no question that the United Kingdom has retained its pre-eminence in the iron markets chiefly by reason of the excellence, abundance, and cheapness of its coke. These have made possible the utilization of its low-grade ores in the production of pig-iron at a low cost, and have rendered feasible the continued competition of English iron with that of other nations, not only in the general markets of the world, but often in the home markets of these nations.

The most important coking district in Great Britain, and consequently in the world, is the Durham, which lies in the northeastern part of England. The production of this district is not only largely in excess of that of any country in the world, but the Durham is a typical blast-furnace coke, bright, resonant, cellular, and low in ash and other impurities. Taking the average of numerous analytical results of the best varieties of Durham coke, 6 per cent. of ash and about 0.60 per cent. of sulphur may be considered as the proportion of these constituents.

As to the extent of the Durham coal-fields that produce the coking coal there seems to be some difference of opinion. Mr. T. Y. Hall, in a paper published in the proceedings of the North of England Institute of Mining Engineers, includes in this field the coal-seams from Etherly on the south to Wylam on the north, an average distance of 20 miles long by about 8 wide, or 160 square miles. Mr. A. L. Steavenson, however, in a paper read before the Iron and Steel Institute of Great Britain, states that the field of coking coal extends from Bradbury station, on the Northeastern railway, on the south to Gateshead on the north, 23 miles long by 11 miles wide, or 253 square miles. Mr. Steavenson is probably more nearly correct than Mr. Hall, the difference in the estimates arising probably from a difference of opinion as to the classification of the coal in certain seams.

The typical Durham coal is high in carbon, low in sulphur and ash, and with but little care or preparation burns into a most excellent coke. The best coal is obtained from the lower seams. The Brockwell and Busty seams, in the Brancepeth district, may be taken as fairly representing this coal. The analyses of these coals, are as follows:

Constituents.*	BUSTY SEAM.		Brockwell seam.
	Upper part.	Lower part.	
	Per cent.	*Per cent.*	*Per cent.*
Carbon	81.22	78.46	83.40
Hydrogen	4.70	4.42	4.40
Oxygen and nitrogen	9.45	8.82	7.18
Water	0.85	0.99	0.90
Ash	3.28	6.17	3.50
Sulphur	0.81	1.83	1.00
Total	100.31	100.69	100.38

* Authority, I. Lowthian Bell.

The coal of the above seams yields from 60 to 65 per cent. of its weight of coke. Its purity will be seen from the appended analyses of the coke made from the seams in the following collieries:

Collieries.	Carbon.	Ash.	Sulphur.	Water.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Hamsteels	92.55	6.36	0.81	0.21
Consett	91.88	6.91	0.84	0.37
Whitworth	91.56	6.69	1.21	0.54
South Brancepeth	93.41	5.30	0.91	0.36

This coke is extremely hard and strong, and is capable of resisting a very high column in the blast-furnace, a cube 2 inches square, made at the Clarence iron works, having supported a weight of 25 hundred-weight when cold and 20 hundred-weight when hot before it was crushed.

The oven used, almost without exception, is the bee-hive, and at some works are larger than those used in this country. At the Consett iron works they are 11 by 11½ feet. At the Browney colliery an oven with flues similar to those in Cumberland and other districts is used, and at least at one works the Carvés oven is used. The bee-hive oven, though not giving as high a yield as others, is believed to produce the best coke for iron metallurgical purposes. The coal, however, cokes readily, and produces a good fuel without much care. There are from 15,000 to 16,000 of these ovens (*a*) in use in Durham, in which about $5,000,000 are invested. (*b*) The time of burning varies from 24 hours to as high as 120 hours, according to the weight of the charge and the use to which the coke is to be put. Shipping and smelting coke is burned from 72 to 96 hours; the Silkstone coal, crushed and washed, when intended for use in steel works, is burned from 72 to 80 hours.

The annual production of coke is estimated by Mr. Meade at 4,000,000 tons, (*c*) and the value as exceeding $10,000,000. Coke-drawers to the number of 2,000 were employed. Mr. I. Lowthian Bell estimates the output of coke of the counties of Durham and Northumberland at 6,000,000 tons annually, and his opportunities for making an estimate are so good that the statement may be accepted as correct. In this case more than 2,000 drawers would be employed. A good man can draw coal and do a share of the charging of six ovens. The coke is not only largely used locally in locomotives and the various operations of iron-making, but is largely exported to other districts of England and to foreign countries, and is chiefly used in iron smelting, though the hard-burnt is used in Sheffield to some extent in melting crucible cast-steel in the form of steel furnaces known as "coke-holes", or "coke-furnaces".

In recent years the quality of Durham coke has not been so uniformly good as formerly. Not only has considerable coke been made from washed coal, but some seams are now used for coking that formerly were not regarded as sufficiently pure for the purpose; at least the coke could not compete with that made from the best seams of coal. Mr. E. Windsor Richards, in a paper read before the Cleveland Institute of Engineers, in November, 1880, remarks that there was no hiding the fact that large tracts of the best coking coals in the county of Durham had been worked out, and though there was still a very large quantity of good coking coal left, yet some of the inferior seams were being largely worked with very little attention to the cleaning of the coal. Attempts are made in many cases to reduce the impurities to a minimum by crushing and washing, but even this is not successful. The washer used is the old trough type, which is not only wasteful of coal, but is an imperfect separator.

Concerning the other districts of England in which coke is made, still less information is obtainable than concerning Durham. In none of them is the coal so well adapted to coking or so pure as Durham, and the coke produced is not as good, especially for use in the manufacture of iron. In most of these districts but little attention was paid to the production of a good quality of coke until within the past few years, when colliery owners found that it would pay to make coke suitable for iron-smelting. The best appliances are now being introduced, and the manufacture of it is extending in the districts outside of Durham, and, by using care in its production, a very good quality is made, which is not only consumed in the local iron works, but is shipped to other districts of England and to foreign countries.

It must be borne in mind, in speaking of the character of the cokes of other districts as compared with the Durham coke, that the latter is an extraordinarily good and pure fuel, and while the cokes of all of the other districts are inferior as compared with Durham, yet, as compared with those of France or Belgium, they are in many cases equal, if not superior.

It is also worthy of note in this connection that the production of coke is not now confined to those districts and seams which yield the best coking coal. The introduction of recent improvements in the manufacture of coke has enlarged the area, permitting its production from coal that would have been previously rejected as unfit for that purpose.

Next to Durham the most important coking district is South Wales. The manufacture of coke is here carried on quite extensively, the greater part of which is used in the manufacture of Welsh iron, copper, and tin, though some is sent to other districts of Great Britain and to foreign ports.

The coals of this district vary considerably in their composition, the seams occupying the northeast side of the Welsh basin being chiefly coking or semi-bituminous, those of the northwest anthracite, while the seams in the

a The *Pall Mall Gazette* estimated them at 16,000 in 1879. Mr. Steavenson's estimate in 1877 was 14,000.

b *The Iron and Coal Industries of the United Kingdom*, page 15. I am informed by a gentleman who has had considerable experience in building ovens in this district that the cost of a 11-foot oven in 1869 was about £25. In 1876 the contract price at the Brythorpe colliery was "£52 odd".

c The *Pall Mall Gazette* in 1879 estimated the production at 5,000,000 tons and the number of coke-drawers at 1,700, each drawing 2,800 tons a year. Thirty years before, the production of all England was, according to the *Pall Mall Gazette*, 2,500,000, and twenty years before 3,500,000 tons.

center of the coal-field are semi-bituminous. Truran gives the following analysis of a coal from the northeast side of the basin near Pontypool, which was used for coking:

	Per cent.
Carbon	80.4
Hydrogen	5.7
Oxygen	5.3
Nitrogen	1.2
Sulphur	0.9
Earthy materials	6.5

Specific gravity, 1.29; yield of coke, 66 per cent. The earthy matter shows the portion of ash. (*a*)

Of the coal that is classed as coking some seams yield a very good quality of coke without washing, but with much of the coal a previous washing is necessary to give a coke of sufficient purity and freedom from ash to be desirable as a furnace fuel.

The oven used most generally in South Wales differs from that in use in Durham, the latter being, as before stated, of the well-known bee-hive form, while the Welsh oven is a modified bee-hive, almost rectangular, and is adapted to discharging by mechanical means. As generally built this oven is about 14 feet long, 5 feet high, and 6 feet wide at the front and 5 feet at the back, this difference between the width of the front and back being to allow of ease in drawing the charge. The coke is drawn by means of a windlass attached to a wrought-iron bar laid along the length of the oven, another being laid transversely across it at the back, both being placed in position before the oven is charged. The ovens are generally built back to back, with a chimney between, sometimes with side and bottom flues, the Welsh oven in these respects anticipating the Belgian, and are in some cases charged through the top, in others through the door. The coke is sometimes cooled in the oven and sometimes after it is drawn.

The charge is about 4¼ tons for the first three days in the week and 5 tons for the remaining four days. For the coking of the smaller charge 72 hours are generally allowed, and for the larger 96. As is noted elsewhere, at the Ebbw Vale, Dowlais, and other works the Coppée oven has been introduced.

As is stated in another chapter, the manufacture of coke in the ordinary way in South Wales, although exceedingly hard and dense fuel is produced, does not appear to have attained all the economical results possible. Experience has shown that the carbonization of the coal is not complete, the long, deep fissures in the coke thus manufactured exhibiting, on examination, a considerable amount of dark carbonaceous matter not carbonized.

No statistics of the output of coke or of the number of ovens in this district have been obtained.

Considerable coke is also made in Lancashire, though the coal is even less adapted to coke-making than either the Durham or the South Wales, and most of it is crushed and washed before coking. At the works of the Wigan Coal and Iron Company the slack from their extensive pits is coked after being washed, the coking being done in 8-ton ovens, the process occupying five days. Some Coppée ovens are also used in this district with good results.

I am indebted to the kindness of Mr. W. H. Hewlett, of the Wigan Coal and Iron Company, limited, for the following description of this field:

The coke district of Lancashire is divided into two parts, southwest Lancashire, of which Wigan may be considered the center, and which is some 23 miles from Liverpool, and northeast Lancashire, of which Burnley may be considered the center, some 45 miles from Liverpool.

Beginning with the former we take first the nature of the coal from which coke is produced.

The coke here is made altogether from slack (that is, riddlings which pass through a mesh of three-quarters of an inch) from the Arley mine seam. This seam, a bituminous coal, is the bottom seam of the Wigan district (save the mountain measures, which are too thin here to be profitably worked), and varies in depth in the district from some 140 to 800 yards. The coal from the seam is used, the largest for house purposes, the next size for gas purposes, and the slack, as hereinbefore named, for the manufacture of coke.

The following may be considered a good average analysis of the quality:

	Per cent.
Ash	4.40
Sulphur	1.60
Volatile matter	32.15
Fixed carbon	62.21

To make this slack into coke there are something like 1,700 ovens in this district, of which the company I represent owns about 700. The slack is washed to remove pyrites and dirt, and is at the larger works (our own, for instance) crushed afterward before being coked.

The following may be regarded as a fair average analysis of the coke produced:

	Per cent.
Ash	8.70
Sulphur	1.26
Volatile matter	0.90
Water	0.75
Fixed carbon	88.46

The ovens are bee-hive almost entirely. The coke is used principally at blast-furnaces, but commands some trade among the founderies in the neighborhood.

In the Cumberland district, where there are large deposits of rich hematite ores, most of the coke used is brought from Durham, at a cost of (June, 1880) from 8*s.* to 10*s.* a ton for freight alone. It is stated that 1,000,000

a Truran *On the Manufacture of Iron*, third edition (London, 1865), page 11.

tons of coke were used at the iron works of this district in 1877, of which but 50,000 were made in the district. Though the coal of Cumberland has an excess of ash and is high in sulphur, it is believed that both of these can be much reduced by careful washing and coking. The Coppée oven, which is especially designed for coking finely-divided coals, is being used successfully, though ordinary ovens are used also. In 1878 and 1879 there was considerable activity in the Cumberland coal-field in building ovens and making coke. At this date three or four seams of coal were worked in the West Cumberland coal-field from which coke was made. A large part of the coke, however, was made from slack or screenings and small coal, generally washed. The largest coke manufactory at the time was at the Clifton colliery of the West Cumberland Iron and Steel Company. Early in 1879 this company had 92 ovens at work and were making about 26,000 tons of coke from 46,000 tons of coal, the coal being crushed and washed at an expense of *5d.* a ton. There were also coke ovens at several other collieries. These ovens, while they were built somewhat on the bee-hive plan, differed from the ordinary bee-hive in being built back to back with large flues between the backs running the entire length of the row, each oven having a connection with this flue, the flue being connected at the end with a large chimney. The ovens are charged through the top and drawn in the ordinary way.

In some cases the waste gases from the oven, after passing through the flues and before passing into the chimney, are conducted under boilers and the waste heat is utilized, these boilers supplying steam for working the machinery in crushing and preparing the coal, for the engines pumping the water from the pits, and in drawing the coke, where mechanical means are used.

The great coal-field which occupies so large an area of Yorkshire is the most continuous of the coal-fields of Great Britain, its length from north to south being upward of 66 miles and its breadth from 5 to 20 miles. Sheffield occupies the center of this great body of coal. In the southern part of Yorkshire the great seam is the Barnsley, which far exceeds in thickness any other of the known seams, except the Silkstone. This latter seam is the most highly prized in the Yorkshire field. Indeed, these two are practically the only seams wrought, and it is probable that no others will be touched, except for local consumption, until they are exhausted.

It is from the "smalls", or the fine coal of these two seams, that practically all the South Yorkshire coke is made. Up to a few years ago the production of coke was limited to the requirements of the Sheffield trade, chiefly for steel melting; but with the development of the Barnsley coal and the contemporaneous discovery of the oolitic ores of Northampton came a demand for a grade of coke which the small coal from the Barnsley seam without washing was well calculated to produce. This coke contains more carbon and less ash and other impurities than the Silkstone, and as a result thousands of tons of this fine coal, instead of going into unsightly and useless piles or being used to ballast railways, are utilized in coke-making. Latterly it is stated that the condition of the market for coal has been such that it has been more profitable to make the "run of the mine" into coke, and a large number of ovens, upward of 1,000, were erected in the Barnsley district in 1881. The coke from this coal is competing with that from the Silkstone seam, and even with the Durham. Bee-hive ovens 11 feet in diameter are most common in this district. The coal is generally crushed in a Carr's disintegrator.

The following shows the range of the analyses of the Barnsley coal from six collieries:

	Per cent.		
Carbon	80.500	to	82.520
Hydrogen	5.025	to	5.500
Oxygen	6.205	to	8.243
Nitrogen	1.496	to	2.120
Sulphur	1.144	to	2.100
Ash	1.226	to	4.100
Yield of coke	62.000		65.520
Specific gravity	1.266		1.290

The Silkstone seam, so named from the village where it was first worked, also furnishes a coal well adapted for coking. (*a*) Its analysis is as follows:

	Per cent.
Carbon	80.46
Hydrogen	5.08
Nitrogen	1.67
Oxygen	6.80
Sulphur	1.65
Ash	3.30
Moisture	1.04

When coked, the yield is about 60 per cent. The coal from this seam raised at the Hoyland colliery yields 64.48 per cent. of coke. This coal is extensively coked, and produces a pure, strong coke, which is in good demand in the steel works of Sheffield, where it is largely employed.

Of the coke made in the other districts of the United Kingdom our information is of the most meager description, and covers very little else than the fact that it is made.

In Staffordshire some coke is manufactured, though the supplies for South Staffordshire come from Derbyshire.

a See Meade, page 41.

These districts and Yorkshire, with Durham, Lancashire, and South Wales, should be regarded as the chief seats of the coke manufacture of the United Kingdom; but here, as elsewhere, concerning output, ovens, etc., the report must be, "No returns."

In London some coke is made from the screenings of the coal-yards, similar to that made at Cincinnati. There are quite a number of these establishments in London, one having 21 ovens, another 12, another 9, and others various other numbers, and are mostly situated on the river banks.

Regarding coke in Scotland, the only definite information received is that in 1878 there was a bank of 160 ovens at the Haugh works of Messrs. William Baird & Co., in Lanarkshire, which at that time was the most extensive works of the kind in Scotland.

Concerning Ireland, the statement is made that, owing to the great competition with English coke, its manufacture scarcely pays the cost of production and carriage.

During the past few years many attempts have been made to utilize the gases and save the waste products of combustion, especially ammonia and tar, but the success has not in most cases been such as to justify the adoption of the process. The waste heat is used at many places in making steam, and the experiments in collecting the waste products have shown that it can be done. The coke, however, was found to suffer much in quality, so that what was gained in one way was counterbalanced by a loss in another. Some recent experiments are said to have been more successful, so that there is every probability of the valuable products of the gas being obtained without injury to the coke. Messrs. Pease & Partners have recently adopted the Carvés system with excellent results, and other systems are being tried. These will be referred to in another chapter.

As has been stated, there are no reliable statements as to the amount of coke produced in Great Britain. Mr. Richard Meade, to whose work (*The Iron and Coal Industries of the United Kingdom*) I am so much indebted for information, writes me on this subject:

The Newcastle and Durham districts of the Great Northern coal-field are the most important and extensive in Britain. Mr. A. L. Steavenson, a vice-president of the North of England Institute of Mining Engineers, in a paper read before that body and printed in their transactions (vol. viii, 1859–'60) gives the following estimate of the coke trade for the year 1858: Coke used in the iron trade, 4,032,070 tons; coke exported, 227,552 tons; railways, etc., 641,611 tons; total for 1858, 4,901,233 tons. The number of coke ovens employed, about 16,660; and the number of hands employed in the kingdom, about 4,000.

In the same year, in Durham and Northumberland, the production of coke was about 2,000,000 tons, employing 1,600 hands, the capital embarked in the coke trade being about £500,000, yielding about 10 per cent. annually.

In the year 1880 the consumption of Durham coke alone in pig-iron manufacture amounted to 4,500,000 tons, and as the make of pig-iron in the same district has increased since 1880 the coke manufacture will have increased in proportion. There is, however, no information of which I am aware showing the extent of increase that is at all reliable.

As a large number of the iron works in this country manufacture their own coke, it is a very difficult matter to arrive at the production even approximately.

From page 41 of the *Annual Report of the British Iron Trade Association* for 1881 I extract the following:

The production and consumption of coke during 1880 has exceeded all former experience. In Cleveland, Cumberland, and North Lancashire, unitedly, about 4,000,000 tons of pig-iron were made last year, exceeding by nearly a million tons the largest quantity made in any former year. And if an average consumption of 22½ cwt. of coke per ton of iron is assumed, it follows that in the three districts named the quantity of coke used was about 4,500,000 tons, chiefly supplied from the South Durham coal-field. During the last twelve or fifteen months coke has fluctuated very much in value. Commencing in Durham to rise from about 8*s*. per ton in August, 1879, it advanced before the close of the year to 13*s*. 6*d*., and in the early part of 1880 large quantities were sold between the latter figure and 20*s*. per ton. In the latter months of the year, however, prices became easier. (*a*)

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a As this report is going through the press a statement, prepared by the secretary of the British Iron Trade Association, is at hand, which contains some interesting information concerning the use of coke in the blast-furnaces of that country in 1882, from which the following is extracted:

"There are no reliable statistics of the production and consumption of coke in the United Kingdom, but the demand for this form of fuel is known to have very largely increased within the last few years. This has chiefly been due to the development of the iron trade, but the demands for locomotive and export purposes have also been extended in a material degree. The economies that have been introduced in blast-furnace practice have, however, so considerably reduced the consumption of fuel per ton of iron smelted that the effect of the greatly increased production of pig has not been so apparent in this industry as it otherwise would have been. The following figures show what the consumption of coke would be in the manufacture of pig-iron in 1882 compared with 1879, assuming for each year an average of 23 hundred-weight of coke per ton of pig:

CONSUMPTION OF COKE IN 1879 AND IN 1882, ALLOWING AN AVERAGE OF 23 HUNDRED-WEIGHT OF COKE PER TON OF PIG-IRON MADE, WITH INCREASE OF CONSUMPTION IN EACH DISTRICT IN THE LATTER YEAR.

District.	Consumption of coke. 1879.	Consumption of coke. 1882.	Amount of increase in 1882.	District.	Consumption of coke. 1879.	Consumption of coke. 1882.	Amount of increase in 1882.
	Tons.	*Tons.*	*Tons.*		*Tons.*	*Tons.*	*Tons.*
Cleveland	2,032,448	3,091,947	1,059,499	Lancashire	726,044	900,150	174,106
West Cumberland	611,383	1,151,358	539,975	Northamptonshire	190,114	220,932	30,818
South Wales	770,336	1,015,801	245,465	West and South Yorkshire	251,626	321,141	69,515
North Wales	21,796	56,020	34,224	Derbyshire and Notts	335,173	512,595	177,422
South Staffordshire*	374,647	458,209	83,562	Shropshire	69,908	92,546	22,638
North Staffordshire	241,930	364,684	122,754	Gloucestershire, Wiltshire, etc	46,000	55,200	9,200
Lincolnshire	151,429	231,795	80,366	Total	5,822,834	8,472,378	2,649,544

* In South Staffordshire probably one-half of the fuel used in iron smelting is raw coal, but as the exact proportions are unknown the whole is dealt with as coke.

"These figures show an increase of 2,649,544 tons, or 46 per cent., within four years; but it should be noted that the average consumption per ton of pig is likely to have been higher in 1879 than in 1882, because of the extensive introduction of more economical

The following table shows the exports of coke from Great Britain for 1878, 1879, and 1880, and the value of the same:

Countries to which exported.	1878. Tons, 2,240 pounds.*	1879. Tons, 2,240 pounds.†	1880. Tons, 2,240 pounds.‡
Russia:			
Northern ports	52,511	48,070	56,309
Southern ports	122	250	714
Sweden	18,411	24,140	40,860
Norway	10,128	10,960	16,028
Denmark	4,902	6,280	6,023
Germany	23,044	32,050	38,761
Holland	2,363	8,230	8,561
France	17,180	14,920	23,033
Portugal, Azores, and Madeira	3,872	5,570	3,879
Spain and Canaries	92,603	106,990	143,218
Italy	15,476	24,420	21,110
Greece	5,051	17,600	21,556
British India:			
Continental territories	4,400	7,620	6,205
Straits settlements	110	200	494
Ceylon	102	170	229
United States of America on the Pacific.	4,851	10,950	16,052
Chili	5,562	11,290	18,750
Brazil	2,437	3,100	3,418
Other countries	11,114	12,628	17,597
Total	274,239	345,438	442,797

* Value: £201,708. † Value: £231,671. ‡ Value: £338,259.

COKING IN BELGIUM.

The coal-fields of Belgium are among the most important of the continent of Europe, and have given to this little bit of territory an industrial importance and competitive power second only to that of Great Britain. These fields extend across the country from east to west, but vary greatly as to their accessibility, the coal at one place cropping out some 600 feet above the level of the sea, while at Mons it is found some 7,000 feet below the level.

The coal-fields are divided into five districts: Mons, Centre, Charleroy, Namur, and Liége. The first three districts named are included in the province of Hainaut, and statements and reports concerning the coal of this country frequently speak only of the provinces or districts of Hainaut, Namur, and Liége. The province of Namur, however, is of little importance as a coal-producing district, its output being only 3 or 4 per cent. of the product of the country.

The quality of Belgian coal, though, as in most countries, it varies greatly, is on the whole good, the deepest seams being the best and thickest. Nearly half the total production is a close-burning coal, and is used principally for

blast-heating apparatus, and also because of the much larger make of hematite relatively to other qualities of iron in the latter year. The difference, therefore, against 1879 is likely to have been even greater than the foregoing figures indicate. The following table shows the consumption of coke in the manufacture of pig-iron in 1882, both as coke and in the form of coal, Scotland being, of course, excluded, in consequence of the general use of raw coal in the blast-furnaces of that country.

CONSUMPTION OF COKE IN THE PRODUCTION OF PIG-IRON IN THE UNITED KINGDOM IN 1882, THE AVERAGE BEING TAKEN AT 23 HUNDRED-WEIGHT PER TON OF THE IRON MADE.

District.	Consumption of coke.	Equivalent of coal, taking 60 per cent. of coke as 100 per cent. of coal.
Cleveland	3,091,947	5,153,245
West Cumberland	1,151,358	1,918,930
South Wales	1,015,801	1,693,001
North Wales	56,020	93,366
South Staffordshire	458,209	763,681
North Staffordshire	364,684	607,806
Lincolnshire	231,795	386,325
Lancashire	900,150	1,500,250
Northamptonshire	220,932	368,220
West and South Yorkshire	321,141	535,235
Derbyshire and Notts	512,595	854,325
Shropshire	92,546	154,243
Gloucestershire, Wiltshire, etc	55,200	92,000
Total	8,472,378	14,120,627
Add coal consumed in Scotland, say		2,300,000
Total coal		16,420,627

"It is probable that the average yield of the United Kingdom will be nearer 56 to 57 per cent. of coke per 100 of coal, 60 per cent. being indeed about the best average result that is obtained in the coke manufacture. It is probable, also, that the average consumption of coke per ton of pig made will, in the country generally, be nearer 25 than 23 hundred-weight. The foregoing table is therefore subject to these two modifications."

domestic purposes, and to some extent for gas- and coke-making. The production of true coking coal is small, only about 27 per cent. of the entire amount raised. Of this only a portion is coked, less than 17 per cent. of the entire production of coal being made into coke.

The beginning of the manufacture of coke on an extensive scale in Belgium dates from the erection of the first blast-furnace, in 1826, by John Cockerill, at Seraing. In 1830 the number of these furnaces had increased to 5, while there were still 72 charcoal blast-furnaces in existence. Many of these charcoal furnaces were out of blast, however, and coke furnaces gradually took their place until 1865, when there were 56 of them in blast. Notwithstanding this increase, the development of the manufacture of pig-iron in Belgium has not kept pace with the manufacture of coke. The output of iron ores has largely decreased in the last fifteen years, and while their importation has more than doubled in the same period, the production of pig-iron and other uses have not been sufficiently large to consume the coke made, and a large proportion of it has gone to the furnaces of other countries. In 1881 nearly one-half the coke made, or 914,885 out of a production of 1,834,669 metric tons, was exported.

While the production of coke in Belgium has thus been of great moment to the industries of contiguous countries, it has not been wholly the amount that has given the manufacture of coke in Belgium so much importance, but rather the improvements that have been made in coke ovens in that country. Bee-hive ovens were at first used, but as the demand for coke increased it became necessary to adopt better and more economical forms, as well as ovens adapted to coking coals of an inferior character, and the Belgian or flue ovens are the result. These ovens, if they did not originate in Belgium, certainly have received the most attention and reached their best development in this kingdom, and the name Belgian, which has been applied to all flue ovens, is therefore exceedingly appropriate. (*a*)

The official statement as to the number of coke ovens in Belgium and the production of coke in 1881 is as follows:

Localities.	Number of coke ovens.		Number of men employed.	Consumption of coal, net tons (2,000 pounds).	Production in coke, net tons (2,000 pounds).	Value per net ton (2,000 pounds).
	In operation.	Idle.				
First division, Hainaut	2,680	826	1,598	1,972,261	1,441,398	} $2 80
Second division, Liége	1,443	608	760	778,334	580,257	}
Total	4,123	1,434	2,358	2,750,595	2,021,655	....

While all the ovens in use in Belgium are flue ovens, heated from the bottom and sides, the variety is considerable, but no statement of the number of each kind is given in the official publications. Most of the ovens are horizontal, sometimes with the floor slightly inclined, and are generally placed in single or double lines or banks, but are occasionally clustered (*en ruche*). In some cases the pitch and other products of combustion are saved. The Appolt or vertical oven is also used to some extent, and for some years has been growing in favor, notably at Seraing. (*b*)

There are 57 firms engaged in the manufacture of coke, and the number of each class of ovens built is as follows:

A.—Horizontal, in lines or banks	4,397
B.—Horizontal (*en ruche*)	152
C.—Vertical	1,008
Total	5,557

Two hundred and fifty-nine ovens of class A and 48 of class B are arranged for the saving of the waste products of combustion.

The following tables give in detail the statistics concerning the production of coke in Belgium in 1881:

PROVINCE OF HAINAUT.*

	First district.	Second district.	Third district.	Fourth district.	Fifth district.	Province of Hainaut.
Number of ovens in operation	413	443	1,188	398	238	2,680
Number of ovens idle	77	130	124	228	267	826
Total	490	573	1,312	626	505	3,506
Number of workmen	....	....	....	....	....	1,398
Coal consumed, tons of 2,000 pounds	283,183	251,272	948,398	330,693	158,733	1,972,279
Production of coke, tons of 2,000 pounds	194,601	175,477	702,610	257,940	110,782	1,441,410

* Report of the engineer-in-chief, director of mines of the province of Hainaut.

The average value of the coke was 16.03 francs per 1,000 kilograms, or $2 81 per ton of 2,000 pounds, and the production exceeded that of 1880 by 722,545 net tons.

a This subject is discussed at length in the chapter on "Belgian Ovens".

b This statement is based on a letter from M. Max Goebel, editor of *La Semaine Industrielle*, Liége, to whom I am indebted for many of the facts given concerning Belgian coke.

PROVINCE OF LIÉGE.*

	Seventh district.	Eighth district.	Ninth district.	Tenth district.	Province of Liége.
Number of ovens in operation	246	90	1,023	84	1,443
Number of ovens idle	132	16	404	56	608
Total	378	106	1,427	140	2,051
Number of workmen	150	44	519	47	760
Coal consumed, tons of 2,000 pounds	174,981	54,588	503,743	45,029	778,341
Production of coke, tons of 2,000 pounds	132,057	39,812	373,917	35,177	580,963

*Report of the engineer-in-chief, director of mines of the provinces of Liége and Namur.

The value of the coke was $2 77½ per net ton, and the quantity of coke made in 1880 was 20,025 tons less than in 1879. There are no coke ovens at the mines of the sixth district.

It should be noted that, in addition to the amount given above, a little coke is made in Belgian Luxembourg. The official statistics, however, give no statement of the amount.

From these tables it appears that 2,750,620 net tons of coal were used in the production of 2,022,373 tons of coke, a yield of 73.5 per cent.—much in excess of that attained in the bee-hive ovens in the United States or England. This excess in yield is largely, though not entirely, due to the use of the flue oven. The output per oven was a little over 490 tons for the year.

The production of coke in Belgium for the five years, 1876–'80, by provinces, is as follows:

Year.	Hainaut.	Liége.
	Tons.	*Tons.*
1876	914,415	459,451
1877	899,447	448,169
1878	1,056,401	462,477
1879	1,004,930	480,990
1880	1,270,024	560,938

As has already been stated, a large percentage of the coke produced in Belgium is exported, chiefly to France. Some little coke is imported.

The following table, from the report of the Belgian ministry of finance, shows the imports and exports for the years 1877, 1878, and 1879:

EXPORTS.

Exported to—	1877.	1878.	1879.
	Net tons.	*Net tons.*	*Net tons.*
Prussia	10,163	....	11
Luxembourg	194,918	153,388	119,209
France	322,343	362,021	432,142
Other countries	3,136	3,360	2,832
Total	530,560	518,769	554,194

IMPORTS.

Imported from—	1877.	1878.	1879.
	Net tons.	*Net tons.*	*Net tons.*
Prussia	16,157	13,795	4,410
France	4,290	5,733	5,222
Other countries	176	90	89
Total	20,623	19,618	9,721

The exports of coke have largely increased since 1879, being 937,345 net tons in 1880 and 1,008,487 tons in 1881.

The apparent anomaly presented by the above tables of the importation into Belgium of coke from Prussia, and even a small quantity from France, to which Belgium sends so much coke, is explained by the location of the works using it relative to lines of transportation, they being of easier and cheaper access to the French and Prussian coke manufactories than to the Belgian.

COKING IN FRANCE.

The French coals, even of the coking variety, are, as a rule, not well adapted to the manufacture of coke, being, as compared with the English and the Belgian coals and those of Westphalia, very impure and high in ash, the amount being such that the fuel would hardly be used at English or American blast-furnaces. By carefully washing the coal and by proper attention to coking, however, the difficulty is reduced to a minimum. The results obtained in French iron works with their fuel is most creditable to their management.

There are in France six principal coal-producing districts. (*a*)

1. *The northern coal-field.*—This district extends over a part of the departments of the Nord and Pas-de-Calais, from the Belgian frontier up to and beyond the city of Bethune, and more particularly in the environs of Valenciennes and Douai. The coal-measures comprise a rather large number of seams, generally varying in size from 0.50 to 1 meter. (*b*) Various kinds of coal are produced, including anthracitic, semi-bituminous, and coals suitable for making coke. These coals vary also as regards the percentage of ash, and a like observation applies to the coke produced. Two kinds of coke are made in the department of the Nord, viz: the washed coke, containing from 7 to 8 per cent. of ash, and the unwashed, containing from 12 to 14 per cent., and sometimes more. This coal-field has the advantage of possessing a great number of railways and canals in connection with the Seine, Marne, and Meuse, so that its products are conveyed a considerable distance.

2. *The Burgundy coal-field.*—This district occupies a portion of the department of the Saône and Loire between Autun and Charolles, its principal collieries being those of Blanzy, Epinac, and Creusot. There are but few seams, and those of somewhat varied characteristics, the thickness being not unfrequently considerable, while the seams are worked by means of shafts sunk to a depth of 250 or 300 meters, or more. At Creusot the coal is nearly an anthracite, but it undergoes a change eastward, where it becomes very flaming, and, to a certain extent, is adapted to coke, without, however, being really a coking coal. The small coals have to be washed in order to produce coke with even as little as 12 per cent. ash. The Creusot coal is not suitable for carbonization, except when mixed with a considerable proportion of coking coal of the Saint-Étienne district.

3. *The central coal-field.*—This is situated in the department of the Allier, and the principal collieries are those near the town of Commentry and the village of Bezenet. A fine seam, with but little incline and an average thickness of, say, 14 meters at the former place and a somewhat irregularly formed seam at the latter, is worked. The coal is flaming and gaseous, and yields a rather light kind of coke, which, when produced from washed coal, contains from 10 to 12 per cent. of ash. To this main coal district may be attached some small outlying coal-basins, one of which is the Saint-Eloy basin, in the neighboring department of the Puy-de-Dôme, supplying coal and coke, with a good proportion of ash.

4. *The Loire coal-field.*—Next to the coal district of the Nord the Loire district is the most important, more especially in the vicinity of Saint-Étienne and Rive-de-Gier. It comprises a number of seams of no inconsiderable extent, the total accumulated thickness of which is calculated at from 50 to 70 meters, the whole depth of the coal-measures being about 1,800 meters. The proportion of ash in the coke obtained from the small washed coal is generally from 12 to 13 per cent.

5. *The Aveyron coal-field.*—This district is situated in the department of the same name, and the chief collieries are those of Decazeville and Aubin. The seams are nearly horizontal, and are of but little depth. The coal here has to be carefully washed in order to obtain such a kind of coke as would be suitable for use in blast-furnaces. This coke, which is not very dense, generally contains from 10 to 12 per cent. ash.

6. *The Alais coal-field.*—This ranks as the third important coal district in France, and is situated in the department of the Gard. The seams differ in thickness (from 0.30 to 2 meters), and yield sundry kinds of coal, varying from the anthracite to the flaming sort, including the intermediate coking and bituminous qualities suitable for coke. Coke of good quality and with but little sulphur is made from the washed small coals, with from 10 to 14 per cent. ash in the kinds suitable for blast-furnaces.

As regards the center of France, mention may be made of the Brassac basin in the Haute-Loire (which sends its coking coal as far as Creusot), and the Ahun basin, department of the Creuse, also producing coking coal and supplying two or three smelting works in the neighborhood.

In the east the Ronchamp coal formation, situate on the southern slope of the Vosges, department of the Haute-Saône, furnishes a certain quantity of fuel to the Franche-Comté iron works.

In the southwest the Carmaux basin (department of the Tarn) supplies coke to some iron works, particularly those near the Pyrenees, and the Graissesac basin (Herault) produces also coal fit for coke.

Generally speaking, coke is no longer manufactured in France except in the Belgian ovens, chiefly of the Smet, Coppée, or Appolt systems. The Smet and the Coppée ovens are principally used in the Anzin, Commentry, Saint-Étienne, Aveyron, and Grand-Combe collieries; the Appolt at Blanzy, Creusot, Bezenet, Portes, and other places. A number of ovens on the Carvès system, for utilizing the waste products, are in use with good results, especially

a Condensed from a paper by Professor S. Jordan, of Paris, read before the British Iron and Steel Institute, at its Paris meeting, 1878.
b The meter is 39.370 inches.

at Saint-Étienne and Terrenoire. Almost all the small coal used is washed, as with few exceptions French coal would not be otherwise pure enough to produce a sufficiently clean coke for manufacturing purposes.

It is very difficult to arrive at the yield of the French coal in coke. In the Saint-Étienne coal-field at one point there are 122 Belgian ovens, using crushed and washed coal, 175 tons of coke being made per day. The charge is from 4 to 4½ tons, and it is burned 48 hours, yielding about 3 tons, or 72 per cent. The average ash in the coal is 13⅓ per cent., but by double washing it is reduced to from 4½ to 8 per cent. At Saint-Étienne 80,000 tons of coal are burned per year, producing as follows:

	Tons.
Large coke	52,008
Small coke	3,500
Graphite	30
	55,538

or 69.4 per cent. of coke, beside 2,400 tons of tar and 300 tons of ammonia product. The best information is to the effect that the average yield of coal in coke in France is 70 per cent.

The price of coke in 1878 varied from 20 to 27 francs ($3 86 to $5 21) per ton at the ovens, according to the purity of the article and the situation of the coal-fields.

In addition to the fuel from French collieries, the French metallurgical works import coal and coke from foreign countries, as, for example, from England (the cargoes being discharged at the channel and ocean ports), as well as from Belgium, and, via the Belgian frontiers, Westphalia. It would even be possible to quote an establishment in the southwest of France which receives its coke, via Rotterdam and Bordeaux, from the Ruhr carboniferous district (Essen, in Westphalia).

Considerable coke is brought into France from other countries, and some small amounts are exported, the imports and exports for 1881 by countries, and for 1879 and 1880 by totals, being as follows:

Countries.	Imports.	Exports.
	*Tons.**	*Tons.*
Belgium	902,771	
Germany	190,487	
Switzerland		7,275
Italy		7,585
Other countries	17,796	9,754
Total 1881	1,111,054	24,614
Total 1880	943,416	40,905
Total 1879	760,529	20,589

* This ton is probably the metric ton of 2,205 pounds.

The official publications of the French government contain no returns of the annual production of coke. Pechar estimates it at 1,400,000 metric tons (1,543,234 tons of 2,000 pounds), requiring about 2,000,000 metric tons (2,204,620 tons of 2,000 pounds) of coal. This would indicate the same yield as is stated above, 70 per cent. Adding to this the imports and subtracting the exports, it would leave for consumption in France, in 1880, 2,302,511 metric tons, or 2,538,081 tons of 2,000 pounds.

COKING IN GERMANY.

The introduction of the steam-engine into the mines and iron works of Germany in 1784 gave, as it did in other countries, a strong impetus to the development of its coal and iron industries, as also to the production of coke. The first coke blast-furnace was erected at Gleiwitz, in Upper Silesia, in 1796. This was followed by the introduction of coke-furnaces in Königshütte in 1802, in Hohenlohhütte, which was the first private works, in 1805, and in the district of the Saar in 1848.

The chief coke-producing region of Germany, as well as the source of nearly half its coal, is Westphalia. The coal-basin of this district, which is also called, after the river which runs through its southern part, the basin of the Ruhr, is about 70 kilometers in length and 20 kilometers in breadth (say 43.5 miles in length and 12.43 miles in breadth). In this space of about 650 square miles are raised more than 20,000,000 tons of coal annually—55 per cent. of all produced in Prussia, and about 49 per cent. of all produced in the German empire. (*a*) There have been developed 74 workable seams of over 20 inches each, the total thickness of coal being 70 meters, or 229¾ feet. The coking coal belongs to the third group of seams, and includes 23 seams. Nearly all the collieries possess apparatus for separating and washing their coals.

a The meeting of the British Iron and Steel Institute at Düsseldorf in 1880 was the occasion of the presentation of a series of papers on the coal and iron industries of Germany. It is from Dr. Gustav Natorp's paper on the "Coal Industry of the Lower Rhine and Westphalia" that most of the facts in this chapter are derived.

The percentage of ash, which varies in the coal between 10 and 15 per cent., is reduced by preparation to an average of from 4 to 5 per cent., even in the least clean descriptions, such as nuts and dust coal.

While the larger descriptions of the prepared product are used for domestic fuel and boiler and other industrial purposes, the dust coal, as well as the greater part of the smallest class of nuts, which are crushed for the purpose in disintegrators and mixed with the dust coal, are used for the fabrication of coke, and when manufactured from this mixture contains on an average from 6 to 7 per cent. of ash.

For the manufacture of coke out of Westphalian coal there existed early in 1880 about 2,400 coke ovens at the collieries, 1,700 at the iron works, 1,200 in private hands; in all, 5,300. This number increased in 1880 about 500. By far the greater number of these ovens is constructed on the so-called Coppée system, which has, however, in late years undergone some improvements in the brick-work and in the volume of the oven. There are only 500 coke ovens on an entirely different system, approaching the English bee-hive in shape. While the Coppée ovens, and especially those of improved construction, coke from 6 to 7 tons of coal in 48 hours, with a production of 70 per cent., the bee-hive ovens hold only 5 tons of coal, require 72 hours to coke the same, and produce from 54 to 60 per cent. of coke.

Although it is the opinion of some iron engineers that the coke produced in the bee-hive ovens is superior in many respects to that of the Coppée ovens, the former have, nevertheless, not been generally adopted, since a coke can be far more cheaply produced in the Coppée ovens, which answer all the requirements, not alone of our own native iron industry, but that of Belgium, Luxembourg, and France. (*a*)

The approximate number of ovens, quantity of Westphalian coal used for coking, and of the coke manufactured, is shown by the following table:

Coking works.	Number of coke ovens.	Coal used.	Coke produced.
		Tons.	*Tons.*
1. Collieries	2,400	1,530,000	1,020,000
2. Iron works	1,700	1,057,500	750,000
3. Private works	1,200	765,000	510,000
In all	5,300	3,352,500	2,280,000
Per year and oven		633	430

Through the kindness of Dr. Hermann Wedding I am enabled to give the following statement regarding the production of coke in Prussia. These statistics are not gathered officially, either as to the amount produced or as to the number of coke ovens, but the following figures, derived from sources not official, may be considered very nearly correct:

	Tons.
District of Upper Silesia	434,199
District of Lower Silesia	127,596
District of Lower Westphalia (Ruhr district)	2,280,000
District of the Saar	510,103
District of Aix-la-Chapelle	13,259
District of Oberkirchen	32,096
Total	3,397,253

In Upper Silesia the coal is somewhat inferior in character, and as a rule does not coke. However, some coking coal exists at Zabize, and from the slack from the mines at this place some coke is made in bee-hive and Belgian ovens. From the non-coking or poor-coking coals of the eastern district of Königshütte, etc., coke, as a rule, is produced either in heaps or in open kilns. Large bee-hive ovens or closed kilns are used to a still less extent, and recently some Belgian ovens have been introduced, the coke made being for furnace use. The number of ovens or heaps is not known.

Lower Silesia contains some good coking coal, which is coked in Belgian ovens, generally on the Coppée system, and is mostly for foundery purposes. A statement regarding the coking coals of Rhenish Westphalia is given above.

In the Saar district there are some good deposits of coking coal, but the coke made is not as good as that of Westphalia. Belgian as well as some Appolt ovens are used, as in Silesia.

In Aix-la-Chappelle the deposits of coking coal are extensive. There are 257 Belgian ovens in use, with some ovens on the system Lürmann for poor coal. The cokes made in this district are for blast-furnace purposes.

In Oberkirchen, where the coal is very pitchy, light, porous coke is made in open kilns, and is used mostly for lead and copper smelting.

The designation of ovens in Germany is so peculiar as to demand a word of explanation. The terms used are open ovens, closed ovens, narrow ovens, and Appolt. The open oven is what we have termed the open kiln, the closed oven either the bee-hive or its modification, the rectangular oven, without flues, the narrow oven the horizontal Belgian oven, and the Appolt oven the vertical Belgian.

a See Dr. Natorp's paper.

Nearly all iron works in the neighborhood of coal-mines have their own coke ovens and use the escaping gas to heat the boilers, but the greater part of the iron works situated at some distance from the mines purchase coke, while some is brought from Belgium.

The total output of the coke works of Germany in 1878 is given in the *Colliery Guardian* at 5,403,392 tons. Prices have fluctuated considerably recently. At the beginning of 1879 furnace coke was quoted at 22*s.* a ton, a decline, as compared with 1878, of 16 per cent. In May, 1879, Silesian and Westphalian coke were quoted at Berlin at from 19*s.* to 20*s.* per ton. As showing the cost of freight, these same cokes were quoted at the ovens at from 7*s.* 6*d.* to 8*s.* 6*d.* In January, 1880, coke at Dortmund was quoted at 26*s.*; in February, at the same place, 28*s.*; in April, at the pit, £1 8*s.* 3*d.*, and in May, 1880, Westphalian coke at Hamburg was 50*s.* About this time speculation lost its power, and coke sold at the close of 1880 at from 9*s.* to 10*s.* per ton at the pits.

COKING IN AUSTRIA-HUNGARY.

Though some portions of Austria-Hungary are among the oldest iron-producing districts of the world, the small supply of coal of a coking character, and its distance from the best deposits of iron ore, have seriously interfered with the development of its iron resources, and consequently with the use of coke. The distribution of these two minerals is also such that the best ores and the good coking coal are not together. In the Austrian alpine countries, Styria and Carinthia, which are very rich in excellent iron ores, charcoal is at present almost the exclusive fuel used for making pig-iron. This section has no coking coal, and the long distances and high railway tariffs admit only of a limited use of coke from other sections and countries. In Bohemia, Moravia, and Silesia there are large deposits of good coking coal, but the ores are inferior to those of Styria and Carinthia. It was not until 1838 that pig-iron was made with coke in this district, the first blast-furnace, which was also the first in Austria, having been erected at Witkowitz in this year; but since the year 1870 its use has become more general, and at present one-half of the production of pig-iron is with coke.

It is in these provinces of Austria that nearly all the coke made in Austria-Hungary is produced, the chief centers of production being Kladno and Pilsen in Bohemia and Ostrau-Karwin in Silesia. The coke from the latter district is an excellent furnace fuel. That from Kladno is used at the works of the Prague Iron Company, the most extensive coke blast-furnaces in the empire. The average yield of the coal of the Ostrau-Karwin district in coke is estimated at from 55 to 61 per cent. About 8 per cent. of the output of the district is coked. At present the production is limited by the high cost of transportation to the iron works.

The manufacture of pig-iron in Hungary has advanced much in the course of the last few years, but a scarcity of suitable coking coal also prevails here. Of the 68 blast-furnaces of Hungary but one uses coke entirely, and one other part charcoal and part coke. Only small quantities of Banatian coal are made into coke, but this is excellent, and the yield is the highest in the empire. For the other operations of iron and steel making most of the fuel used is brown coal or lignite, of which Austria-Hungary possesses rich deposits of a most excellent character. There are, however, some deposits of coal of a coking quality well adapted for use in furnaces, and, though inconveniently situated in respect to the ore deposits, those metallurgists who know the country best are sanguine as to its availability in the near future. While some quite successful experiments have been made in producing coke from lignite, the amount made is quite small.

The statistics of coke-making in this empire are very meager. The following quantities of coal were, according to Pechar, used for coke in the year 1876:

	Metric tons.
In the Ostrau district	126,419
In the Kladno district	71,973
In the Pilsen district	43,281
In the Schatzlar-Schwadonitz district	7,340
In the Rossitz district	7,129
In Hungary	2,974
Total	259,116

Assuming the yield to be 58 per cent., this would make a total production of about 150,287 metric tons. From another source the following statement of the make of coke in Austria in 1878 is given:

	Metric centners.
Bohemia	1,192,566
Moravia	574,026
Silesia	1,073,445
Total	2,843,037

or 175,503 net tons, a result that does not differ much from the production estimated above. A portion of this, some 13,400 metric centners, was exported in 1878 to Prussia and Russia.

The same causes that result in a high price of coke and fluctuations in the price in other countries rule in Austria, though the high price is more largely due to the heavy cost of railway carriage. In 1879 coke cost, delivered at Loeben, 17 florins 40 kreutzers, or, at 48 cents the florin, $8 48 per ton, and at Bordenberg 16 florins, or $7 68.

COKING IN OTHER EUROPEAN COUNTRIES.

But little coke is manufactured in continental Europe outside of the countries already named, viz, Belgium, France, Germany, and Austria-Hungary. In the other states the coal is either non-coking or is so situated with reference to transportation, ores, and centers of demand that it is more economical to use other fuel. In Norway no coal is mined; in Sweden the only coal worked is in the Lias, and is non-coking. There are a few coke ovens, less than ten, at Stockholm, which make coke from English coal and its slack, for use in small passenger river steamers. As no coke is used in the Swedish blast-furnaces, the demand is very small, and, with the exception noted, is supplied from England. Denmark proper has no coal-beds. There are two small mines in the island of Bornholm, a dependency of Denmark, but the whole output is used on the island, chiefly in the manufacture of brick. Lignite is also found in Iceland, but no coke is made from it. Russia has very extensive deposits of coal, some of which is well adapted to coking, but the immense forests of this empire furnish such boundless supplies of charcoal that most of the iron is smelted with this fuel. The means of transportation are also so inadequate and expensive that it is cheaper to purchase iron abroad, and as a result, the demand for coke is light, and but little is made. The Donetz coal, which is coked to some extent, yields from 51.75 to 81.99 per cent. in coke. In Holland coal is found only in the province of Limburg; but the output is insignificant, and no coke is produced. Coal is found in many places in Turkey and Greece, but very little of it is mined and no coke is made, though some of it is of a coking character, and many deposits of iron ore exist. The coal deposits of Italy are mostly lignite, and of Switzerland anthracite and lignite, little or no coking coal being found. In Portugal there are but two coal-fields worth mentioning, and no coke is made.

But little is known of the production of minerals in Spain, with the exception of iron ore, and that little not of recent date. The Spanish coal-basins are of considerable importance, furnishing some coal adapted to coking, and, on the whole, are well situated with respect to outlet, the deposits of iron ore being among the most extensive, richest, and purest in the world. Notwithstanding these natural advantages, however, Spain imports fully half the coal she uses, and exports nearly all the iron ore, instead of working it into the various forms of cast and manufactured iron. Some pig-iron is made in Spain with coke, chiefly imported, however, but the fuel generally used is charcoal. Probably the main obstacle in the way of the development of its coal, and, consequently, of its coke industries, is the lack of transportation in the interior of the country. In 1872, in the province of Cordova, 5,717 metric tons of coke were produced; in 1871, 4,707 metric tons; and in 1870, 2,589 metric tons; but as the estimated annual consumption of coal in the iron and metal industries of Spain is 500,000 metric tons, this is probably below the actual make.

At the close of 1882 there were in Spain five coke works. At one of these, that of Sociedad Anónima, at Mieres Asturias, three methods of coking were used.

First: A bank (macizo) of 40 furnaces, Smet system (Belgian), with a capacity of 3,000 kilograms each of washed coal. The burning lasts 40 hours, and a yield of 60 per cent. is obtained.

Second: A bank of 30 ovens, similar to the Coppée, but modified by the society. Each oven holds 3,000 kilograms of coal, and yields 63 per cent. in 30 hours.

Third: Beside this, some 7,000 or 8,000 tons of coke are produced annually in heaps in the open air with the same class of coals, but in this system the yield does not exceed 48 per cent.

PART IV.—COAL, COAL-WASHING, ETC.

COKING AND NON-COKING COALS.

Certain kinds of bituminous coal when heated to a temperature varying somewhat with their character swell, become pasty and sticky, and throw off bubbles or jets of gas, which burn with a bright flame as they escape into the air. When lumps or particles of these varieties of coal are thus heated to the pasty condition they lose all traces of their original form, appearance, and structure, and unite into a coherent mass, or, in technical language, are said to "coke" or "cake", and the coal which thus cokes or cakes is termed a "coking" or "caking" coal. (*a*) On the other hand, a non-coking coal (*b*) is one that, under similar treatment, either coheres feebly or not at all, the forms of the original particles or lumps being clearly distinguishable. The solid product or the carbonaceous residue of the burning or heating of both the coking and non-coking coals is termed "coke", though in the arts this word is generally applied only to that coke which is made from true coking coal, or from admixtures of non-coking coal in proper proportions with coking coal or pitch, by which a firm coherent coke can be produced.

It is important to distinguish clearly between what may be termed "industrial coke" and "crucible" or "laboratory coke". The latter is the coke produced in a small way in the laboratory of the analyst, and includes not only the carbonaceous residue obtained in the analysis of coal, but that from pitchy and other carbonaceous substances as well. "Industrial coke" includes only the firm coherent cokes made from coal on a large scale for use in the manufacturing or industrial arts. The percentage of carbon and other elements in "industrial coke" and "laboratory coke" from the same coal will differ very materially, owing to the difference in the methods of manufacture and the greater care exercised in the production of the latter. It is important, therefore, in making comparisons of the analyses of different cokes and the yield of coal in coke, to know that the cokes were made in a similar manner, industrial coke being compared with industrial coke and laboratory coke with laboratory coke. Any comparisons of the analyses of industrial with those of laboratory cokes will be misleading unless due consideration is given to the fact that they are not made in the same way, and unless the necessary deductions are made. Much costly disappointment has arisen from a failure to make this distinction.

Industrial coke can be broadly divided into two classes: "oven coke," or that made in ovens, pits, or mounds, and which is a direct product, the manufacture of coke directly being the object of the carbonization of coal; and "gas coke", or the solid carbonaceous residue of the process of manufacturing gas. In this report I deal chiefly with that termed "oven coke", and unless otherwise specially noted the word coke will be synonymous with "oven coke".

Coke is not the result of simple fusion, the temperature necessary to produce it being above that at which the coal suffers decomposition. In the process the volatile bodies are driven off and a portion of the non-volatile compounds are decomposed, their carbon becoming to a great extent fixed, their hydrogen and oxygen being dispersed. The earthy and non-volatile substances of coal and those not decomposed by heat are nearly all found in coke.

The coking power of different coals differs greatly, and the quality of the coke made under different conditions and in different ovens from the same coal will show marked differences of character as well as of economic efficiency. A coal that in its natural state will make a very poor coke will, when crushed and washed, sometimes give very good results. (*c*) Some coals that are practically non coking when treated in the usual way, will, when rapidly exposed to a high temperature, give a fairly solid, hard coke. (*d*) It is therefore evident that something beside analysis or a trial in a single oven is necessary to determine whether or not a given coal is adapted to the making of coke. Analysis will give some indication of this fact, and the character of the laboratory coke obtained from the coal still further indications; but the most satisfactory evidence of the value of a coal for making coke is given by a practical trial in ovens or pits, and even then, in case of failure, it is not fully settled but that in different ovens, under different conditions of preparation and coking, different results might not be obtained.

These uncertain relations between coal and the character of its coke have led to many investigations, having for their object the determination of the element or elements upon which its coking properties depend. In a general way, it can be said that as a coal approaches the vegetable on the one hand and the anthracite on the other it loses its coking qualities; but so far investigation has failed to show which is the element or elements the presence or absence of which in a greater or less degree determine its value in coke-making, or has failed to show, if it is not so determined, upon what the coking power of a coal depends. It certainly is not the carbon, nor is it the amount of volatile matter, for the non-coking coals contain these in the largest amount. With this uncertainty as to what is the element on which coking depends, analysis would of course fail to show the value of a coal for

a The terms "caking" and "cake" are used much less frequently in this country than in Europe.

b "Free-burning" and "non-coking" are synonymous terms, as are "binding" and "coking".

c See *Second Geological Survey of Pennsylvania*, Report KKK, page 200.

d See Percy's *Metallurgy: Fuel*, page 309.

the manufacture of coke. Indeed, Professor Stein, of the polytechnic school of Dresden, has shown that coals having the same ultimate analysis may in the one case be coking and in another non-coking. (*a*) The same has been noticed of American coals. Mr. J. J. Stevenson, of the geological survey of Pennsylvania, notes that the coal of the Conemaugh is apparently the same as that obtained on the Youghiogheny. The coke of the latter is compact, silvery, and retains its luster for an indefinite period, whereas that from the Conemaugh is comparatively tender, dull-looking, and on exposure soon loses its little luster. (*b*) Mr. John Fulton, mining engineer of the Cambria Iron Company, gives the opinion that "ordinary analyses fail to indicate the essential qualities of a good coking coal". It has sometimes been claimed that it is the amount of hydrogen and oxygen, or the relation of the amount of oxygen to the carbon, that determines the coking qualities of coal; but both Percy and Fulton refuse to accept this, and suggest that the coking properties of a coal depend, not on the elements or their proportion, but rather on the presence of different kinds of bitumen, or, in other words, on the manner in which the elements other than the ash are combined; that is, on the proximate, not the ultimate, analysis. Considering the difficulty of reaching the true proximate analysis, it will still hold true that the only sure way of determining the adaptability of a coal to the manufacture of industrial coke is to try it and study the result.

It also appears that, in addition to this uncertainty as to the coking value of coals, judged by their analysis, there are other conditions that materially affect this property. For example, some coals speedily lose their power of coking after leaving the pit: in some cases after the expiration of one or two days; in others, after having been exposed to the weather for some weeks or months. In other cases, coals from pits in which fire-damp occurs lose their coking powers on exposure to a certain temperature (300° C.). It has also been noted that while the presence of a large amount of inorganic matter, or what would be the ash, in the coke diminishes, and beyond certain limits destroys, its coking qualities, yet examples are not wanting in which a coke with as much as 21 or 22 per cent. of ash has retained its coking property.

The following analyses, in addition to those found in other parts of this report, will show the composition of the coking coals of Great Britain and the continent of Europe that are used in the manufacture of industrial coke. When not otherwise stated, the yield and composition of the coke given is of laboratory coke:

BRITISH COKING COALS.*

Number.	Localities.	Specific gravity.	Composition, exclusive of water only.†						Water.	Coke.	Composition, exclusive of nitrogen, sulphur, ash, and water.		
			Carbon.	Hydrogen.	Oxygen.	Nitrogen. (‡)	Sulphur.	Ash.			Carbon.	Hydrogen.	Oxygen.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	Northumberland	....	78.65	4.65	13.66	....	0.55	2.49	....	....	80.67	4.76	§ 14.57
2	......do	....	82.42	4.82	11.11	....	0.86	0.79	....	....	83.09	4.85	§ 12.06
3	......do	1.276	81.41	5.83	7.90	2.05	0.74	2.07	1.35	66.70	85.58	6.12	8.30
4	......do	1.259	78.69	6.00	10.07	2.37	1.51	1.36	....	....	83.05	6.33	10.62
5	Nottinghamshire	....	77.40	4.96	7.77	1.55	0.92	3.90	3.50	63.18	85.88	5.50	8.62
6	Blaina, South Wales	....	82.56	5.36	8.22	1.65	0.75	1.46	....	....	85.88	5.57	8.55
7	......do	....	83.44	5.71	5.93	1.66	0.81	2.45	....	....	87.77	6.00	6.23
8	......do	....	83.00	6.18	4.58	1.49	0.75	4.00	....	....	88.53	6.59	4.88

* Percy's *Metallurgy: Fuel*, pages 322 and 323.
† The water is included in the case of No. 5.
‡ The nitrogen, when not quantitatively determined, is included in the number indicating oxygen.
§ Includes nitrogen and sulphur.

COKING COALS OF THE CONTINENT OF EUROPE.

Number.	Localities.	Specific gravity.	Composition, exclusive of water.						Water.	Coke.	Composition, exclusive of sulphur,* ash, and water.		
			Carbon.	Hydrogen.	Oxygen.	Nitrogen. †	Sulphur.	Ash.			Carbon.	Hydrogen.	Oxygen and nitrogen.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
9	Épinac	1.353	81.12	5.10	11.25	....	....	2.53	....	63.60	83.22	5.23	11.55
10	Alais, department du Gard	1.322	89.27	4.85	4.47	....	....	1.41	....	78.00	90.55	4.92	4.53
11	Rive-de-Gier	1.298	87.45	5.14	3.93	1.70	....	1.78	....	68.00	89.04	5.23	5.73
12	.....do	1.288	82.04	5.27	9.12	....	....	3.57	....	72.00	85.08	5.46	9.46
13	Céral, department de l'Aveyron	1.294	75.38	4.74	9.02	....	....	10.86	....	58.40	84.56	5.32	10.12
14	Saint-Girons	1.316	72.94	5.45	17.53	....	....	4.08	....	44.80	76.05	5.69	18.26
15	Mons	....	85.10	5.49	7.25	....	....	2.16	....	72.90	86.98	5.61	7.41
16	.....do	....	80.55	5.53	9.52	....	....	4.40	....	69.15	84.26	5.78	9.96
17	.....do	....	86.38	4.48	6.09	....	....	3.05	....	80.58	89.10	4.62	6.28
18	Charleroi	....	86.47	4.68	5.30	....	....	3.55	....	84.43	89.65	4.85	5.50
19	Valenciennes	....	84.84	5.53	6.83	....	....	2.80	....	67.75	87.28	5.69	7.03
20	Pas-de-Calais	....	86.78	4.98	5.84	....	....	2.40	....	77.05	88.91	5.10	5.99
21	Hungary	1.295	86.93	4.35	6.47	....	0.86	0.89	1.20	78.85	88.72	4.66	6.62
22	.....do	1.300	86.95	4.13	6.76	....	0.99	2.85	1.14	83.14	88.85	4.23	6.92
23	.....do	1.313	80.67	4.38	6.30	....	2.83	5.82	1.04	82.82	88.30	4.80	6.90
24	.....do	1.378	69.59	4.12	9.35	....	5.53	11.41	1.57	77.81	83.76	4.97	11.27
25	.....do	1.350	79.63	4.46	4.68	....	0.90	10.33	1.08	81.55	89.69	5.08	5.28

* Except when the sulphur is not esparately stated.
† The nitrogen, when not quantitatively determined, is included in the number indicating oxygen.

a See Percy's *Metallurgy: Fuel* (London, 1875), pago 308.
b Report KKK, pages 199 and 200, *Second Geological Survey of Pennsylvania.*

As has already been indicated, neither the composition of a coal nor the analysis of the coke made from it in the laboratory is an unfailing evidence of its value as a coking coal or of the character of coke it will make. The quality and some of the properties of coke depend, not only upon the composition and character of the coal from which it is made, but also upon the manner in which the coking process is conducted, upon the oven used, and in some cases upon the previous preparation of the coal. In view of this, it is especially true that the only way to judge properly as to the value of a coking coal is first to study the character of the coal to be coked and endeavor to adopt the plan best suited to its character, and then try the plan and study the coke.

It should also be borne in mind that the yield of coke, as shown by analysis in the laboratory, is generally in excess of the actual yield in the oven. The laboratory coke made from Connellsville coal in one of the analyses given is 68.633 per cent., but the actual yield in the bee-hive ovens in the Connellsville region, as shown by the reports to the special agent, is from 62 to 67 per cent., averaging about 64 per cent. Some samples of the Miller coal at Bennington, Pennsylvania, yield theoretically, or in the laboratory, 77.25 per cent., but the actual yield, when coked in open pits, was 59.10 per cent. This discrepancy between the theoretical and the actual yield is due largely to a partial consumption of the carbon of the coal in the process of coking. For example, in coke made from Connellsville coal, in which the amount of carbon in the coal used was 59.62 per cent., which amount should have been found in the coke if none had been burned, the actual carbon was but 54.25 per cent., the ash and the sulphur being the same in both the laboratory and the industrial coke; in other words, but 91 per cent. of carbon was found in the coke. In the Miller coal at Bennington, above referred to, the carbon found by analysis was 68.50 per cent., whereas the actual amount found in the coke was only 50.35 per cent., or but 73½ per cent. of the amount of carbon actually in the coal. It would therefore follow that by those methods of coking in which the air is the more perfectly excluded from the oven less of the carbon of the coal would be consumed in the process of coking, and consequently the yield of the coal in coke would be greater. This is borne out in actual experience. As, for example, the Miller coal above referred to, when coked in open pits, yielded 50.33 in a possible 68.50 per cent. of fixed carbon, or 73.5 per cent., whereas the same coal coked in a Belgian oven yielded 61.25 in a possible 68.50 per cent. of fixed carbon, or 89.4 per cent. of the amount of carbon in the coal, showing a loss of but 10.6 per cent. of the fixed carbon when coked in the Belgian oven, as compared with 26.5 per cent. when coked in open pits. These facts show again the necessity of not depending fully on analyses, and also the importance of having careful practical trials made before deciding on the manufacture of coke.

PROPERTIES AND COMPOSITION OF COKE.

Industrial cokes differ greatly in their external appearance, their physical character, and their chemical constitution. In external appearance coke may be light gray and bright, or, as it is generally termed, "silvery" or of "metallic luster", or it may be dull and black. Occasionally it is iridescent. It is generally rough surfaced, but sometimes, especially that portion of a charge near the walls of the oven, it is smooth and glassy, having the appearance of polished graphite. Sometimes also hair-like threads are observed on masses of ordinary coke.

In its physical structure it may be porous and light, or compact, dense, and heavy; hard and capable of sustaining a high crushing and compressive strain or load, or soft and brittle, with a low crushing point and compressive strength. Its "ring" or sound, when struck, is in some samples almost metallic, and in others dull and heavy. Its degree of combustibility, as well as its ease of ignition, also varies.

The terms "dense" and "hard" as applied to coke have a special meaning that should be carefully noted. All coke is more or less cellular in its structure. The less the cell space the denser the coke; the greater the cell space the more porous; that is, "dense" and "porous" are opposite conditions. Hard is a term properly applied to the cell walls of the coke, and not to the cell space, and coke is hard or soft as the cell walls are hard or soft. Coke may, therefore, be very dense and not hard; that is, its cell space may be small and the walls of the cells weak, or it may be porous and hard, or its cell space may be large and the walls hard and strong. Physically, the typical coke for blast-furnace use should be bright silvery, hard and porous, with a metallic ring, and some of these conditions of physical structure are of more importance in determining its value than has been generally apprehended, and are deserving of more careful consideration than has usually been given them. It is no doubt important that the amount of certain of the chemical constituents of coke should be as high, and of others as low, as possible; but it is equally true that for certain purposes, for iron-smelting for example, unless certain physical conditions exist, the coke is comparatively useless. The content of carbon may be the highest and of ash and sulphur and volatile matter the lowest; but if the coke is soft and brittle its value as a furnace fuel is very small. A dense coke, or one with a small amount of cell space, other things being equal, is within certain limits inferior to one that is porous or with considerable cell space; while a hard coke, or one in which the walls of the cells are hard and strong, is superior to one in which the cell walls are brittle and weak. The importance and bearing of these physical properties of coke will be treated of in later pages.

In its chemical composition coke is essentially carbon and ash, which is the fixed, inorganic matter of the coal from which it is derived. It contains also hydrogen, oxygen, nitrogen, phosphorus, and sulphur, and, in the coke of commerce, more or less water. All of these constituents, with the exception of the carbon, are impurities, and the value of cokes of the same physical structure is inversely as the amount of these impurities.

In an analyses of coke the impurities are usually grouped under the general terms ash, volatile matter, sulphur, and in some cases other impurities are given separate from the ash. Ash is the unburnt and unvolatilized residue of the complete carbonization of coal or coke. Its chief constituent is silica, with considerable alumina and sesquioxide of iron. In the description of the Connellsville region of Pennsylvania an analysis of coke by Mr. E. C. Pechin is given, in which there is 9.523 per cent. of ash. A complete analysis of this ash is as follows:

	Per cent.
Silica	5.413
Alumina	3.262
Sesquioxide of iron	0.479
Lime	0.243
Magnesia	0.007
Phosphoric acid	0.012
Potash and soda	traces.
	9.416

Another analysis of the ash in Connellsville coke is as follows:

	Per cent.
Silica	44.64
Alumina	25.12
Sesquioxide of iron	22.73
Lime	6.95
Magnesia	1.91

The chief objection to most of the impurities is their reduction of the calorific value of coke. The phosphorus and sulphur, however, exert a decidedly deleterious effect upon the iron if coke is used in furnace or cupola work. For these reasons cokes that are low in ash, if high in either of these ingredients, are of but little value.

The amount of water in coke is also an important consideration, and all commercial cokes contain more or less of it. As cokes are usually dried before analysis, analyses do not usually indicate the amount of water present in the coke in the condition in which it is supplied to purchasers. It should not exceed 2 or 3 per cent., but at times it is as high as 5 or 6 per cent. As the presence of water reduces the value of coke as a fuel, it should be as low as possible. This water comes chiefly from that used in quenching the coke, and it is therefore of the greatest importance that some method should be used which shall leave the least water. The evidence seems to indicate that coke quenched in the oven, as in the bee-hive plan, contains less water than that quenched outside, as in the Belgian.

The amount of oxygen in coke is also a very important consideration, especially if it is to be used for smelting iron, where the process is essentially the combination of the oxygen of the ore with the carbon of the coke; and if the coke has already absorbed a portion of its oxygen, its heat value is reduced to that extent. Cokes that, so far as ash is concerned, would seem to be of a fair quality are, more frequently than is supposed, really inferior fuels, by reason of the presence of water, oxygen, and other substances, which not only reduce the percentage of carbon, but in some cases require the expenditure of a portion of what remains in the coke to expel the injurious elements.

From what has been said, it is evident that when it is necessary to arrive at the approximate true value of a coke, without actually testing it in furnaces, which is oftentimes expensive and sometimes involves great risk, not only is a thorough analysis necessary, but a most careful consideration of its physical structure should be made.

In various parts of this report, especially in the chapters on "Coking and Non-coking Coals" and those devoted to the coals and cokes of specified localities, a number of analyses of coke are given. In this place it is only necessary to bring together analyses of certain of these cokes that may be regarded as types, giving here only analyses of industrial cokes, or those made commercially, and not in the laboratory. It is not claimed that these analyses are of the best specimens, or of average specimens even, unless so stated, and it is fair to presume that parties in selecting specimens for analysis would not select the poorest.

ANALYSES OF EUROPEAN INDUSTRIAL COKES.

Localities.	Mine or seam.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Oxygen.	Nitrogen.	Authority.
English:								
Durham	Browncy, average	91.580	6.86		0.230	1.310		I. Lowthian Bell.
Do	do	91.490	6.32		0.460	1.730		Do.
Do	South Brancepeth	92.980	4.61		0.300	2.110		Do.
Do		93.150	3.95		0.720	0.900	1.28	Richardson.
Belgian	Mons basin	91.300	6.20		0.330	2.17		M. de Marsilly.
Do	do	91.500	5.89		0.470	2.05		Do.
Do	Séraing	80.850	16.510		0.510	2.130		I. Lowthian Bell.
German	Westphalia	85.060	6.400		0.860	7.680		Dr. F. Muck.
Do	do	91.772	6.933		1.255	0.040		Do.
Do	do	83.487	10.309		0.737	5.467		Do.
Do	Saar	86.460	8.540		1.980	3.020		Do.

ANALYSES OF AMERICAN INDUSTRIAL COKES.

Localities.	Mine or seam.	Carbon.	Ash.	Sulphur.	Moisture.	Volatile matter.	Authority.
Pennsylvania:							
Connellsville	Broad Ford	89.576	9.113	0.821	0.300	0.460	McCreath.
Do	Coketon	89.150	9.650	1.200	....	....	B. Crowther.
Irwin's	Penn Gas Company	88.240	9.414	0.962	....	1.384	Carnegie Bros. & Co.
Allegheny mountains	Bennington "B"	87.580	11.360	1.060	....	....	McCreath.
Blossburg	Arnot Seymour vein	84.760	13.345	0.998	0.175	0.722	Do.
Allegheny River	Lower Freeport	85.777	11.463	2.107	0.330	0.623	Do.
Beaver county	Holmes & Bro	84.727	12.636	1.994	0.100	0.633	Do.
West Virginia:							
New River	Quinnimont	93.850	5.850	0.300	....	....	J. B. Britton.
Do	Fire Creek	92.180	6.680	0.618	0.110	....	Do.
Do	Longdale	93.000	6.730	0.270	....	....	C. E. Dwight.
Do	Nuttallburg	92.220	7.530	0.910	....	....	Do.
Ohio:							
Leetonia	Washingtonville	93.750	5.380	0.870	....	....	Professor Wormley.
Steubenville	Shaft coal	90.630	8.380	0.270	....	....	Dr. Wuth.
Tennessee:							
Tracy City	Sewanee	83.364	15.440	0.142	....	....	Land.
Whitesides	Kelly	94.560	4.650	0.790	....	....	Etna Coal Company.
Rockwood	Roane Iron Company	84.187	14.141	0.182	....	....	Land.
Alabama:							
Warrior field	Pratt seam	88.224	11.315	0.563	0.362	0.990	Professor McCalley.
Cahaba field	Helena seam	84.035	15.216	0.445	0.683	0.660	Do.
Illinois:							
Big Muddy	Mount Carbon	88.180	10.070	0.610	....	0.930	Thomas M. Williamson.
Colorado:							
El Moro	El Moro	87.470	10.680	0.850	1.85		
Crested Buttes	Crested Buttes	92.030	6.620	....	1.35		

COAL-WASHING.

"Coal-washing," so called, is, strictly speaking, not washing, but the separation or classification of the coal and its impurities so far as the latter are mechanically mixed with the coal and can be separated from it. To accomplish this separation advantage is taken of the different specific gravities of the coal and of the schist, pyrites, and other minerals that form the impurities. The action of all coal-washing or coal-cleaning appliances depends upon this difference.

It will be evident that the problem of coal-washing is an extremely complicated one. The specific gravity of the coal itself as it comes from the mine varies greatly, that from the same pit and the same lump varying oftentimes from that of pure coal to that of shale, while the shale or schist presents all the intermediate gravities from that of schist to that of coal. In washing it is evident that the denser coals and lighter schists would be classified together, and thus the object of cleaning would not be accomplished, or the process would be so wasteful as to make the washing a commercial failure.

The problem is still further complicated by the impossibility of securing a uniformity in the sizes of the particles of the coal. In washing it is necessary that the particles to be treated do not exceed a certain size, which varies somewhat with their character. Preliminary screening, and in some cases crushing, are therefore necessary, but after such screening there will be certain sizes smaller than the mesh through which it has passed, including considerable dust. This dust will be carried away with the water, and is either wasted or requires some arrangement for settling and collection, while the difference in weight of the different sizes causes the heavier pieces to arrange themselves with the lighter impurities. In addition to these difficulties, some coals are of such a character that washing, though necessary to remove slate and similar impurities, is so wasteful of the coal and certain constituents of the same as to forbid its use. As is explained in the portion of this report treating of Ohio coke, the Steubenville coal is not washed, because of the large amount of "mineral charcoal" contained in it that would be wasted in the process. The same is true of some coals poor in hydrogenous matter.

It will be evident from the above that coal-washing is an operation that does not admit of any definite rules suitable for general application with absolute reliability in all localities, and the advisability of washing and the method to be employed are subject to variations dependent upon the collieries, the localities in which they are situated, the commercial conditions affecting them, and the amount of water available. It is thus evident that coal-washing, in the language of M. Marsaut, "is a function of a great number of altogether independent variables, among which no sort of connection exists." For this reason it cannot be expected that any one washing apparatus can prove perfectly satisfactory for all cases.

In this report it will not be possible to enter into a full discussion of coal-washing, but only to indicate in a general way its principles, methods, advantages, and disadvantages. (*a*)

In Germany the cleaning of coal is done to some extent by the use of air. The coal, first crushed quite small, is fed into a strong inclosed current of air, the larger and heavier particles being first deposited by the winnowing and the smaller and lighter carried farther on. This process could, no doubt, be economically adopted in sections where water is scarce, and perhaps with some coals that would be hurt by cleaning with water.

Though the method by air may be used in exceptional circumstances, coal-washing is generally done by the use of water. The washing or separation is effected either—

First, by a running stream of water, carrying the materials along with it and depositing them according to their specific gravity;

Second, by the fall of the materials through water; or,

Third, by the action of an upward current of water.

In most recent works on coal-washing the first method is ignored, as being too antiquated and wasteful; but as this plan of washing by a stream of water in boxes or sloping spouts or troughs is still largely used in England, and is regarded with great favor, a description is given, though the process is wasteful, and can only be used to advantage where water is plenty and coal cheap and dirty.

The accompanying cut shows in plan and section one form of the trough-washer. (*b*)

The method of operation of this trough or channel will be readily seen. The trough is constructed of wood, varying in length from 30 to several hundred feet, in width from 2 to 4 feet, and in depth from 12 to 15 inches. This trough is divided into compartments by means of cross-boards or flash-boards from 4 to 6 inches high and from 10 to 25 feet apart. A screen of wire-cloth or perforated sheet-metal is placed at the lower end of the trough for separating the washed coal from the water before the coal reaches the car or hopper in which it is shipped. Sliding gates are provided in the sides of the trough for clearing it from stones and other impurities. The operation is as follows: The slack coal, with a large and constant stream of water, is introduced at the upper end of the channel. By the action of the water-current the fragments of coal, having a lower specific gravity than the impurities, are carried down and over the steps, while the impurities find their way to the floor of the trough, and are kept back by

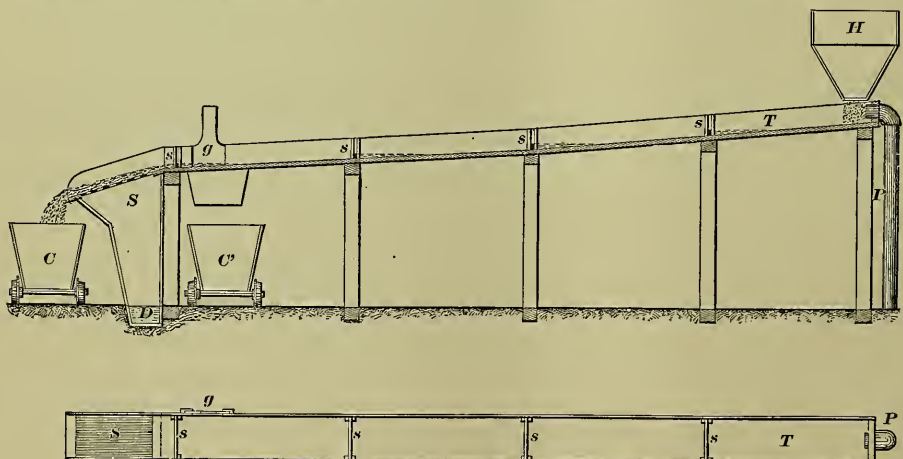


FIG. 4.—Plan and section of trough-washer.

the cross-boards. To prevent the larger pieces from becoming too much mixed with the impurities, especially behind the steps, the material is stirred with poles. These operations are continued until the bed of the channel above the cross-boards is filled with impurities to near the top of the boards, when the inlet of slack is stopped. The water is kept flowing and the material stirred from the upper dam downward until all the coal has been floated away, leaving only the impurities at the bottom of the trough. Then the sliding gate near the screen is opened, and communication with the coal-hopper is closed and established with the outside. The steps are removed, commencing with the lowest one, and the channel is washed out to be ready for a new round. The cleaning of the trough has

a Those desirous of investigating this subject further are referred to Rittinger's *Lehrbuch der Aufbereitungskunde*, Ernst und Korn, Berlin, 1867, M. Marsaut's treatise reprinted in *Engineering*, London, vol. 29, 1877, and to *Coal-Washing Machinery*, by S. Stutz, Pittsburgh, 1881.

b For this and the cuts of the Hartz jig I am indebted to Mr. David Williams, of the *Iron Age*, New York.

to be repeated every three or four hours, varying with the amount of impurities in the coal, and during this cleaning the process of separation is interrupted. The effectiveness of this washer depends largely upon the carefulness of the workmen.

According to Mr. Stutz, the amount of coal that can be washed in a day in a single trough from 40 to 50 feet long varies from 2,000 to 3,000 bushels, according to the amount of impurities. About five men are required, and, estimating labor at from $1 to $1 25 a day, the expense of washing per ton is from 10 to 12 cents. The volume of water used is very large; it may be estimated at from 300 to 400 gallons per minute for a single trough.

In the cut on the preceding page *H* is the coal-hopper, from which the slack is let into the trough *T*, water being supplied by the pipe *P*, flowing down over the steps *s*, carrying the coal with it over the screen *S* into the car *C*. The water, after passing through the sieve, passes out by the drain *D* to catch-tanks, where the fine coal is allowed to settle. The gate *g* at the side of the trough is used for removing the impurities which drop into the car *C'*.

In the washers most commonly in use the separation is accomplished by the action of an upward current of water, or by washers of the third class, and in constructing them for the cleaning of a given coal it is important to know and regulate two things:

First, the size of the pieces of coal to be operated upon.

Second, the speed of the upward current of water.

Herr Rittinger, who has so fully investigated the mechanical dressing of ore, has shown that if spherical pieces or grains of any substance of different diameters and different densities are allowed to fall through still water they severally acquire in an exceedingly short time a limiting velocity of descent, which thenceforth continues uniformly for each separate piece respectively. By a series of calculations and experiments he has deduced a formula giving the mean uniform velocity of irregular-shaped pieces of any substance, coal in particular, when falling through water or when subjected to the action of an ascending regular current of water. This formula is:

Velocity in feet per second $= 1.28 \sqrt{D(d-1)}$, *d* being the density of the material and D the diameter of the mesh riddle or screen, or virtually the diameter of the pieces to be operated upon. From this formula tables can be deduced showing the rapidity of the fall of coal and its impurities when these are known for a given coal, which will indicate what must be the sizes of the coal to be operated upon, and consequently the size of the mesh of the riddle used in separating prior to washing.

This will also indicate the velocity of the upward current of water, as it must be proportioned to the size of the material treated. M. Marsaut has shown that if a mixture of coal, slate, etc., is subjected to the action of an ascending current of water the following conditions may occur:

1. The speed of the upward current may be exactly equal to the limiting velocity of fall of the pieces of coal or other substances through still water, in which case the corresponding fragments will remain stationary.

2. The speed of the current may be greater than the limiting velocity, and in this case the fragments will rise with a velocity equal to the difference.

3. The speed of the current may be less than the limiting velocity of the pieces, and in such case the latter will fall with a velocity also equal to the difference.

In all cases, however, the formula of Rittinger is applicable.

It is evident that the velocity of the upward current should neither exceed nor fall short of certain limits. A current too strong will interfere with the classification, while a velocity inferior to that of the larger or denser fragments of coal will be incapable of separating the latter from the surrounding pieces of slate. It is also necessary that the upward current be uniform throughout the whole of the mass of material, since differences in this respect at particular points will produce unequal displacement of pieces, which otherwise would fall with equal velocity.

In the action of the washers about to be described the coal is fed upon screens, and the upward current permits of the arrangement according to gravities and in accordance with the law of Rittinger. The particles do not have the same independence of motion as when falling through water isolated from each other, but any interference is obviated if sufficient time and space are given for the action of this intermittent current.

M. Marsaut divides coal-washing machines into three principal classes:

1. Machines in which the water absolutely filters through the coal to be washed. This is the case of the old piston or Hartz jig in its different forms, whether worked by machinery or by hand.

The filtering action of the water comes fully into play in this machine, and slack of poor quality may be treated to advantage, since the action caused by the back suction is brought to bear upon the fine particles of impurities forming the slimes. For this very reason, however, it causes a serious loss of combustible matter in the shape of fine coal, and the apparatus is therefore wasteful.

We give on page 76 cuts of two forms of the Hartz jig, in one of which the coal is removed from the sieve by rakes or by hand (Fig. 5), and in the other by the revolving scraper R (Fig. 6). The operation of these machines will be readily understood from an inspection of the drawings.

The water flows into the settling-tank through the pipe *p*, and by the action of the plunger *P* is given a reciprocal motion, which forces it up through the sieve *S*, into which the coal is let from the hopper *J*, in Fig. 1.

As the water flows over the delivery bridge *b*, with each stroke of the piston it carries with it into the channel *c* a certain amount of coal. By means of the screw *a*, the impurities are let into compartment *d*, through which they reach the outside through the opening *e*. As is already explained, this process is somewhat wasteful. Mr. Stutz estimates that from 150 to 200 bushels per square foot of surface of screen can be washed per day of ten hours, requiring a volume of water of from 5,000 to 6,000 gallons, or from 30 to 35 gallons per bushel of washed coal. Generally two men are sufficient to wash from 2,500 to 4,000 bushels per day, making the expense from 3 to 5 cents per ton.

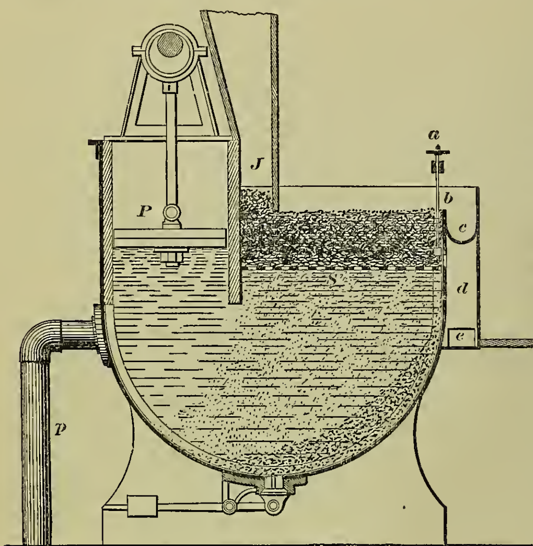


FIG. 5.—Hartz jig.

2. Machines in which the filtration of water through the material is either entirely or partially obviated, and in which a continuous or intermittent ascending current of water produces the separation.

These washers possess the great advantage over the former class of machines of effecting a more complete separation, and thus the loss of fine coal is reduced to a minimum. They also require far less driving-power for their working. Great improvements have been made in the arrangements of some of these machines, in view of the quantity of washed coal produced and in the economy of attendance; but here I may state that at some places the free delivery or overflow of the washed coal is the source of the greatest trouble, as the machine is pushed and made to deliver more than can be properly washed. The discharge by the overflow being controlled by the quantity of water let into the machine, some machines are forced to turn out double the intended amount, and the consequence is that the coal is badly washed. A certain time is of absolute necessity to obtain a good cleansing, and the quantity of washed coal has a direct and invariable relation to the surface of the sieve of the washer.

An illustration is given on page 77 of the Stutz form of this class of machines, most largely in use in this country.

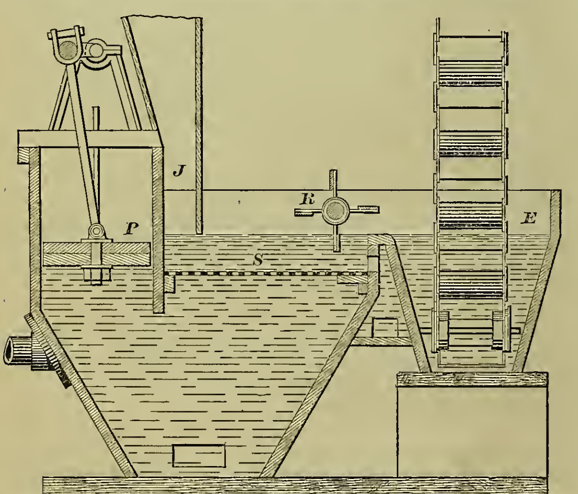
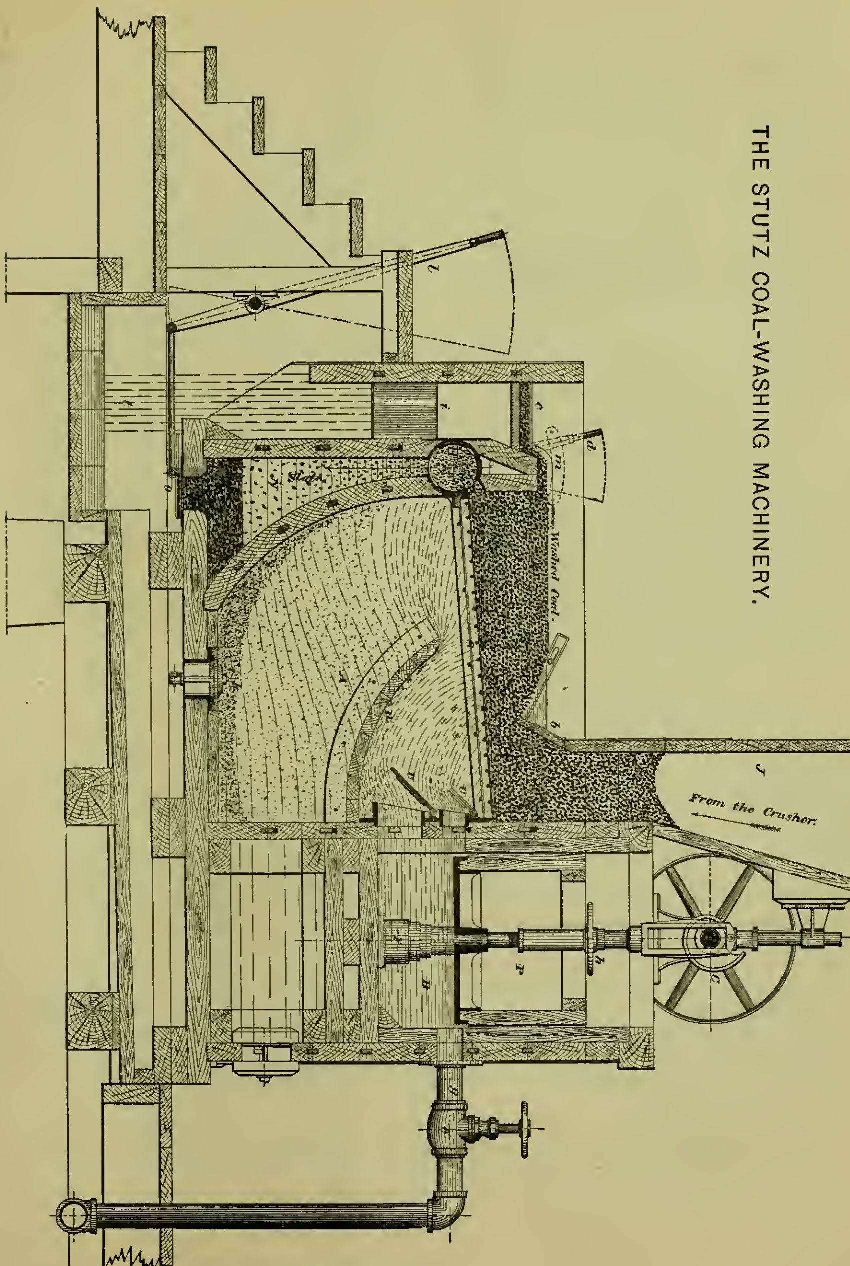


FIG. 6.—Hartz jig, with revolving scraper.

Two wooden boxes, *A* and *B*, strongly bolted together by tie-rods and flat iron bands, contain, respectively, the sieve *S* and the plunger *P*. The water is taken into the machine by the pipe *g*, and the current is produced by means of the plunger *P* and a differential cam, *C*, and its action may be easily regulated to suit the size of any substance. In this apparatus the yoke of the cam *C* is connected with the plunger-rod by a swiveled screw-nut, and can be raised or lowered, according to the current required. This is done by the hand-wheel *h*. *F* is a spring-buffer, to limit the downward stroke of the plunger, and *v* are valves to prevent the filtration or back-suction of the water. The arrangement of the curved partition *n* has for its object to direct the fresh water upward through the sieve and the layer of the material, and to prevent its being mixed with the slimy and muddy water of the lower portion of the box *A*. Coal is brought upon the sieve from the bin *J* by passing below the gate *b*. At each fall of the plunger *P*, a certain volume of fresh water being driven through the openings of the valves *v* into the box *A*, a sudden rise of the water-level and the layer of the material is thus produced, causing an equal volume of water to flow over the bridge *m* into the channel *c*, carrying with it an amount of pure coal. Before leaving the washer the mixture of water



THE STUTZ COAL-WASHING MACHINERY.

FIG. 7.

and coal passes over a drying sieve, *i*, leading the coal to the elevator buckets, while the water goes out through the meshes of the sieve and flows out below. By their greater density the pieces of slate, sulphur, etc., form the layer immediately upon the sieve *S*, and, being forwarded at the same time as the coal, will pass through the valve *H* into the slate-chamber *N*. The inlet of the slate into the valve *H* is regulated by the lever *d*, according to its percentage. From the chamber *N* the impurities are let to the outside of the gate *o*, worked by the lever *l*, and reach the trough *t*, from which they are carried away by the waste water. The fine particles of slate, etc., forming the slimes, settle below the partition *n* and are discharged by the valve *k*. The use of a differential cam for the working of the plunger allows the material after each stroke the necessary time to deposit, according to gravity. An eccentric or crank cannot produce the same movement. The usual size of the sieve is 3 feet by 4 feet 6 inches, or by 4 feet 9 inches, hence its surface is 13½ or 14¼ square feet. Washers with one or more sieves are constructed. An apparatus with two sieves of the above dimensions can prepare from 200 to 300 tons of slack per day of ten hours. The amount of water required varies from 12 to 25 gallons per bushel (76 pounds) of coal, and sometimes even more, according to the percentage and nature of the impurities contained in the material.

Mr. Stutz estimates that from 3,000 to 4,000 bushels of coal can be washed per day in this machine with a simple screen. At the works of Charles H. Armstrong & Son, at Pittsburgh, an apparatus of two screens 3 by 4 or 4½ feet washes daily from 6,000 to 7,000 bushels. A 4-gallon pump, running at from 50 to 60 single strokes per minute, furnishes the necessary water, thus giving from 20 to 25 gallons of water per bushel of coal.

The labor needed to the above amount is:

One man attending engine and washing-machine, at	$2 50
One man attending to boilers, etc., at	1 25
Total	3 75

or from 1½ to 2 cents per ton.

At the works of the Colorado Coal and Iron Company, near El Moro, in Colorado, where the coal is crushed and washed in this machine, the cost of crushing and washing 200 or 250 tons daily is from 4½ to 5⅝ cents, as will be seen from the following statement, the amount washed being, as above given, 200 or 250 tons:

Interest per day on $12,000 at 10 per cent. per annum	$4 00
Coal, oil, packing, etc	1 50
One machinist	2 50
One fireman	1 75
One laborer	1 50
Total	11 25

The third method of washing of M. Marsaut includes a number of plans of sorting by equivalents, none of which are in use in this country, and which it is not necesssary to refer to here.

As many of the coals of Illinois especially require washing, I give a cut and description of a washer that has been especially adapted to these coals. It is the Osterspey jig, improved by the Messrs. Meier, of Saint Louis. (See page 79.)

The upper box A B is composed of 2-inch plank, feathered at the joints, and bolted to a stout bottom frame of 4-by-8 inch scantling and an upper frame of 3-by-6 inch scantling. The bottom frame serves to rest it on floor timbers, either lengthwise or crosswise, as most convenient. The lower box C, also of 2-inch plank, fits into it, secured by heavy feathers and bolts. It is pointed toward the bottom to cause the fire-clay, etc., to settle around the mud-valve M, through which it is discharged.

The upper box has a rear chamber, B, with plunger P, and is separated from the forward chamber A, with screen bottom *g g*, by means of the diaphragm E. This is double, and admits the water-supply pipe W and the mud-valve rod *r*, both of which pass through the cross-plate *c*, which forms a fulcrum for the mud-valve level *m* and a support for the housing H, carrying the two shafts. The forward shaft carries a pulley, S, and a slotted cross-head, T, in which a T-headed bolt, I, is clamped at a point giving the desired stroke. A sleeve on the bolt I works in boxes sliding freely on the guides G attached to the rear shaft, thus giving a quick down-stroke and slow up-stroke to the crank K and the plunger P.

The bed *g* is made of fine wire-cloth, supported on coarser netting, or on perforated plates of iron, braced by six small angle-irons crosswise and two heavier ones lengthwise, held down by key-bolts, *a a*, and resting on a narrow cast-iron frame, *f f*.

By driving back the keys and unshipping the six bolts *a a* the whole bed can be lifted out and replaced in ten minutes. By having a few extra bed-screens on hand, we avoid delays in case of choking up by fire-clay, or in case of repairs to screens.

The screen-plates perforated with fine holes in use in Europe will not answer, frequently choking up with fire-clay several times a day.

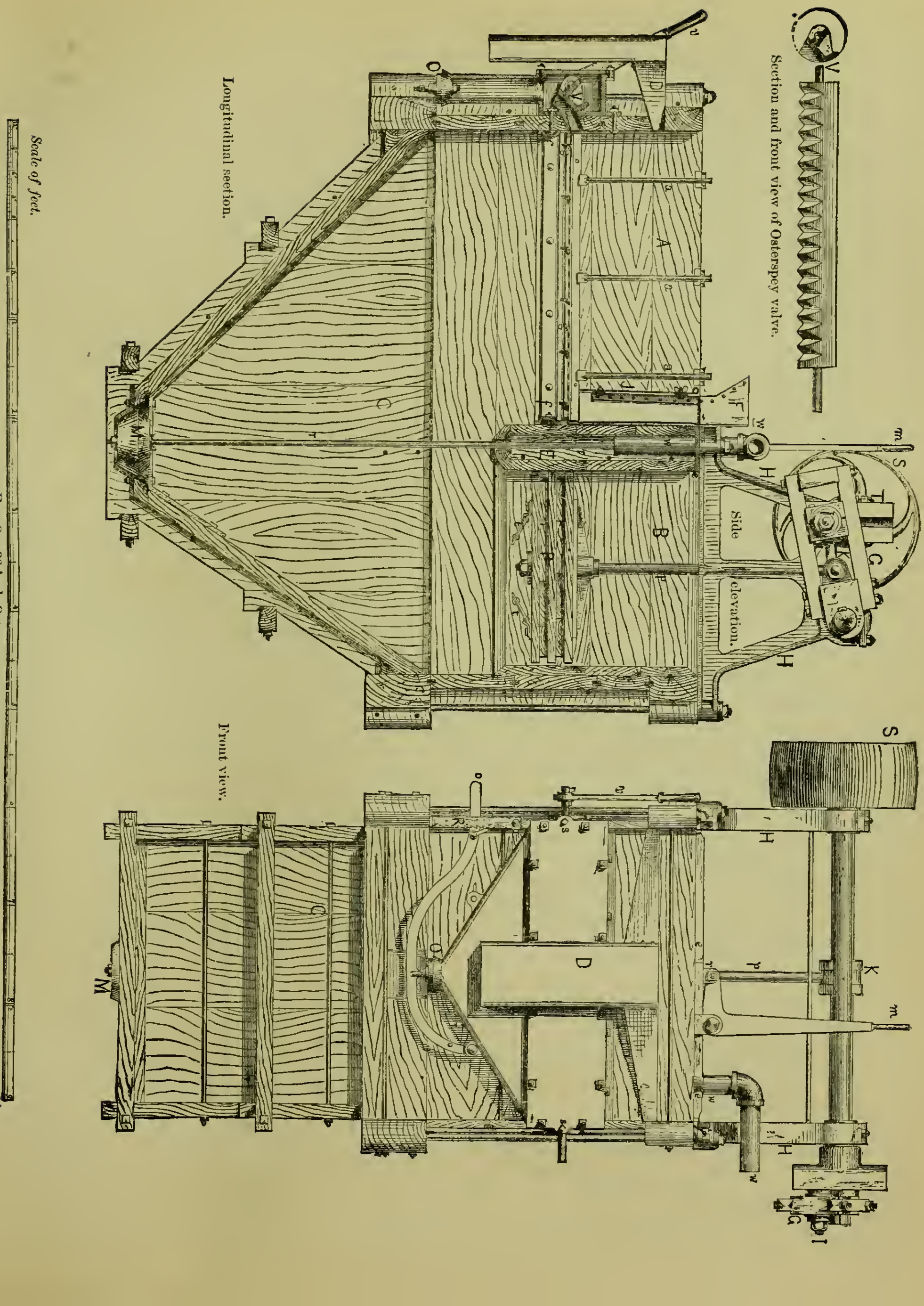


FIG. 8.—36-inch Osterspey jig for coal.

The coal is fed through a hopper, F, and under the slide J, which regulates the quantity. It is jigged along the whole length of the screen *g*, the washed coal discharging over the bridge through the hopper D. The slates and dross pass through a slot flush with the bed-screen and through the valve V, and drop into a pocket, from which they are occasionally drawn by means of the slate-valve O.

The main valve V consists of part of the periphery of a cylindrical roller which has been perforated by a number of parallel triangular prisms. This presents to the discharge-slot a number of triangular openings, giving, equally distributed over its entire width, just as much free area as is required to continuously discharge the dross as it accumulates on the bed *g*.

When it becomes necessary to open the valve O, the valve V is momentarily closed by turning the lever *v* until V presents its smooth cylindrical surface to the discharge-slot. Then O is thrown suddenly open, the dross washes out, O is as rapidly closed, and V slowly returned to the position previously determined as giving the required discharge area. The plunger has valves, *t t*, of such opening as to prevent any possibility of suction. The feed-pipe *w* supplies water when needed to fill the jig or to supply the waste when V is closed and O open. The value of having the lower discharge as far as possible from the feed and of the full width of the screen, whether in washing coal or concentrating ores, will appear upon reflection, and can be shown by ocular demonstration when working a jig.

A certain number of strokes will be necessary to create regular layers of materials of different gravities, and within certain limits this classification must be improved with each stroke. These layers will, in uniform action of the upward currents of water, be of equal thickness across the jig, *i. e.*, perpendicular to the line of travel.

The quantities washed, preserving the quality above given, varied from 30 pounds for the smallest size, I, to 223 pounds for size IV per hour. On Pennsylvania coal the same machinery could easily furnish 60,000 pounds per hour.

As to the advantage and benefits of coal-washing, there can be no doubt that in many cases where the coal to be coked is impure, containing a large mixture of slate or sulphur in the form of pyrites, it is advantageous to crush and wash previous to coking. It would also be advantageous to wash slack in which there is a large amount of the same impurities, but it by no means follows that all coals would be improved by washing, even though the impurities might to some degree be removed. The Kemble Coal and Iron Company, at Riddlesburg, Pennsylvania, which for some time used a modification of the Berard washer, abandoned it some two years ago. The operation carried away the hydrogenous matter, which made a desirable physical structure and afforded heat in the coke oven. Other works in this country using other forms of washers have ceased washing. A coal with a large surplus of pitchy matter can be washed without serious loss; in fact, in some instances, with gain; for it has frequently too much of this matter, and a reduction is advantageous. This fact should be carefully borne in mind in deciding as to the advisability of washing a coal to reduce the percentage of ash. Connellsville coal, no doubt, would be injured by washing, and the small excess of ash or slate in the coke, if aluminous, is not objectionable in a furnace working mainly with lake ores. It may be that in this statement will be found an explanation of the fact that a good many cokes, with what might be termed an excess of ash but a good physical structure, are superior as blast-furnace fuels to cokes with a less amount of ash.

In some cases, where washing is not advisable, it has been found that simply crushing the coal prior to washing has a very good effect. Mr. I. Lowthian Bell stated before the Iron and Steel Institute of Great Britain that he found crushing the Durham coal prior to coking a great advantage, and in many parts of England the coal is thoroughly crushed before coking.

In many sections of this country the coal is washed prior to coking, and it has been found to be decidedly advantageous. Illustrations of this are given in the remarks on coking in the different states. It is also found in some sections of Europe that great advantage results from careful washing. Washers are largely used in Belgium, and in Westphalia especially a great deal of ingenuity has been expended in improving the methods of washing.

COKE AS A BLAST-FURNACE FUEL.

By far the largest part of the coke made in the world is consumed in blast-furnaces in smelting iron; indeed, it has been with its use in these furnaces that its manufacture in any country may be said to have begun. It was Darby's successful use of coke at Coalbrookdale that made coking an English industry, as was the use of the Connellsville coke at the Clinton furnace of Graff, Bennett & Co., at Pittsburgh, the beginning of the wonderful development of that region.

It is impossible to say how much of the pig-iron of this country is made with coke as a fuel, either in whole or in part. In 1879 1,438,978 net tons, out of a total of 3,070,875, were made with bituminous coal as a fuel, either raw or as coke; in 1880 1,950,205 tons out of 4,295,414. Nearly all this was with coke. In addition to this some of the iron reported as made with charcoal is made with charcoal and coke mixed, while a much larger proportion of the anthracite iron is made with part coke. Mr. James M. Swank, special agent, states that 2,128,255 tons of coke were used in the manufacture of pig-iron in the United States in the census year, while 2,615,182 tons of anthracite and 53,909,828 bushels of charcoal were used in the same time.

The use of coke has been rapidly increasing since 1871. For some years prior to this date considerable coke had been used, but a large portion of the iron made with bituminous fuel was made with raw coal. In 1872 the Lucy and Isabella furnaces, at Pittsburgh, went into blast, and the results obtained with Connellsville coke undoubtedly attracted attention to this fuel. No other furnaces in the world, except the Edgar Thomson, also located at Pittsburgh, and using the same coke, have ever made so much iron in a week. The results obtained led some anthracite furnaces at the time of the great strike in the anthracite region in 1875, which cut off the supply of coal, to try coke, with most remarkable results, and a practice begun from necessity was continued from choice. The make of the furnaces has been largely increased, accompanied with an economy of fuel.

It is not within the scope of this report to enter into a discussion of the relative value of coke and anthracite; but it may be said that the superiority of coke as a furnace fuel is largely due to its physical structure. It is not as dense or as pure a fuel as anthracite, but its physical conditions are such as to especially fit a good, well-made coke for a blast-furnace fuel. (*a*) It bears a heavy burden, retains its shape as it passes down the furnace, does not splinter or grind away, allows the passage of the blast, is swift in combustion, and acts with great energy. Some of these characteristics explain how it improves the yield of anthracite furnaces. Its swift combustion and energy assist the slow-burning anthracite, and by retaining its shape without splintering it gives a better draft to the blast.

While not entering into a discussion of the relative merits of these two fuels, it may be well, however, to indicate the results obtained in practice, both when used singly and when used together in the furnace. The following table, furnished by Messrs. Taws & Hartman to Mr. James M. Swank, special agent, and published in his report on the statistics of iron, page 173, shows the consumption of fuel, together with other necessary details for comparison, at eleven prominent coke and anthracite furnaces in the United States, taken from an average of six consecutive weeks' work in each case in the summer of 1881:

Details.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.	No. 11.
Bosh ....feet..	18	11	13	20	18	16	15	17	20	20	17
Height ....do....	78	60	65	75	70	70	56	70	80	75	65
Fuel to ton of pig-iron ....ponnds..	2, 227	2, 264	2, 314	2, 900	2, 987	2, 822	2, 603	2, 357	2, 490	2, 677	2, 618
Carbon in fnel, ...per cent..	85	94	85	82	88	85	87. 4	83	85	87	86
Ore to ton of pig-iron ....pounds..	2, 610	4, 816	4, 099	2, 481	4, 480	4, 239	3, 413	3, 920	3, 971	4, 212	4, 362
Rolling-mill cinder to ton of pig-iron ....do....	1, 030	......	......	1, 230	......	......	488	......	......	......	......
Limestone to ton of pig-iron ....do....	1, 546	1, 355	1, 815	1, 756	2, 240	1, 815	1, 050	983	1, 339	2, 309	1, 107
Quality of pig-iron ....nnmbera..	1, 2, 3	3, 4	1	1, 2, 3	1, 2	2	2, 3, 4	3	1	2, 3	1, 2 Bessemer.
Heat of blast	1, 150°	750°	1, 050°	1, 150°	1, 100°	1, 348°	870°	1, 371°	1, 080°	765°	750°
Kind of fnel nsed	Coke.	Coke.	Coke.	Coke.	Anthracite.	Anthracite.	Anthracite.	$\frac{1}{3}$ coke, $\frac{2}{3}$ anthracite.	Coke.	$\frac{1}{8}$ coke, $\frac{7}{8}$ snthracite.	$\frac{1}{8}$ coke, $\frac{7}{8}$ anthracite.
Average weekly prodnction of pig-iron in tons of 2,268 pounds.	700	170	562	986	470	292	403	359	1, 274½	527	390

a In a recent discussion as to the requisites of a good blast-furnace fuel, Mr. John Fulton, in a letter to the *Keystone Courier*, mentions four characteristics as essential: 1. Hardness of body; 2. Well developed cell structure; 3. Purity; 4. Uniform quality.

Part V.—OVENS.

COKING IN PILES.

Coking is essentially a process of distillation, its object being to expel from the coal the volatile matter at the least expenditure of its carbon, which remains in the form of a firm, hard coke. To accomplish this three methods of coking are employed:

First: In piles or mounds, a method analogous to that used in the manufacture of vegetable charcoal.

Second: In rectangular kilns, having brick or stone sides, and entirely open at the top.

Third: In closed kilns or ovens of brick or stone.

The simplest of these methods, and the least expensive in plant, but the most wasteful and expensive in coal, is that in heaps, piles, or mounds. This method is termed in various parts of the world "coking in coke-fires", on "coke-hearths", "in ricks," "racks," and "on the ground". The earliest method of coking in piles, and one evidently suggested by the method employed by charcoal-burners in charring wood, is in a small circular heap. The coal, which must be in lumps, is piled in the open air in circular mounds, the lumps being set on their sharpest angle, so that air-spaces are left, and as small a surface as possible touches the ground. This process is at first conducted without any external covering and with a free access of air. As it progresses the burning is checked at the proper time by the application from the base to the top of a coating of breeze coke, or earth. When sufficiently burned, all access of air is prevented, the burning stopped, and the coke is allowed to cool. The coke heap is always erected on the same "station", where sufficient breeze soon accumulates for damping the fire in the heap. This process is very wasteful, the yield often being less than 50 per cent. It is still used, however, especially in sections where the demand for coke is small and its manufacture has just begun.

Instead of the circular heap, pyramidal piles, with narrow, rectangular bases, are sometimes used. This method is preferred to that of the small circular heap, as it is not so wasteful, and a much larger amount of coal can be operated upon. Usually these piles are quite long, oftentimes from 150 to 200 feet, and instead of one long pile, frequently a number of short ones, parallel to each other, are used. At the Coalbrookvale iron works, in South Wales, pits or piles 12 feet wide by from 3 feet 6 inches to 5 feet high in the center are burned, the pits containing from 2 tons 10 hundred-weight to 3 tons per linear yard. This method seems to have been used at an early date in the history of coking in England. Mushet, in an article written prior to 1800, thus describes the method as practiced at that time:

> In preparing pit-coal for the blast-furnace, well understood among manufacturers by the term "coking", flat surfaces are appropriated. These are firmly beat and puddled over with clay, so as to pass the necessary cartage without furrowing or loosening the earth. These spaces form squares, more or less oblong, and are called hearths, upon which the pieces of coal are regularly placed, inclining to each other. Great care is taken to place each piece upon the ground layer on its acute angle, in order that the least surface possible may come in contact with the ground. By this means large interstices are preserved for the admission and regular communication of the air necessary to excite and effect complete ignition.
>
> The quantity of coke charred in one heap or hearth is various at different and even at the same works. About 40 tons of coal form the smallest fires, and some hearths again will admit of 80 or 100 tons. The length of the fire is in proportion to the quantity of coal built; the breadths and heights are also subject to no determined standard, but are from 30 to 50 inches high and from 9 to 16 feet broad. In building each fire they reserve a number of vents, reaching from top to bottom, into which the burning fuel is introduced. This is immediately covered by small pieces of coal beat hard into the aperture; these repress the kindling fire from ascending, and oblige it to seek a passage by creeping along the bottom, which is most exposed to air. In this progress the fire of each vent meets, and, when united, it rises gradually and bursts forth on all sides at once.
>
> If the coal contains pyrites, the combustion is allowed to continue a considerable time after the disappearance of smoke; the sulphur then becomes disengaged, and part of it is found in flowers upon the surface of the heap. If the coal is free from this hurtful mixture, the fire is covered up in a short time after the smoke disappears, beginning at the foundation and proceeding gradually to the top.
>
> The length of time necessary to produce good coke depends upon the nature of the coal to be coked and the state of the weather. In fifty, sixty, or seventy hours the fire is generally completely covered over with the ashes of char formerly made. The coke, thus entirely secluded from the air, soon cools, and in twelve or fourteen days may be drawn and wheeled to the furnace. (*a*)

The practice at the present time in England where piles are used does not differ much from that described by Mushet. In preparing these heaps the ground is first leveled and covered with a layer of small coal, from 12 to 16 inches thick, upon which the large coal is stacked, inclining toward the middle in such a manner as to leave air-passages all through the inside of the pile, the outside being covered with a layer of small coal. The piles are ignited on the top at intervals, and the process of coking is conducted downward. If the heaps are long, the coking is facilitated by a series of chimneys that are formed by building into the pile stakes of wood, which, after being withdrawn, are replaced by burning coals. The fire is thus communicated to the mass in so many

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a Mushet *On Iron and Steel* (London, 1840), page 53.

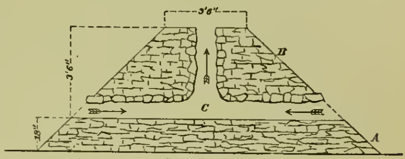
parts at the same time that ignition soon becomes general, and coking proceeds throughout the whole extent. As the flames ascend upon the outside of the pits, the coker damps them with wet coke dust until the coal is completely coked throughout, when the wet dust is carefully packed down, the entrance of air is prevented, and the fire deadened. The heap is allowed to remain two or three days to cool, care being taken to supply it with thicker covering on the side that is exposed to the wind than on that which is opposite to it. When the fire is nearly extinguished the coke is withdrawn and quenched by the use of water. This method, as well as that in circular heaps, is far from economical, and the coke made is by no means uniform.

In this country the method of coking (*a*) in open heaps or pits, as practiced by the Cambria Iron Company in the Allegheny Mountain region, is probably the most systematic and thorough of any. The accompanying engraving gives a good idea of the pits used.

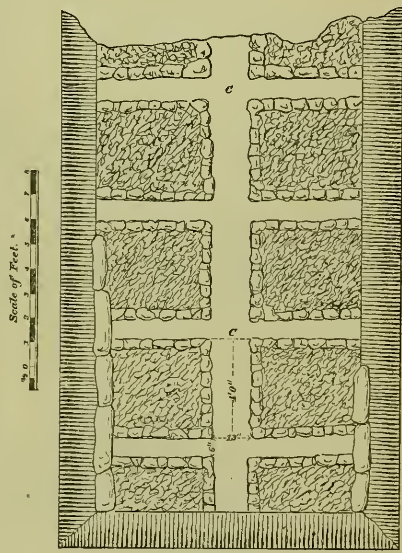
CAMBRIA IRON COMPANY.

BENNINGTON COKE-PITS.

JOHN FULTON, E. M.



Cross Section.



Ground Plan.
FIG. 9.

The coke-yard is prepared by leveling a piece of ground and surfacing it with coal dust. The coal to be coked is then arranged in heaps or pits, with longitudinal transverse and vertical flues, sufficient wood being distributed in these to ignite the whole mass. Beginning on a base of 14 feet wide, the coal is spread to a depth of 18 inches, A. On this base the flues are arranged and constructed as shown in the plan, the coal being piled up, as shown in section B. These flues are made of refuse coke and lump coal, and are covered with billets of wood. When the heap is ready for coking, fire is applied at the base of vertical flues, C, C, igniting the kindling-wood at each alternate flue. As the process advances the fire extends in every direction, until the whole mass is ablaze. Considerable attention is required in managing this mode of coking—in diffusing the fire evenly through the mass, in preventing the waste of coke by too much air at any place, and in banking up the heaps with fine dust as the operation progresses from base to top.

When the burning of the gaseous matter has ceased, the heap is carefully closed with dust or duff and nearly smothered out in this way. The final operation is the application of a small quantity of water down the vertical flues, which is quickly converted into steam, permeating the whole mass. This gives coke, if carefully applied, the least percentage of moisture.

The time necessary for coking a heap with the Bennington coal is from 5 to 8 days, depending mainly on the state of the weather.

The coke made in this way is beyond any doubt excellent, and its yield accurately determined at Bennington and Hollidaysburgh is as follows:

BENNINGTON.

	Gross tons.
Coal used	56.87
Coke drawn	33.63
Loss	23.24

Yield of coke, 59.1 per cent.; loss, 40.9 per cent.; 1.69 tons of coal to 1 ton of coke.

HOLLIDAYSBURGH.

	Gross tons.
Coal used	63.80
Coke drawn	38.02
Loss	25.78

Yield of coke, 59.6 per cent.; loss, 40.4 per cent.

a Report L of the *Pennsylvania Geological Survey*, p. 122.

The yield at both these places is substantially the same, 59 per cent., exhibiting a loss of 24 per cent. of the carbon contained in the coke. The surface of the heap is coked before the central parts are reached, and the outside is, therefore, burning to waste while the central portions are but little acted upon.

This method of coking in heaps or piles is practiced to but a small extent in this country, though it is still used in some parts of Europe. It has the advantage of requiring but little capital and the erection of inexpensive structures, only necessitating a slight preparation of the surface; but it has the disadvantage of requiring that the greater portion of the coal be in lumps. The coke obtained is lacking in uniformity, and the yield is comparatively small, from 50 to 55 per cent., that by other methods yielding from 60 to 70 per cent. The manufacture in piles or mounds is justifiable only when building material is high-priced and coal very cheap.

As is already stated, the circular heap is not used to any great extent in England at the present time, and an improvement on this method, in which a chimney is used in the centre of the pile, is thus described by Percy in his *Metallurgy.*

The accompanying cut, from Jordan's *Metallurgy*, shows the circular pile in use in France, the measurements being in meters.

COKING LARGE COALS IN CIRCULAR PILES.

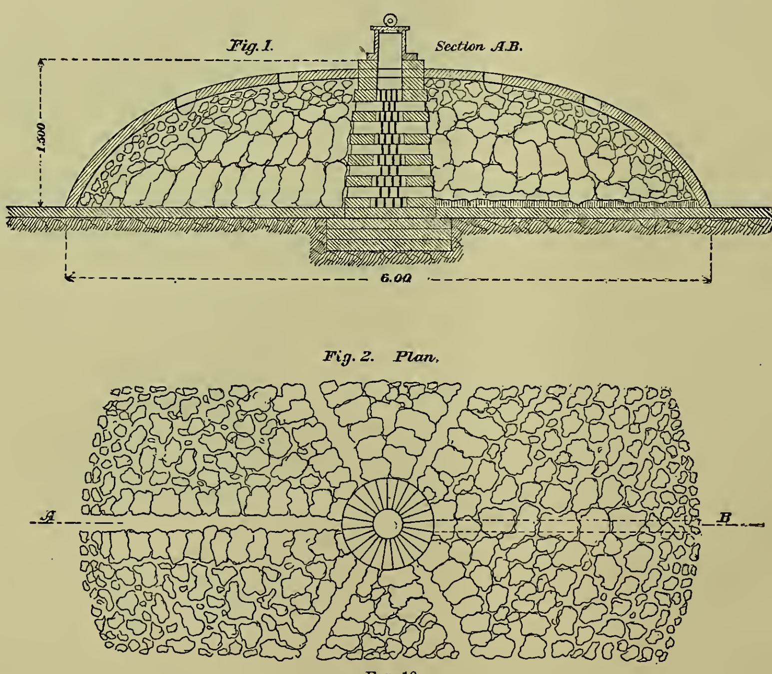


Fig. 10.

A large circular pile, containing some 20 tons of coal (1 ton=2640 pounds), is stacked around a chimney built of bricks without mortar. The diameter of this pile at the base varies, in some instances being 18 and in others 30 feet, the height at the center nearest the chimney being from 5 to 6 feet. The bricks in the chimney are laid so as to afford openings for the escape of gas and flame, a large flat brick at the top serving as a damper, and the heat of the pile is sufficient to vitrify the surface of the bricks of which the chimney is built and to bind them together. The outside is covered with wet coke dust. The pile is lighted at the top from the chimney, and combustion is downward through every part of the mass. Too free combustion is checked by wet coke dust applied with a spade, including the space around the bottom previously left uncovered, and, if necessary, the chimney is left unclosed. About 10 days are required for coking by this method, water being thrown upon the pile before it is drawn. In some cases, instead of lighting from the top, coals are dropped to the bottom of the chimney, and the pile is lighted from the middle of the bottom outward.

COKING IN OPEN KILNS.

As coking in the circular mound developed into the bee-hive oven or kiln, so coking in long rectangular piles resulted in the open kiln. This process of coking in open kiln is only the long-pile process, with permanent walls for retaining or holding the sides.

The kiln as used in Silesia, which is shown in the accompanying cut, consists of a rectangular inclosure, having two parallel side walls of brick, *a a* (Fig. 2), floored with brick set on edge, beneath which is a layer of glassy blast-furnace slag, broken small, through which proper drainage is secured. The inner surface of the walls and the bottom is of fire-brick; the outer wall may be of red brick or stone. The walls are 5 feet high, 8 feet apart in the clear, and from 44 to 60 feet long (Prussian measure). In each of the walls *a* is a series of openings, *c* (Fig. 1), 2 feet apart and the same distance above the floor of the kiln, so placed that those on one side of the kiln are opposite the corresponding ones on the other. From each of these openings rises a vertical chimney, *d*.

Dr. Percy thus describes the process of charging, firing, and burning this kiln:

COKING IN RECTANGULAR KILNS.

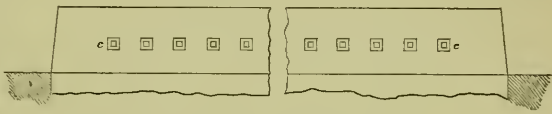


Fig. 1. Rectangular Kiln; side elevation.

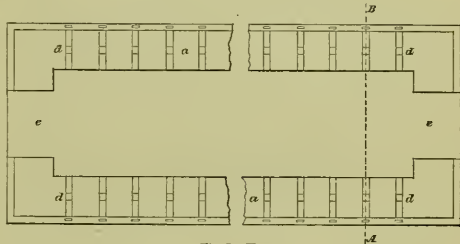


Fig. 2. Plan.

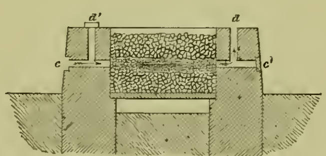


Fig. 3. Section on the line A.B. after filling.

FIG. 11.

The space *e* between the two walls at one end of the kiln is bricked up, and through the opposite end coal slack is wheeled in, spread over the bottom, watered, and stamped down so as to form a solid stratum 9 inches thick, or as high as the lower edges of the openings *c c*, etc. Indeed, this height may be made 2 feet with advantage, if the coal be suitable. Pieces of wood 6 inches in diameter at one end and 4 at the other, and in length equal to the width of the kiln, are then passed through the openings in one wall, so that their opposite ends may respectively lie in the corresponding openings in the other wall. Wetted coal slack is spread over the pieces of wood and stamped carefully down. The kiln is then filled up with slack, which at every 6 inches of additional height should be watered and stamped down. Brand well remarks that the mode of filling just described is very hard work when the kiln exceeds 40 feet in length. After the filling is completed the top of the coal is covered with a layer, 2 or 3 inches thick, of coal dust, or, failing this, of loam. The end opening, through which the kiln has been charged, is at last bricked up. The pieces of wood are now carefully drawn out, and thus a series of channels is left in the coal, upon the maintenance of which the success of the process essentially depends. Should an injury occur to any of the channels at the commencement it can hardly be repaired afterward. Before lighting the kiln all the chimneys on one side are stopped by placing a brick, *d'*, on the top of each, those on the opposite side being left open, while on the second side the openings or draught-holes are stopped by bricks, *c c'* (Fig. 3), the holes on the first side being left open, as at *c* (Fig. 1). The kiln is now lighted by means of sticks of easily inflammable wood introduced into all the openings c on the left. A current of air is established through the transverse channels in the coal. After the lapse of six or eight hours the fire will have reached the opposite ends of these channels, when the chimneys on the left, *d*, and the draught-holes on the right, c, must be opened, and the chimneys on the right, *d*, and the draught-holes on the left, c, must be closed. This, however, should only be done when the fire has regularly spread through the entire extent of the channels. Special care in this respect at the commencement will prevent further trouble afterward. According as the weather is, stormy or settled, the direction of the currents of air through the kiln may be changed from every two to four hours. Should the coking be found to proceed irregularly, it may be necessary to keep open some of the chimneys on one side longer than others, and, consequently, not to change the direction of all the currents at once. Irregularity in the coking may result either from the quality of the coal or negligence in piling it in the kiln; and in either case the yield will be diminished.

In the management of the process the work of the coke-burner is reduced to keeping open the transverse channels in the coal by raking out any pieces of coal which may fall into them and obstruct the passage of the air, and by preventing their sides from sintering together. For this purpose he uses a slender iron rod, somewhat bent at one end. The reopening of a channel which has once become stopped is attended with much difficulty, and is generally impracticable; and if several neighboring channels are closed, the process is thereby much impeded. In windy weather the draught of air through the kiln must be carefully regulated by closing, in a greater or less degree, the chimneys. Any cracks which may occur during the process in the covering on the top of the coal must be well stopped in order to prevent the ascent of currents through them. The proper regulation of the draughts through the kiln has an important influence upon the quality as well as the yield of coke.

In about eight days the process will be completed, as may be known by the escape of white flame from the chimneys and the hardness which is perceived on plunging an iron rod through the cover on the top. All the openings must now be closed, and in the course of two days afterward the fire will have become gradually extinguished. One of the end walls is now taken down and the coke removed. The coke at the height of the channels will be separated into two distinct layers; that in the upper layer especially is remarkably beautiful [*sic*], dense, hard, and when carefully withdrawn is frequently in pieces 3 feet long and 1 foot in diameter. The yield per 7.768 English cubic feet of coal ranged from 241.25 to 261.87 pounds avoirdupois. The loss in weight is 20 per cent. of the coal, an amount which, according to the quality of the coal, is often much reduced.

The theory of coking by this method is perfectly intelligible. The coal surrounding the transverse channels is ignited and through these are established currents of air. Heat is thus developed partly by the combustion of the coal in the vicinity of the channels and partly by that of the volatile products arising from its destructive distillation. The coking will therefore proceed simultaneously upward and downward. No currents, as has already been stated, can ascend through the coal above the channels if the kiln be properly attended to, and obviously none can descend from above; consequently, the air which sustains combustion can only enter the kiln through the lateral draught-holes. At the conclusion of the process an accumulation of tarry matter always occurs immediately under the coal at the top of the kiln, which would further tend to prevent the descent of air from above as well as the ascent of currents from below; and it is there that the most solid coke is produced.

In South Wales and in other districts kilns of this kind have been erected of not less than 15 feet in width from wall to wall, measured within. The transverse channels have been made by suitably piling lumps of coal without the use of poles. When the coal is of different sizes, it is advantageous, according to Mr. Rogers, to place the smaller pieces toward the top of the mass. In these larger kilns the mass becomes well ignited in from 24 to 36 hours. During the process the workman walks on the top of the coal, and from time to time he thrusts through different parts of the surface an iron bar, which is easily pushed down until it reaches the mass of coke, and in this way the height to which the coking process has reached is satisfactorily ascertained. If he finds it to have progressed higher at one part than at another, he closes the chimney communicating with that part, and so retards the process there. When the mass has been coked up to the top, which takes place in about seven days, it is quenched with water, and the coke is withdrawn in the manner already described.

Mr. Rogers writes to Dr. Percy as follows:

The new kilns have proved entirely successful; they are already in use at some of the largest iron works in the kingdom, and are being erected at a number of other works. The great saving in the first cost of oven, economy in working and maintenance, increased yield, and improved quality of coke, will probably soon cause this mode of coking to supersede the others now in use. The kilns are most advantageously made, about 14 feet in width, 90 feet in length, and 7 feet 6 inches in height, this size of kiln containing about 150 tons of coal.

Mr. Rogers asserts that an outlay in plant of only £4 was required to produce one ton of coke per day from the Welsh coals, and that the cost of working does not exceed 6*d.* per ton. In some places the coal has been actually tipped into the kiln from the colliery wagons, and the coke wagons were afterward run into the kiln to be loaded direct from the mass of coke produced, thus reducing the labor to a minimum. The kilns need only to be built of rough rubble-work, with a plain lining of fire-brick, and without any iron work, so that the expense of repairs amounts only to a small sum.

As to the results from the use of these kilns, Dr. Percy makes the following statement:

In 1859 I visited several of the large iron works in South Wales, where these kilns had been tried, and I inquired particularly concerning the results. Opinions on this subject were certainly not concordant. At the Dowlais iron works they were erected, and, after repeated trials, abandoned. Mr. Menalaus, the manager of those works, considers them to have been a complete failure, and informs me (June, 1873) that, after making allowance for the water in the coke, the yield was very bad indeed.

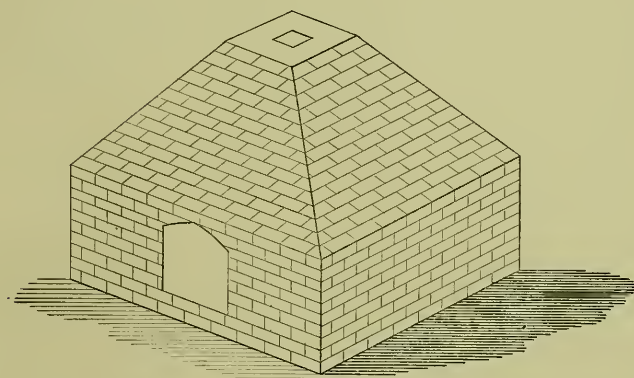
The Ebbw Vale Iron Company also made a trial of them, and Mr. Adams, the then manager, informed me that they appear to be suitable for one kind of coal, but that for their usual good coal they are wasteful and expensive. Much of the large coal which is used to form the transverse channels is burned away, and, as he quaintly observed, "You might hunt badgers through the coke." At the Pontypool works I inspected one of these kilns from which the coke had been partially drawn, and I remarked that a good deal of the coal in the vicinity of the draught-holes appeared to have burned away. Some of these kilns were much higher than I had seen elsewhere. Experiments have been made at these works with kilns having double rows of draught-holes on each side; but I was informed the result was unsatisfactory.

THE BEE-HIVE OVEN.

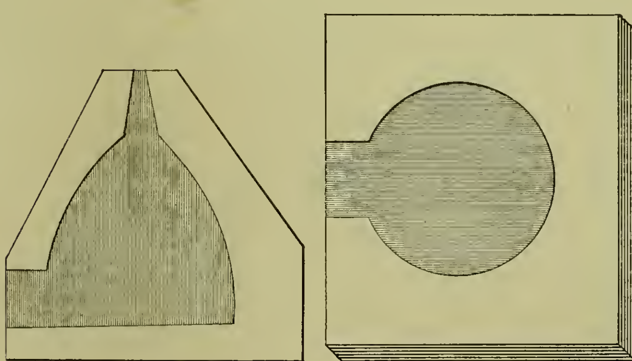
The method of coking in piles can be used to advantage only in exceptional cases. Where coal is very cheap and oven-building materials are expensive, or in those localities where the demand for coke is light, or in cases of a large increase in demand at high prices, especially if this increase promises to be temporary, coke can be burned to advantage in heaps; but under ordinary circumstances of manufacture and condition of the market it is too wasteful of coal, requires too much care in management, and the product is too uncertain in quality and variable in density to make this method economical or desirable. It therefore happens that as the demand for coke increases and becomes reasonably certain the long pile gives place to the open kiln and the circular mound or heap to the bee-hive oven, which is evidently such a mound or heap with a permanent covering of fire-brick, instead of a temporary one of slack and clay or wetted coke dust.

The earliest form of the closed kiln or oven is the "bee-hive", so named from its general resemblance to the old-fashioned conical-shaped bee-hive. This is a flat-bottomed, vaulted chamber of fire-brick or other refractory material, with an opening in the top or crown, through which the oven is charged, and which also serves as an outlet for the waste products of combustion, while an opening or slightly-arched doorway in the side at the bottom serves as an inlet for the air necessary for combustion, and also for drawing the coke. In the process of coking this opening is either built up with bricks, or a door with a frame-work of iron filled in with fire-brick is used, the frame-work being either hinged or raised by a chain passing over a pulley with a counterpoise weight at the other end, or a pair of hinged doors may be used. These ovens are not usually built separate, but in long banks, and sometimes in blocks of two banks, back to back, with the spaces between the ovens filled in with some material that retains the heat, generally in this country loam, thereby preventing radiation of the heat left in the walls, keeping them at a more even temperature, and facilitating the coking process.

PLAN OF COKE OVENS NEAR NEWCASTLE-UPON-TYNE.



A. D. 1765.



Section. FIG. 12. *Ground Plan.*

The bee-hive oven in its earlier and most common form was solid-walled and vaulted, as described above. In the improvements, however, that experience showed to be advantageous both on the score of economy of time and material, and in some cases of product, this has been changed. The bee-hive developed and extended into a long oven, in some cases oval, in others rectangular, while the solid wall of the oven was pierced with flues, and finally developed into that form of oven known as the "Belgian". These forms will be treated of in another part of this report.

The earliest recorded use of coke ovens is in 1763, in Newcastle, England. M. Jars, in a work published in 1774, says:

> There are nine kilns at Newcastle, upon the edge of the river, to destroy the sulphur contained in the coal and reduce it to what is called "cinders and coaks". The principal use of the cinders is to heat the malting-kilns; it is also used by a silversmith. I have seen a manuscript upon "the art of working coal-mines", in which the first attempts in this manufacture were given as of very ancient date, being made in England. (*a*)

The cut on page 87 shows the plan of these ovens as figured by M. Jars.

Horne's statement regarding the use of coke ovens near London (see page 54) is of about the same date as this of M. Jars.

From this time quite frequent notices of the use of ovens are found. About A. D. 1800 coke ovens were found on the outcrops of the Brockwell coal-seams, at various pits in the southern part of the county of Durham, the coke being used for breweries and founderies. Parkes, in his *Chemical Catechism*, published early in the present century, describes ovens of this kind which were used at the Duke of Norfolk's colliery, near Sheffield. He describes each oven as a circular building, 10 feet in inside diameter, with a floor of common brick, set edgewise. The wall, which was 18 inches thick, rose perpendicularly 19 inches above the floor, and was surmounted by a conical roof, of which the apex within was 22 inches above the floor, the entire height from the floor to the top of the arch, outside measure, being 5 feet, and the floor was raised 3 feet above the ground, in order that a wheelbarrow or low wagon might be placed under the doorway to receive the coke as it was raked from the oven. After this notices of the use of ovens are so frequent as not to require mention.

Experience has shown this form of oven to be so well adapted to coking those coals that have furnished most of the English coke that the bee-hive oven, with the exception of the Welsh oven, which is either a modified bee-hive or an inclosed rectangular open kiln, was for many years, and until quite recently, the only one used in England. Latterly, however, Belgian ovens of various forms, especially the Coppée, are coming into some favor, though the bee-hive is still the one chiefly used.

In this country, as will be seen by the statistical tables, the oven almost universally in use is the bee-hive, though the Belgian also is meeting with some favor. The bee-hive ovens, as built in the Connellsville and Allegheny Mountain regions, differ but little in size at the different works, being from 11 to 12 feet in inside diameter and from 5 to 6 feet in height from the floor to the crown of the roof. The floor is slightly inclined to the front. The method of constructing an oven in the Allegheny Mountain region and its relation to wharf and tracks are shown in the accompanying sketch of the ovens built by Mr. John Fulton, of the Cambria Iron Company, at their Bennington coke works. (*b*)

These ovens are circular, the diameter being 11 feet 6 inches, and are 6 feet high from the level of the floor to the crown of the dome, the charge filling the oven as far as the dotted line in the left completed oven. The radius of the dome, which is built up on centers, as the right-hand oven shows, is 6 feet 10 inches, the diameter of the charging-hole being 1 foot.

The Bennington coke ovens are placed in a double row, inclosed between two strong retaining-walls of sandstone masonry. Between these walls, and up to level of the floors of the ovens, the space is carefully filled and compactly rammed with clay and loam, constructed in horizontal layers of 12 inches each. Under all an ample drain is laid longitudinally under the bank of the oven. The ovens are founded on this thoroughly-packed filling, having a fall in their floors toward the doors of 6 inches to each. The order of the work of construction consists of four consecutive operations:

1. The setting up on front walls of the iron door-frames, with the necessary anchors built up with the shaped jamb-brick.

2. The building of the vertical circular section to the springing of arch or dome, the circular line of oven being preserved by a wooden sweep pivoted on pin in center of oven.

3. The laying of the 3-inch floor-tiles and the erection of the wooden centers to build dome of ovens. These wooden centers consist of seven sections, made of boards and laths, which are shaped and fit together like the sections of an orange when cut by a plane at right angles to its stem-line. These sections are supported at the base by small benches, easily adjustable, and are supported under the crown by a single post, capped by a circular collar, and are made of a size to be easily taken out through the oven doors.

The fourth operation consists in building the dome, which is completed by wedging in carefully and firmly the annular charging-ring, which becomes a keystone of the arch as well as the charging-hole of the oven.

The filling in around ovens or backing should follow the progress of the brick-work as closely as possible, the material, clay and loam, being laid down in horizontal layers of 12 inches deep, and carefully rammed. The track on the top of the ovens is laid with iron tie-pieces, and has a gauge of 6 feet, to allow space for lorrie containing 5 tons of coal. The water for quenching the coal is supplied by 3-inch cast-iron pipes, with taps and hose between the ovens.

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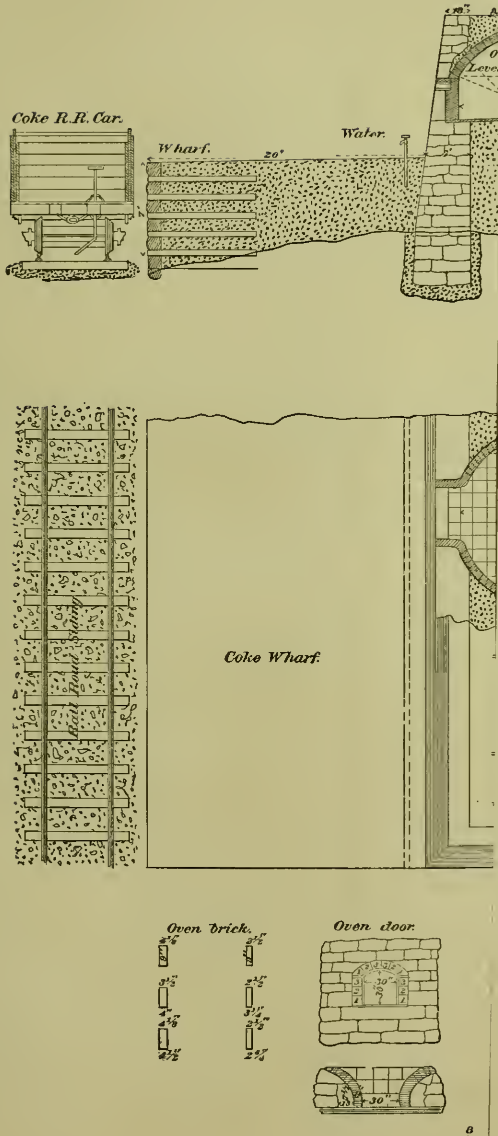
a I quote from a paper by Mr. A. L. Steavenson, published in the *North of England Institute of Mining Engineers' Transactions*, vol. viii, 1860, pages 111, 112.

b These drawings are taken from the *Report of the Bureau of Statistics of the State of Pennsylvania* for 1877 and 1878.

PLAN, ELEVATION, AND



CAMBRIA IRON COMPANY.

PLAN, ELEVATION, AND DETAILS OF BEE-HIVE COKE-OVENS AT BENNINGTON SHAFT.

1878.

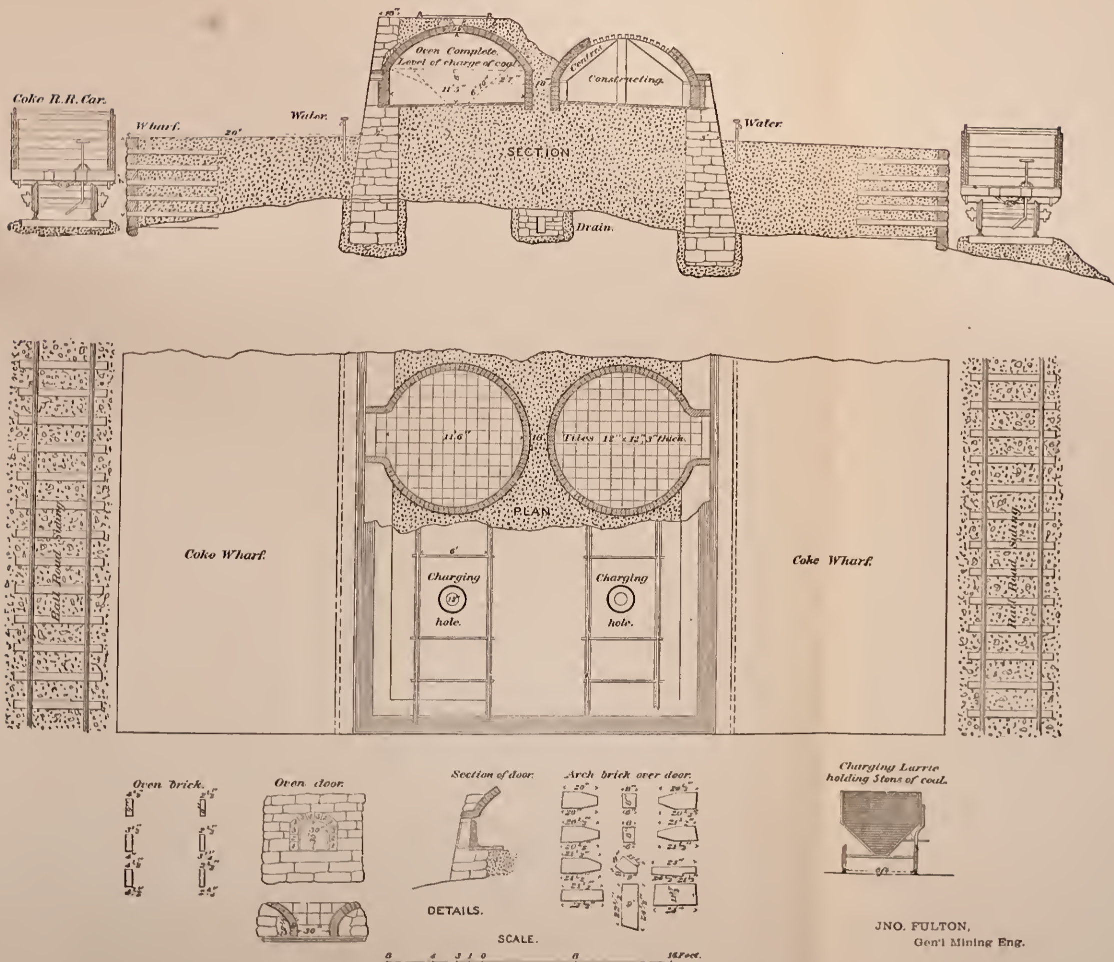
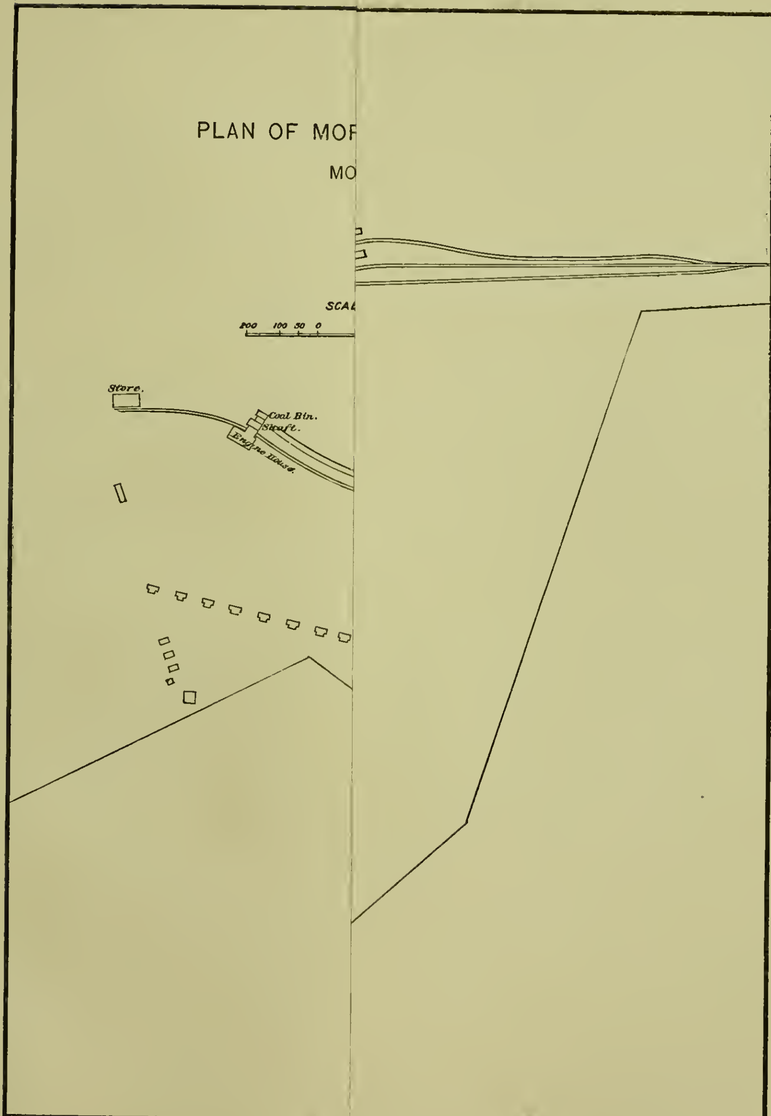


Fig. 13.



PLAN OF MOR
MO
SCAL
200 100 50 0
Store.
Coal Bin.
Shaft.
Engine House.

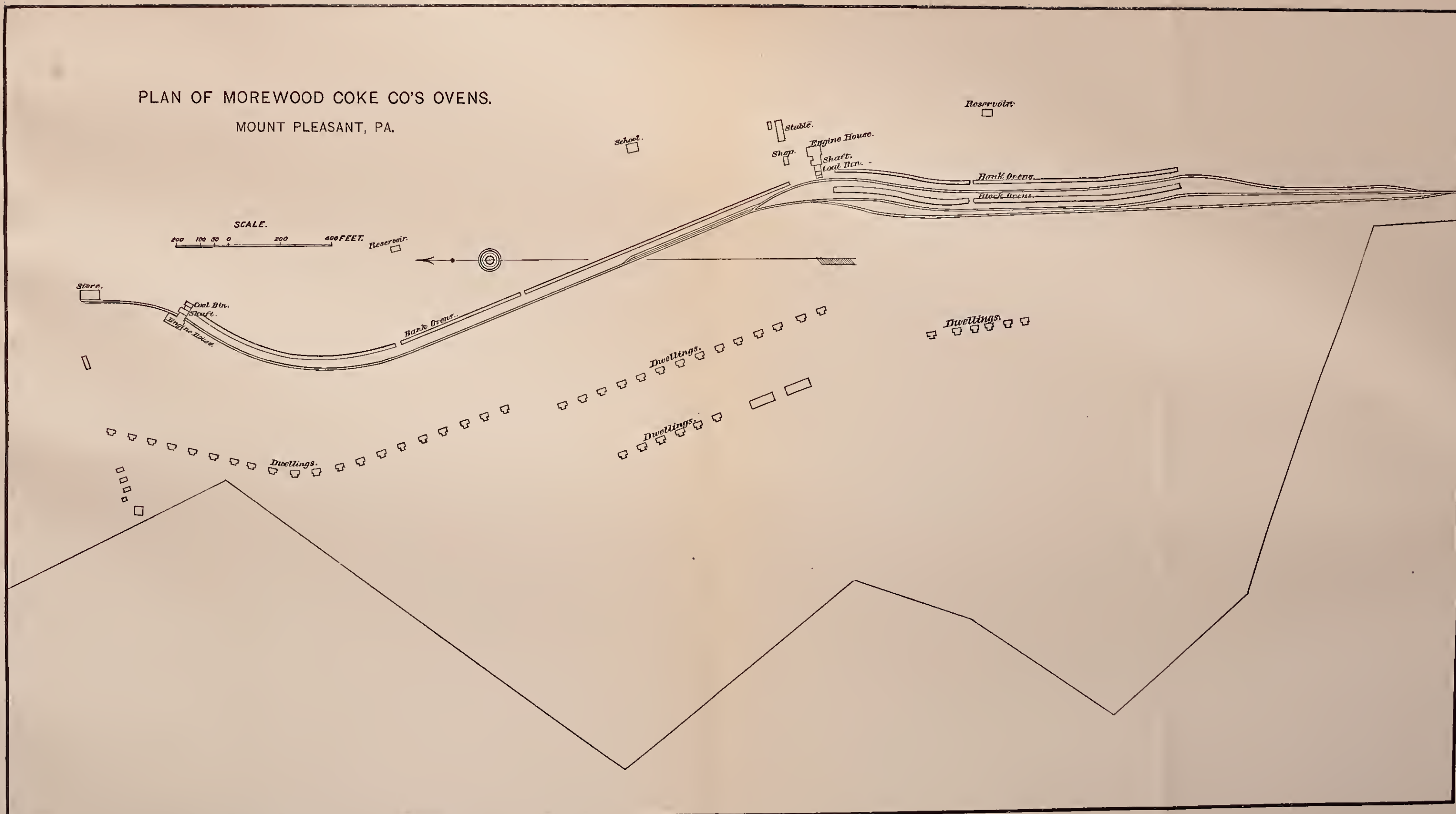
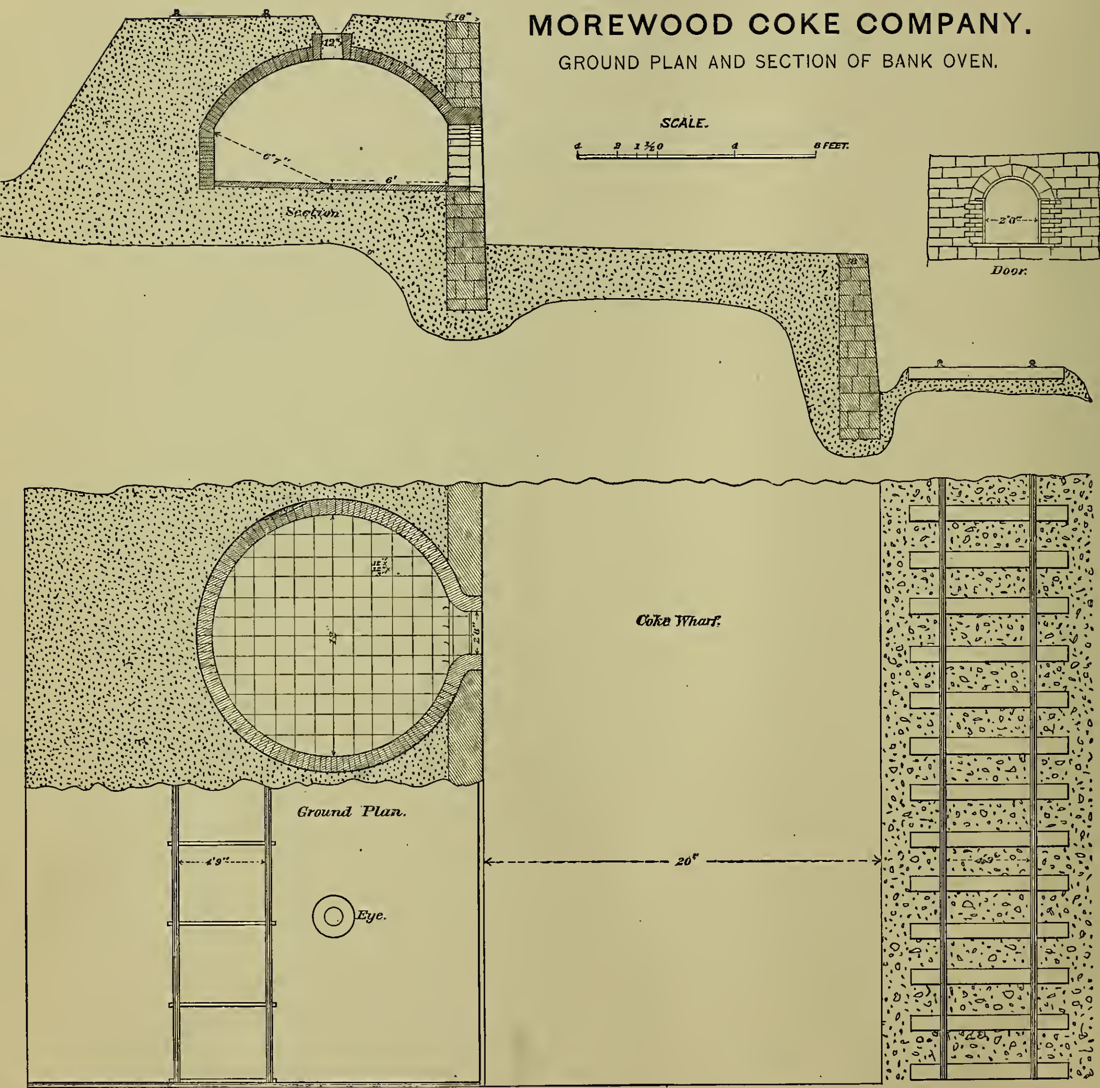

PLAN OF MOREWOOD COKE CO'S OVENS.
MOUNT PLEASANT, PA.
SCALE.
200 100 50 0 200 400 FEET.
Reservoir.
Store.
Coal Bin.
Shaft.
Engine House.
Bank Ovens.
Dwellings.
Dwellings.
Dwellings.
School.
Stable.
Shop.
Engine House.
Shaft.
Coal Bin.
Bank Ovens.
Block Ovens.
Reservoir.
Dwellings.

Fig. 14.



MOREWOOD COKE COMPANY.
GROUND PLAN AND SECTION OF BANK OVEN.
SCALE.
8 FEET.
Door.
Section.
Coke Wharf.
Ground Plan.
Eye.
20'
4'9"
2'0"
6'

FIG. 15.

As showing the style of these ovens, as well as the general plan of a coke works in the Connellsville region, I have given the accompanying cuts, representing the works of the Morewood Coke Company, limited, one of the latest and best built coke works in that section. The method of operating these ovens in the Connellsville region is quite simple, and may be taken as the usual practice in this country. The coal is generally brought to the oven in lorries holding each a full charge, 125 bushels, for 48-hour furnace coke. The lorrie is run to the charging-hole on a railroad over the top of the oven, and the coal is dumped through the hole in the crown of the roof and carefully leveled by means of a long iron hook inserted into the door. This door is bricked up and plastered or daubed, except some small interstices at the top, so as to admit only sufficient air above the coal to carry on combustion. The heat which the oven acquired in the preceding operation is always sufficient to ignite the new charge, combustion being carried on by the entrance of the air through the doorway, and the coal soon begins to emit aqueous and sulphurous vapors, followed by a thick, black smoke and reddish flame all around the sides. At this stage of the process the gases are particularly offensive. The heat of the oven at this time is a low red. In a few hours the mass of burning coal cracks downward, enabling the volatile matter below the surface to pass off, and by its ignition to generate additional heat for carrying on the process. In about 12 hours a clear, bright flame prevails over the entire surface, which increases almost to a white heat. Basaltiform columns are formed, which allow the gases to rise as the heat ascends. Finally the clear, bright flame dies off gradually, and the coke becomes a glowing red mass. Now the sooner the oven is quenched and drawn the better, for the coke will continue to take up air in spite of every precaution, and the red-hot coke will waste, lose heat, and become inferior as a fuel.

A description of the coking process in bee-hive ovens in the Durham region is thus given by Mr. Meade:

> When the oven is refilled with a proper charge, the coal is fired at the surface by the radiated heat from the roof, enough air being admitted to consume the gases given off by the coal, and thus a high temperature is maintained in the roof of the oven. The coal is by this means melted, and those portions of it which, under the influence of a high temperature, can of themselves form gaseous compounds, are given off, forming at the moment of their liberation small bubbles, or cells. The coke now left is quite safe from waste, unless a further supply of air is allowed to have access to it. At this stage of the process the coke assumes a pentagonal form and columnar structure. When the coke is left exposed to heat for some time after it is formed it becomes harder and works better, from being less liable to crush in the furnace or to decrepitate on exposure to the blast.

In England the coke was formerly drawn from the bee-hive oven in a heated state and afterward cooled by water thrown on with buckets outside, but this method has been discontinued, and the coke is cooled inside of the oven by water thrown upon it, either from buckets or with a pipe and hose. The only drawback to the method of quenching is that the oven is cooled by the contact of the water with the hot bricks. It is generally believed, however, that coke cooled inside of the oven absorbs less water than when cooled outside. The quenching causes the coke to separate or crack open and facilitates the drawing.

In drawing the coke from the oven the usual plan is to pull it out, piece by piece, with long bars of iron turned up at the end, similar to a large poker or hook. This method is the only one that can be used in the ordinary bee hive oven. Other methods of discharging by what are termed "drags" are used in modified forms of the bee-hive oven and in the Belgian oven.

It will be noted that the coking process is essentially a process of distillation, the oven being the retort, the heat in the bee-hive oven necessary for volatilization after it is once heated being derived from the burning of the volatile products, and the heat remaining in the walls of the oven instead of being applied from the outside. Some of the heat is at the expense of the carbon of the coal, as it is impossible to prevent the destruction of a portion of the carbon by the admission of the air necessary for combustion, though it is avoided as much as possible. The combustion is maintained over the top of the coal, and the coking or distillation proceeds in the bee-hive oven downward from the top, and also slightly inward from the sides, the current of inflammable gas and vapor arising through the coal and meeting the air admitted through the doors above the burning in what may be called the "combustion chamber", until the lowest stratum is converted into coke. It is evident that air should be admitted only over the top, as, if the air enters below or through the coal, coming in contact with it when hot, a portion will be consumed, and the coking will not be effected exclusively by the heat resulting from the combustion of the volatile products, as it should be, but largely at the expense of the coke, which should be avoided.

As has already been noted, considerations of economy in various directions have led to many changes and improvements in the construction of coke ovens, and it is impossible to describe the numerous forms that these improvements have taken. They seem to have had for their object, first, the more rapid discharging of the ovens; second, the avoidance of the rapid cooling of the oven by watering the coke inside the oven; third, the utilization of the heat in the escaping gases by passing them through flues, where they are burned; and, fourth, the exclusion of air from the coking chamber, the heat necessary for coking being applied from the outside of the oven.

In providing for the more rapid discharging of the oven and the cooling of the coke outside, chiefly for the purpose of greater ease of handling, and to prevent cooling, the oven assumed the rectangular shape, and one of the best of these forms, which may perhaps also be regarded, not as a development of the bee-hive oven, but as a rectangular kiln, closed in at the top, is known as the "old Welsh oven". This is simply a rectangular chamber, 7 by 12 feet, with an arched roof 6 feet high. As generally built, they are set in rows, back to back, with one chimney to each pair to carry off the gases, the length of the oven requiring a greater draught than a vent-hole would supply. A flue from the roof of the oven about one-third way from the back wall leading into the chimney conveys the gases to it. The whole front of this oven is movable, and the coke is drawn by means of a "drag". This drag has various forms, but is essentially a strong piece of flat iron laid across the back of the oven prior to the charging, having attached to it at right angles a rod of iron sufficiently long to extend beyond the front. The protruding end is attached to a chain, operated either by a windlass worked by hand or by a small engine, and the whole mass of coke is drawn at once. In some ovens only the transverse piece of the drag is left in the oven during coking, the rod of iron being inserted after the process is completed through a gutter left in the middle of the floor the end of the rod being shaped something like a fish-hook barb. This rod is pushed in with the bent-up part or, barb flatwise until the end passes under and behind the drag, when the rod is turned, the barb catches on the drag, and the coke is drawn out in one mass. Sometimes the transverse piece or drag is a short length of an ordinary rail; sometimes, also, instead of a single piece of iron attached to the center, which might bend the drag or transverse piece in drawing, two rods, attached near the ends and brought together outside of the oven, are used.

This Welsh oven seems to be preferred in many parts of Great Britain either to the bee-hive oven or to the recent forms of the Belgian oven, as being easily managed and yielding a homogeneous and well-burned coke. Sometimes these rectangular ovens, and also the bee-hive ovens, have bottom flues, through which the escaping gases pass to flues running between the two banks of ovens placed back to back. In this way a portion of the waste heat is utilized for keeping up the heat. In other cases the heat so escaping passes into flues between the two banks of ovens, where the heat is utilized in raising steam for boilers. Such a method is shown in the accompanying drawings of the ovens at the Browney colliery, in the Durham region, England. These ovens will also show the size and general appearance of the Durham bee-hive ovens.

These ovens are in double rows, back to back, as usual, but the flues between are much larger, averaging 6½ feet in height and 3 feet 6 inches in width. To each chimney of 106 feet in height are connected about 100 ovens, an equal number on each side, and the flues and boilers, four in number, are so arranged that the heat can be carried past when cleaning or repairs are requisite, the small connecting flues being built as compact and tight as possible, and thus the remarkable freedom from smoke seems owing to the air-tight and perfect character of the flues, the small amount of surplus air present not cooling the gases to a point below which the hydrocarbons escape imperfectly burnt. This has been tested by admitting a large surplus of air, when smoke was immediately evident.

No coal whatever is used for boiler purposes at these works, and the product of the pit at the colliery where these ovens are situated is drawn from a depth of 100 fathoms, and the water pumped, whereas before this system was adopted 600 tons of coal per fortnight was the amount virtually wasted. At another colliery belonging to the same firm, and where the small coal is valuable for coking purposes, the advantages of the system described are equally evident.

As to the economies in the use of ovens of the Browney type and arrangement, Mr. A. L. Steavenson, in a paper read before the British Iron and Steel Institute (*Journal*, 1877, page 406 *et seq.*), makes the following calculation and statement, which contains many important facts that are not generally known to coke-makers:

In order to ascertain the amount of heat available for evaporative purposes, the first step was to measure the volume and temperature of the gases passing to one pair of boilers from 50 coke ovens at the rate of 230 tons of coal in 84 hours. The temperature was found to be 1,500° F. The volume, measured by taking the velocity of the current in a given length of the flue, was ascertained by introducing sodium at one point and noting the time required to effect a flame, made by putting a little coal into the flue, spectroscopically at another, to be 1,187 feet per minute, which, multiplied into the area of the flue, 24 square feet = 28,488 cubic feet per minute. This exceeds by 4,005 cubic feet the theoretical quantity of the gases, supposing that only just sufficient atmospheric air is admitted to effect the complete combustion of the known weight of material lost in coking 230 tons of coal; and this 4,005 cubic feet represents roughly the unavoidable excess of air used in coking, and the presence of which was evident by the ease with which a piece of charcoal burned when lowered into the flue.

The theoretical quantity above referred to was thus obtained: 230 tons of coal of the following approximate composition—

	Tons.
Oxygen	15.3
Carbon	195.3
Hydrogen	10.3
Nitrogen	2.3
Sulphur	1.4
Ash	5.3
	229.9

yield, on coking, about 60 per cent. of coke, of the following approximate composition:

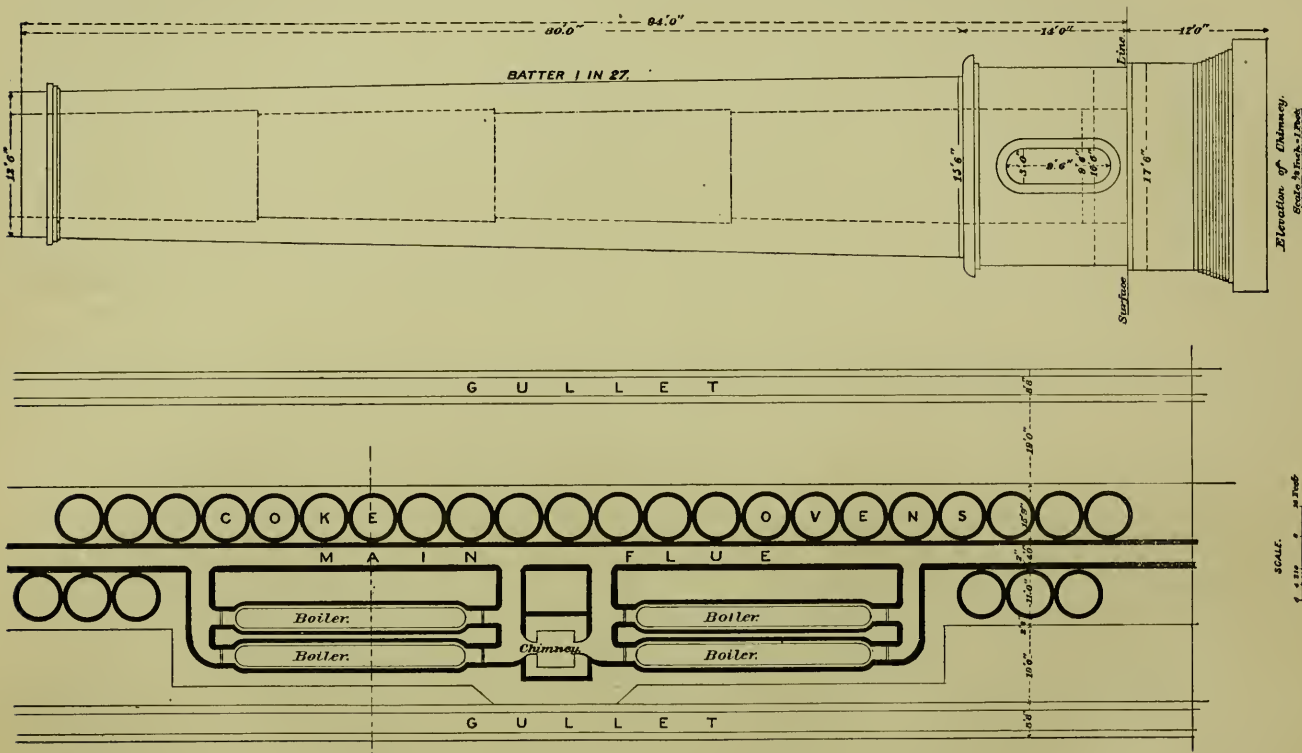
	Tons.
Carbon	132.7
Ash	5.3
	138.0

Therefore, the composition and weight of the materials lost in coking are:

	Tons.
Carbon	62.6
Hydrogen	10.3
Nitrogen	2.3
Sulphur	1.4
Oxygen	15.3

BROWNEY COLLIERY.

ARRANGEMENT OF COKE-OVENS, BOILERS, CHIMNEY, &C.



PLAN

Fig. 16.

BROWNEY COLLIERY.

ARRANGEMENT OF COKE-OVENS, BOILERS, CHIMNEY, &C.

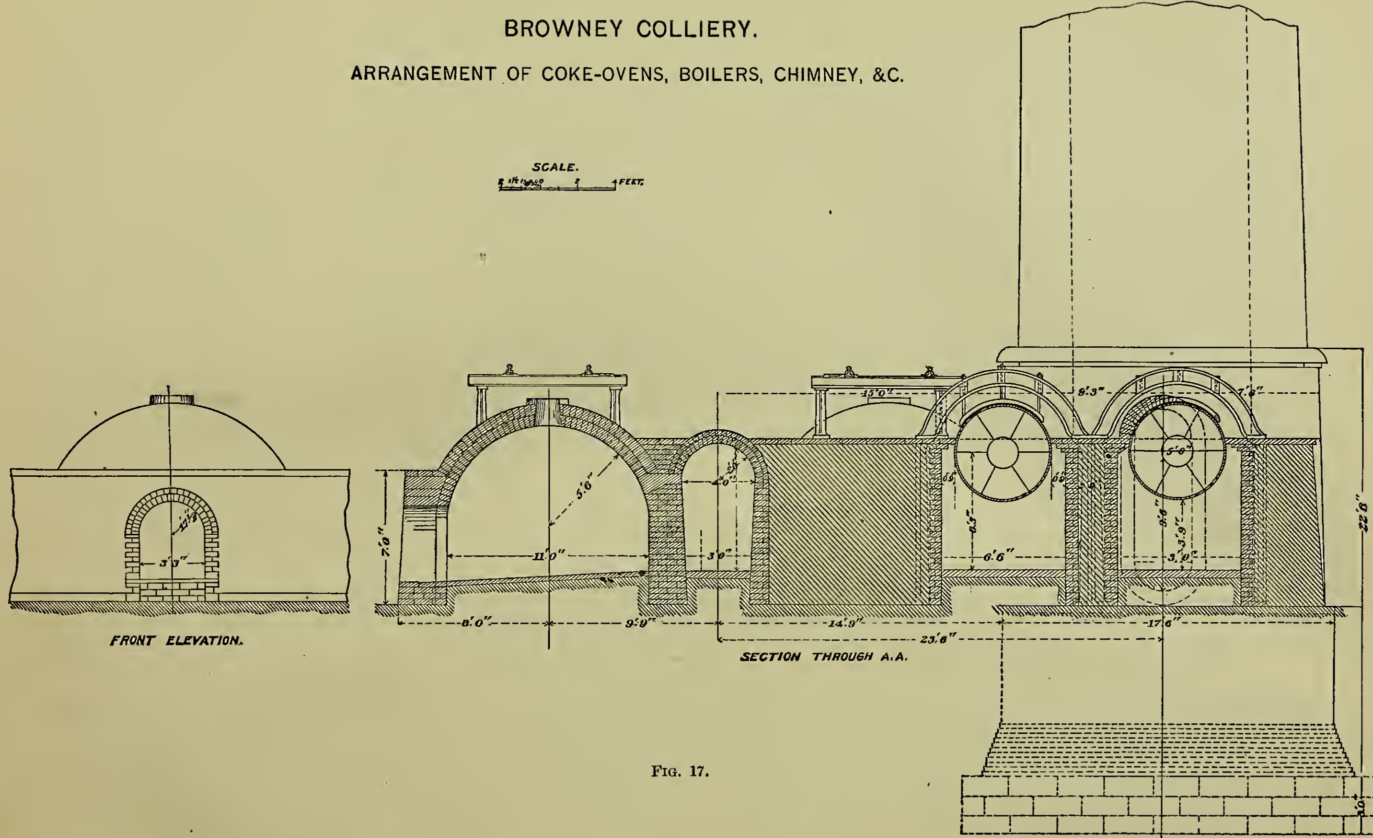


FIG. 17.

To complete the combustion of these into CO_2, H_2O, and SO_2 are required 1,023.4 tons of air, making a total weight of waste gases of 1,115.4 tons, of which 790.3 tons are nitrogen, 229.5 tons carbonic acid, 92.8 tons steam, and 2.8 tons sulphurous acid, which, at a temperature of 1,500° F., will occupy a space of 123,399,000 cubic feet; and since the coking of 230 tons of coal occupies, on an average, 84 hours, we have 24,483 cubic feet per minute, or 4,005 cubic feet less than the observed quantity.

Next, as to the heat commonly wasted: We have 1,115.4 tons of mixed gases, at a temperature of 1,500° F., which, if they could be reduced to the temperature of the atmosphere (say, 60° F.), would have the following heating value in tons of H_2O raised 1° F.:

	Tons.	Temperature. Deg.	Sp. heat.	Tons H_2O.
N	790.3 ×	1,440 ×	0.244 =	277,680
CO_2	229.5 ×	1,440 ×	0.216 =	71,384
H_2O	92.8 ×	1,440 ×	0.475 =	63,475
SO_2	2.8 ×	1,440 ×	0.155 =	625
Tons H_2O				413,164

which is equivalent to evaporating 415 tons of water at 212° F. But, owing to the fact that the temperature of the gases was only reduced 750° F., instead of 1,440° F., the above quantity is reduced to about one-half, or 216.1 tons, evaporated in 84 hours, or 2.6 tons in one hour. This was tested in an actual experiment (on the two boilers supplied with the gases from 50 ovens, coking 230 tons in 84 hours), the quantity evaporated in one hour being 2.4 tons, an approximation quite as close as can be expected.

The total theoretical heat actually developed in the process of coking at the above rate is equivalent to evaporating 17 tons of water per hour, which is thus expended:

	Tons.
Heat utilized by boilers	2.40
Heat escaping in chimney	2.54
Heat lost in radiation from ovens and flues and watering the coke	12.06
Total	17.00

Thus, even in the plan described, but a small percentage of the total heat generated in the ovens is utilized, although if this even was carried out throughout the district of South Durham, where in colliery boilers not more than 6 pounds of water on an average are evaporated per 1 pound of coals, we should have a saving of 1,085,869 tons of coal per annum, or a money value of £271,467. But this by no means represents the total saving to the colliery owners, as foremen are entirely avoided, with the exception of one man on each shift to attend the boilers, so that the total economy which would be effected, were the system generally adopted in the country, would be fully £300,000 per annum.

THE BELGIAN OR FLUE OVEN.

Under the general term "Belgian ovens" is included a number of forms of coke ovens, not all of which, however, are of Belgian invention, which have certain points of resemblance, but all differing from the bee-hive or solid-wall ovens in two, or possibly three, particulars:

First. In the exclusion of air from the coking-chamber, the heat necessary to coking being applied from the outside.

Second. In the utilization of the waste heat and waste gases to facilitate the process of coking.

Third. In the more rapid discharging or drawing of the ovens and in cooling the coke on the outside, thereby saving labor and reducing the loss of heat in drawing and cooling.

Coking in ovens on the Belgian plan is of the nature of distillation in a close vessel or retort, the process proceeding at the same time from the sides, bottom, and top inward toward the center of the mass, the heat for distillation being applied from without and being supplied by the combustion in flues of the waste gases supplemented by the heat retained in the walls. Theoretically this should give all the carbon in the coal; practically there is some waste, but much less than in the bee-hive.

Coking in bee-hive ovens is from the top downward gradually through the mass, the heat necessary to expel the gases being supplied partly by the heat in the walls and the burning of the escaping gases in the coking chamber above the coal and partly at the expense of the carbon of the coal. The coke is cooled inside the bee-hive oven by throwing water upon it before drawing, thereby cooling the oven also. In the Belgian oven, almost without exception, the coke is first drawn out and then cooled, the oven losing but little heat in drawing.

It will be seen, therefore, that, considering only the yield of coal in coke, theoretically the Belgian plan is the better, as it should give more coke to a given weight of coal than the bee-hive oven. The practice is found to agree with the theory, the yield of coal in coke in the Belgian oven being greater than in the bee-hive. Yield, however, is not conclusive as to the economic value of coke, and in deciding which is the better plan, the original cost of the oven and expense for repairs, as well as the character of the coke produced, should be considered. Which is the better oven for making a fuel for blast-furnace purposes is discussed in another place.

To attempt even a brief description of the various forms of the Belgian oven would far exceed the limits of this report. The three that have been selected for description (the Dulait, the Coppée, and the Appolt) are regarded as presenting the most important principles of construction and as being of the most practical importance to the coke manufacturer. These are all flue ovens, but differ in shape and in the location and arrangement of the flues. In all of them the air is excluded as far as possible from the coking chamber, and the volatile matter is expelled from the coal by heat applied outside the walls of the coking chamber, the coke being discharged from the ovens before cooling. It should also be noted that the discharging of these ovens, which is by mechanical means, is facilitated by building them not quite rectangular in form, but with the walls slightly diverging, and, in the case of those which are horizontal, the bottom slightly sloping downward toward the front.

The Dulait ovens are horizontal, long, and narrow, and are heated by the combustion of their volatile products in horizontal flues placed in the sides and bottom, numerous jets of heated air being supplied to the gases in their passage through the flues. They are built in pairs, one oven heating the adjoining one. This division into couples also exists in the Coppée system.

As generally constructed, these ovens are 7 meters (*a*) long, 0.75 meter wide, varying somewhat, however, according to the quality of the coal, and 1.15 meters high to the base of the arch, the arch being 0.10 meter in height. The incline of the bottom of the oven to the front is 0.02 meter to the meter. To prevent waste of heat and the penetration of air the oven is furnished with double doors, the outer one, which is on a plane with the front, being of sheet-iron 0.005 meter thick, and the inner one, which is 0.30 meter from the first, of cast-iron. The space occupied by the coal is thus reduced to 6 meters. The ovens are charged through hoppers closed both at the top and bottom, the lower part being shut by a cast-iron slab cemented with clay in the brick-work, while the upper opening is closed by a cover, the edges of which rest in a channel filled with powdered coal.

The flame from the coking chamber of one oven passes out and descends directly below the bottom of the other member of the pair, where it is divided into four currents, which flow in between the partition walls, and after traversing every flue reach the chimney. To supply the air necessary for the combustion of these products one of the walls of the flues through which the gases pass is built of two rows of hollow bricks, superposed. These bricks have a section of 0.10 by 0.12 meter, and are pierced by a longitudinal hole 0.05 meter in diameter, in such a manner that by their juxtaposition they form two superimposed channels as long as the whole flue. The lower channel is open at the front of the oven and closed at the other extremity, where it rises in order to communicate with the upper parallel channel. This is pierced by holes 0.008 meter in diameter, placed at a distance of 1 decimeter from each other, and opening into the flues in which the combustible gases are circulating. By this arrangement the external air taken in by the draught penetrates into the lower channel, where it becomes heated, and, reaching the upper passage, is projected across the stream divided into innumerable streamlets, which increase the surface of contact, thus effecting perfect combustion and producing the highest possible degree of temperature, so that the gases are in this way fully utilized. As a result, if the coal is of the right quality, the combustible gases are produced in sufficient quantity to secure a complete distillation of the coal and the regular and continuous heating of the whole of the apparatus. This system does away with the necessity for providing openings into the coking chamber for the admittance of air or secures a theoretical absence of draught, limited only by the care with which the clay has been applied to the doors.

The Dulait is a very hot oven, somewhat expensive in its first cost, but requiring only slight repairs, works large charges, and gives a yield nearly equal to the theoretical maximum. It requires, however, constant and careful attention to secure the best results. The charge of coal is from 5,000 to 10,500 pounds, about 7,000 being the average. With the medium or lighter charge the time of coking is 24 to 30 hours, with the heavier 48 hours. The yield as compared with the Smet oven, which it has in some cases superseded, is much greater. Coal that in the Smet oven yielded 71 per cent. yields in the Dulait 79.17 per cent. of large and 1.75 per cent. of small coke, or 80.92 per cent. The cost in Belgium in 1873 for a Dulait oven to produce 5,300 pounds of coke every 24 hours was 2,700 francs. (*b*) In that year there were 1,100 of these ovens in Belgium and 700 in France, Prussia, and Austria.

The Coppée oven is designed for coking only finely-divided coal. It resembles the Dulait oven in being horizontal, long, and narrow, but its side flues are vertical, instead of horizontal, as in the Dulait and Smet ovens, and the methods of supplying air for the combustion of the waste gases, as well as of firing and utilizing the waste heat, are improvements on the Dulait and Smet.

As generally built, the Coppée ovens are in banks or batches of thirty, arranged in groups of two each, one oven of each pair being charged when the contents of the other are half coked, and *vice versa*. Connected with each oven of a pair are a number of vertical flues, or chambers, through which the volatile products from both ovens are conveyed downward to a horizontal flue under one of them. After passing under this oven to its end, the gases return by a similar flue under the other and enter a channel running at right angles to the ovens and under them, passing from this channel either directly into a chimney or carried under boilers and used to generate steam. Air is supplied to these vertical flues in the sides by a smaller vertical flue, one or two to each oven,

a The meter is 39.370¾ inches.

b *Journal of Iron and Steel Institute*, No 2, 1873, page 345, from which the details of cost and yield are taken.

COPPEE'S COKE-OVEN.

COKE-RAM.

ELEVATION.

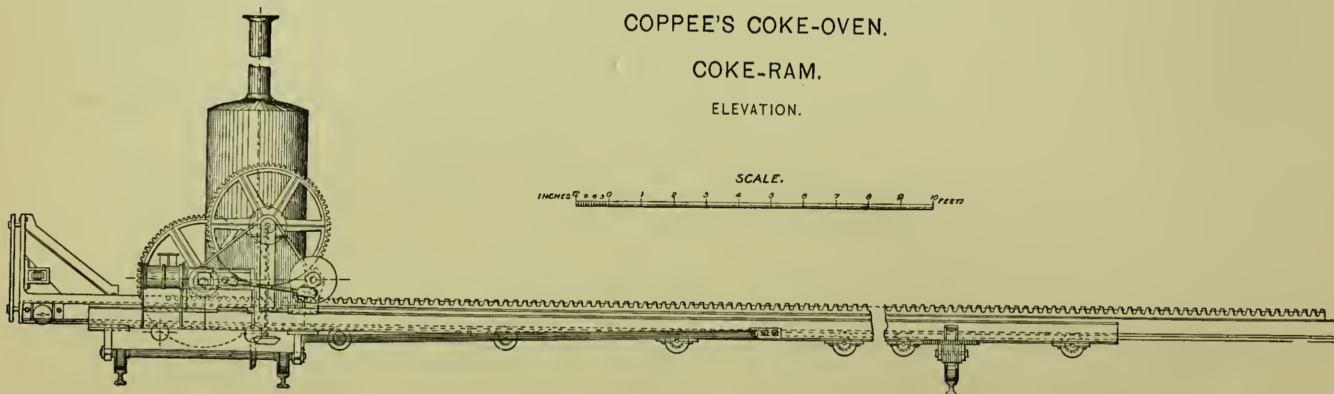


FIG. 18.

COPPEE'S COKE-OVEN.

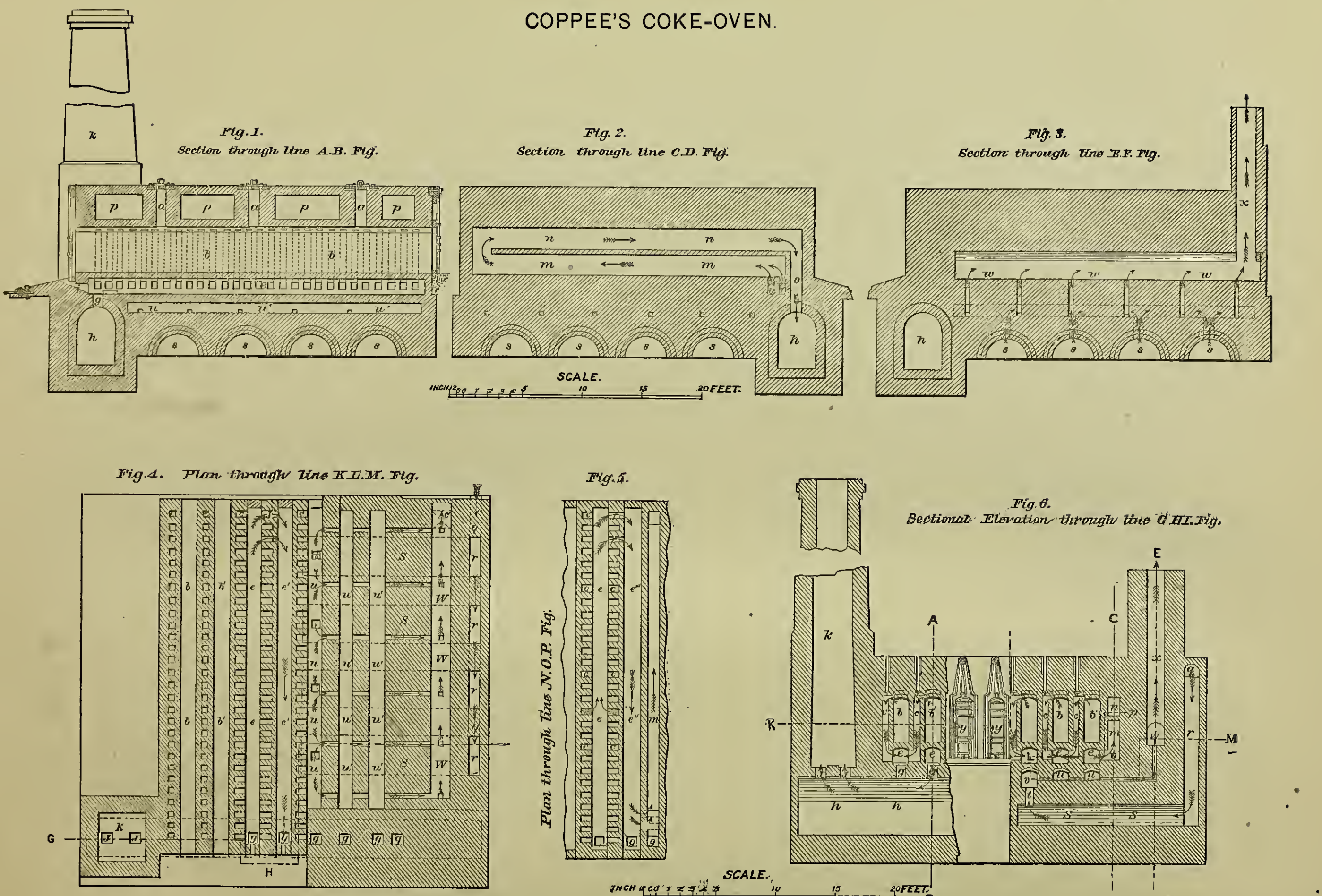


FIG. 19.

APPOLT'S COKE-OVENS.

18 RETORTS.

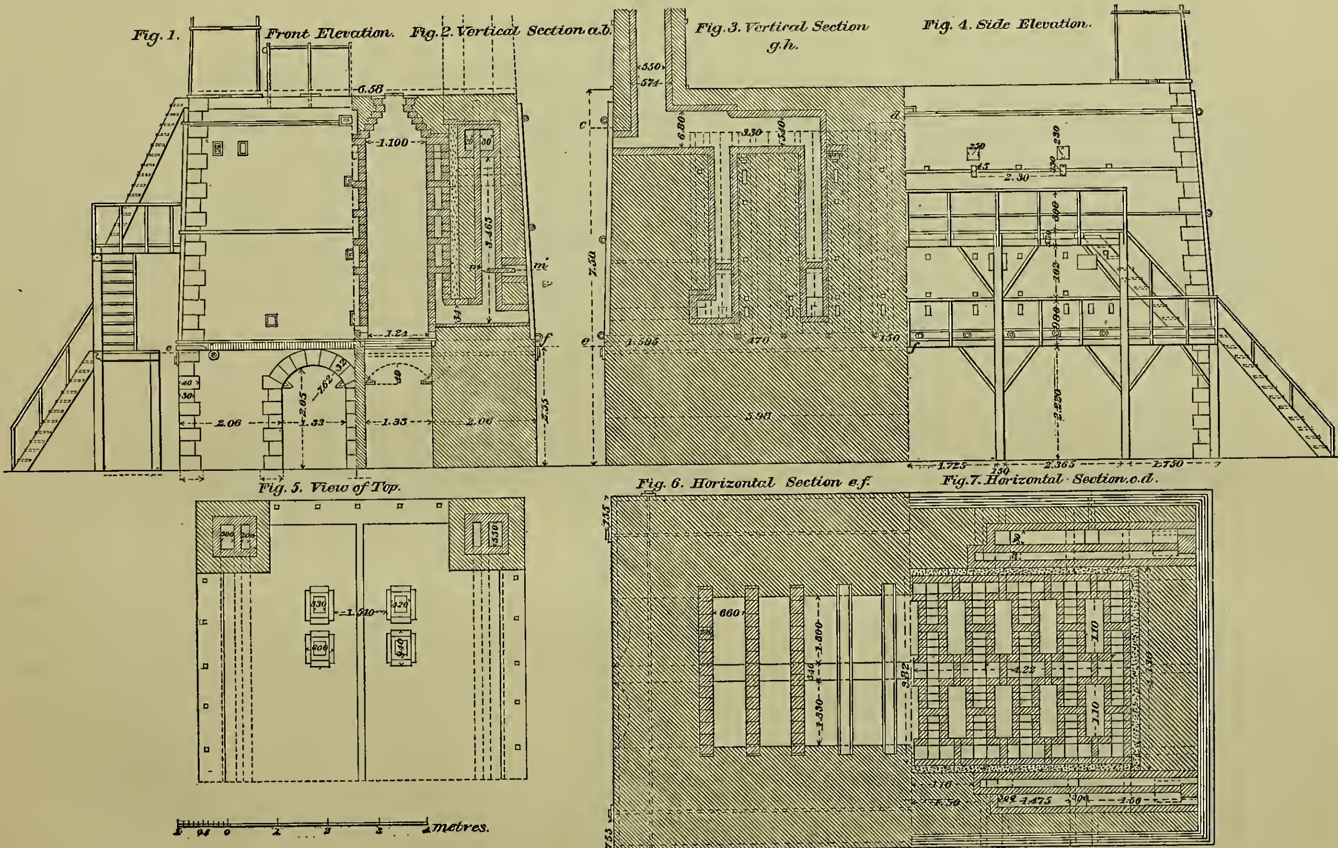


FIG. 20.

connected with the top near the center charging-hole, the air becoming heated while passing through the flue. The ovens are charged from the top through three hoppers, and are drawn by means of a mechanical ram propelled by a cogged driving-wheel, worked by a small portable engine. At each end of the oven are two iron doors moving on hinges and fixed securely in metal frames, the lower 3 feet high, the upper 1 foot. The usual dimensions of the ovens are 26 feet 6 inches long, about 19 inches broad at the back and 17 at the front, and 4 feet high. Ovens of this size are charged every 24 hours; others, arranged to be charged every 48 hours, are 5 feet 7 inches high and 5 feet broad. The thickness of the brick-work between is 13.2 inches. (*a*)

The accompanying drawing will give an idea of this oven.

The operation of the ram used in discharging the oven by pushing will be readily seen from an inspection of the drawing.

In working the ovens it is necessary first to heat them thoroughly, which is done by lighting fires of coal at the end of every oven close to the doors. When sufficiently hot, the first few charges of coal are in small lumps, the coke produced being of an inferior quality; but in a few days the ovens become so thoroughly hot that crushed coal of the consistency of very coarse meal is used, it being washed, if necessary, to remove impurities.

As has already been stated, one oven of the pair is charged when the coking in the other is about half completed. When ready to charge, the previous charge not having yet been withdrawn, the front and back doors are opened, and the mass of coke pushed out by a ram. The ram is then quickly withdrawn, and the two lower doors are closed. The oven is charged through the three hoppers or openings, and the coal is leveled, by means of rakes, by two men working through the upper doors at each end. The doors are then closed and carefully luted, and carbonization commences immediately. The processes of emptying and refilling the ovens need not occupy more than eight minutes. The coke is quenched immediately upon being withdrawn. Six charges are coked in each oven per week, each charge yielding about 2 tons of coke.

Regarding the yield of the coal in coke it is claimed that within 2 per cent. of the theoretical yield is obtained. Mr. E. Windsor Richards stated to Mr. Percy that at the Ebbw Vale iron works (*b*) 13,400 tons of coal (containing nearly 20 per cent. of shale) were sent to the washing-machine, and that 8,400 tons of coke were obtained, which is equal to a yield of 62.7 per cent. of the unwashed coal. If the washing process be effective in removing the shale, the yield of the washed coal must be considerably greater. Mr. Richards, however, found as much as 6 per cent. of water in the coke—a point of considerable importance in estimating the yield—the large quantity of water being due to the fact that the coke is quenched outside the oven, and to the want of sufficient care in performing this operation. A series of determinations, recently obtained from Bolckow, Vaughan & Co., limited, of Middlesborough, of the quantity of water in coke made in bee-hive ovens at their Newfield collieries and quenched inside the ovens, gave an average of only 0.8 per cent.

At Ebbw Vale, where there is a bank of these ovens, the work of coking is let to a contractor, who commences by filling the trams from the bin containing the crushed coal; and he finds all the labor for filling the ovens, discharging their contents (inclusive of working the coke-ram), and loading the coke into trams, for one shilling per ton of coke. The additional cost of crushing the coal in a disintegrator must be borne in mind.

In France, in 1878, the cost of making a hundred-weight of coke was about 28 cents, with 20 cents per ton for repairs and incidental expenses.

On page 99 will be found a statement made by Mr. Bainbridge, of the Duke of Norfolk's colliery, regarding the work of the Coppée oven. The advantages claimed for this oven by its inventors are rapidity of coking, largely increased yield, and better coke. It is further recommended by them on the ground that—

> Some qualities of coal which are not sufficiently bituminous to coke in the old oven (or bee-hive) make good coke when burnt in the Coppée ovens; that there is a slight saving of labor by the Coppée system, and that the waste gases of the oven may be utilized for the raising of steam without involving extra expense in the construction.

It may be questioned whether a coal which cannot be coked in a bee-hive oven will make good coke in a Coppée oven. Coke can be made from such inferior coals in the Coppée, but it will be inferior coke. The occasion of the invention of the Belgian oven was to utilize these inferior coking coals, to make it possible to coke them; but it is evident that no oven treatment can supply the lacking chemical elements demanded in making good coke.

In 1873 there were in operation in Belgium 524 Coppée ovens, and 192 were in course of erection. In Prussia 305 were at work and 138 building; in France 186 at work, and in England 30 at work and 30 building. According to Professor Jordan the cost of each oven is from $300 to $350 in France (2,500 to 2,750 francs). (*c*)

Though not strictly a flue oven, being more of the nature of a retort entirely surrounded by flame, the Appolt oven is very properly treated in connection with the Belgian ovens, as it may be regarded as surrounded by one large flue.

The Appolt oven differs materially from those previously described. It is upright instead of horizontal, and the coke is discharged from the bottom by gravity, instead of being pushed out by a ram. The method of supplying air for the combustion of the waste gas is also theoretically more perfect than in either of the other systems.

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a A full description, with working drawings of this oven, may be found in Percy's *Metallurgy: Fuel.* London, 1875.

b Percy's *Metallurgy: Fuel*, page 584.

c *Album to Course of Lectures on Metallurgy*, by S. Jordan, C. E. (London, 1878), page 20.

This oven consists of a series of upright rectangular retorts, the longer sides of the rectangle being two or three times the length of the shorter. The retort is also wider at the bottom than at the top, to facilitate the discharge of the coke. These retorts, in groups of 12, 18, or 24, as the case may be, are inclosed in a large rectangular brick chamber, which may be termed the combustion chamber, the retorts being surrounded on all sides by air-spaces, these spaces being in communication, and the walls which form the sides of the retorts connected together by solid blocks of fire-brick. Between the fire-brick walls of the combustion chamber and an outside brick wall is a space filled loosely with some powdered substance, as sand or other bad conductor of heat, which allows a certain degree of expansion and contraction of the fire-brick wall of the combustion chamber within. The combustion chamber for a group of 12 retorts would be about 17 feet long by 11 feet 6 inches wide and 13 feet high. The retorts are about 4 feet long and 1 foot 6 inches wide at the base, and 3 feet 8 inches long and 13 inches wide at the upper part, the walls being about 4¾ inches thick. The distance between the corresponding walls of the neighboring retorts varies from 7¾ to 9¾ inches. (*a*) The ovens are placed in two rows, back to back, the bottoms being provided with cast-iron doors, strengthened by transverse bars of wrought-iron. The partition walls of each chamber, at a distance of from 16 inches to 2 feet from the base, are traversed by two rows of small horizontal openings 5½ inches long and about 3¼ inches high, 9 on each wide and 3 on each narrow side. At the upper part there are three similar openings on each wide side only. Through these openings the volatile products evolved during the coking of the coal pass into the surrounding open spaces of the combustion chamber, where they are burned by atmospheric air admitted through holes in the wide sides of the outer wall of the oven. In the wide side walls are the flues which receive the products of combustion from the flues surrounding the spaces and convey them to the chimneys. There are twelve vertical flues in all, three below and three above in each of these walls.

In operating the oven it is first heated with coal, as in the case of the Coppée oven, until the walls have become red hot. After eight or ten days firing the oven will be found to have attained a temperature of from 1,200° to 1,400° C. (*b*)

In order always to insure an equal degree of heat through the oven, and to simplify the management of the latter by the dampers and air-flues, it is expedient to charge the two series of compartments alternately, the temporary grate and brick lining at the bottom being removed from the compartment which it is proposed to charge. The door is closed and securely fixed, and is then covered with a layer of coke dust about 1 foot thick. This is done to protect the door from heat, to close effectually the bottom of the compartment, and to prevent loss of heat. The charge of coal is now introduced, and a cover is placed over the top, luted with coke dust or clay.

The gases, which are immediately evolved when the coal comes in contact with the red-hot sides of the compartment, pass into the surrounding free spaces, where they are burnt, and so sustain the heat of the oven. An hour afterward a second compartment is charged in like manner, and so in succession until all have been charged. As the amount of gas produced increases during the day with the number of charges, it is necessary to open the dampers, and all that is required to be done during the night is gradually to shut them again in proportion as the evolution of gas decreases. Carbonization being completed at the end of the 24 hours, on the following day the coke is drawn from the first compartment at the same time as the charging took place on the previous day. Immediately afterward the compartment is charged again. The process is thus continued without interruption, the coke being drawn from each compartment 24 hours after it has received a charge of coal. No inconvenience arises from the use of washed coal which still retains moisture. By suitably decreasing the admission of air and the exit of gases from the oven the charging may be omitted on particular days, and yet the heat will continue sufficiently high to enable the charging to be effected on the following day.

The advantages claimed for this oven are as follows: (*c*)

1. The calcination is effected in a close chamber solely by the combustion of gas disengaged from the coal, a condition favorable to a high yield.
2. The heating surface is very considerable, reaching 190 square meters for a charge of 1.5 tons. The comparatively small size of the retort secures a rapid and regular carbonization.
3. The flames from all the compartments uniting in a common chamber, which surrounds them, insure a uniformity of temperature.
4. The vertical position of the compartments, beside the facility of rapid charging and emptying, gives more compactness to the coke, while the arrangement occupies less space.

The following are the inconveniences incident to the system:

1. If the general arrangement does not allow of the coal being led directly out upon the loading platform, lifts must be provided to raise it.
2. Masses sometimes adhere to the sides of the retorts, which have to be broken by bars before the coke can fall.
3. The management of these ovens is not so simple as in some other systems, and when repairs are required for one compartment the whole group has to be stopped.

In the Appolt oven the yield is very nearly the theoretical maximum. At the Blanzy collieries, in France, an oven of 18 compartments is charged with about 24 tons of coal and 3 tons (2,240 pounds) of ashes and dust for covering the

a These dimensions are to be regarded as about the dimensions, they being the equivalents in English feet and inches of the meters of the original paper.

b Percy's *Metallurgy: Fuel*, pages 449, 450.

c *Journal Iron and Steel Institute*, 2, 1873, page 348.

movable bottoms. The operation lasts 24 hours, and produces 17 tons 6 hundred-weight (2,240 pounds) of coke. Taking into consideration the water in the coal (5 per cent.) and in the coke (10 per cent.), the yield would be 68½ per cent., about the yield in a crucible. The cost of the construction of an oven of 18 retorts is about $10,000 (50,000 francs); the cost of coking at a French colliery, including the mixing and breaking of coal and maintenance of oven, amounts to about 43 cents per ton (2 francs 15 centimes).

Dr. Percy, in summing up regarding the Appolt oven, makes the following remarks: (*a*)

This oven differs much in construction from most other coke ovens, and appears completely to fulfill the conditions of a close vessel or retort. Although it certainly is a costly structure, yet according to the inventors the cost in proportion to yield is less than in any other kind of coke oven. Now, it has been previously stated that the non-coking, thick coal of South Staffordshire will cake and produce a solid coherent coke, provided it be rapidly exposed to a high temperature in a perfectly close vessel; and a prodigious amount of the fine slack of such coal has either been wasted or left in the pits because it could not be raised with profit. It may be possible to imitate on a large scale the conditions of the experiment in a crucible and to heat rapidly a large mass of slack to bright redness; but of all the coke ovens known to me, that on the Appolt system seems to be one of the most favorable to the solution of the problem.

Mr. Menelaus, however, informed Dr. Percy (June, 1873) that some years before he saw the Appolt ovens at work near Saarbrück, and that the late M. de Wendel, to whom they belonged, and who was an excellent judge of coke ovens, did not, at least at the time of Mr. Menelaus' visit, see any great merit in Appolt's scheme.

While it thus appears that theoretically the Appolt oven is the nearest to a perfect coke oven, it is not used to the same extent as either the Smet, the Dulait, or the Coppée. It is by far the most expensive to construct, and, as has already been noted, the stoppage of operations to repair one retort necessitates the stoppage of all.

As to which of the many forms of the Belgian oven is the best, but little information has been obtained, as results of comparative trials have in but few instances been made public; indeed, it would be almost impossible to arrive at a general conclusion on this point. It will doubtless be found that one form will give the best results with one kind of coal, while another form will be better adapted to the coking of coal of a different character, but it will always be found true that inferior coal of whatever character will invariably give an inferior coke. Some forms of oven may give a better coke than other forms with the same coal. The true method is to study the character of the coal and adopt the oven that seems best suited to it, having in view economy of operation. At the Cockerill works, at Seraing, Belgium, where a number of Smet ovens had been used for some time, a trial was made of the Dulait, but after careful and thorough experimenting it was abandoned and the preference given to the Smet. On the other hand, at the works of the Société Anonyme des Charbonnages de Marihaye, Belgium, some experiments have been made as to the relative value of the Dulait and the Appolt ovens, with the following result as to the contents of the coke produced:

Constituents.	WASHED.		UNWASHED.
	Treated in the Dulait oven.	Treated in the Appolt oven.	Treated in the Dulait oven.
	Per cent.	*Per cent.*	*Per cent.*
Ash	2.8400	4.4900	9.3400
Water	0.5100	0.4800	0.5800
Carbon	96.6500	95.2300	90.0800
Sulphur	0.0790	0.1016	0.1016
Phosphorus	0.0125	0.0292	0.0292

In England, in the South Wales district, where the Belgian oven has been introduced, and in other parts of England having coals of similar or inferior character, the preference seems to be given to the Coppée ovens, with modifications in some cases, suggested by the experience of the English engineers. While other ovens have been tried, no record has been found of any other form of Belgian oven in use at the present time. The Cox oven, of which the Dulait is in some respects an imitation, and which was at one time used at the Ebbw Vale works, does not seem to meet with continued favor, as at this works, as stated elsewhere, Coppée ovens have been lately built. As noted by Percy in his *Metallurgy*, all of the Belgian ovens, with the exception of the Appolt, seem to be improvements of the old rectangular Welsh oven. In this process of development the Smet, Dulait, and Coppée seem to be successive steps, and the late action of the English coke manufacturers would indicate that with the inferior coals of that country the last step in this development, that is, the Coppée oven, is the best.

SPECIAL ADAPTATIONS OF EACH FORM OF OVEN.

A question of the utmost importance in connection with the manufacture of coke is which is the best oven, and is as difficult to answer as it is important. The form of oven that might be the best, the most economical, and produce the best coke under certain conditions, would not necessarily be the best when these conditions are changed. The oven that would give the most satisfactory results with the coals of Durham, England, or Connellsville, in this country, would not necessarily be the best for the inferior coals of France or Belgium.

a A full description of this oven can be found in Percy's *Metallurgy: Fuel.*

This question as to which is the best form of oven, while it is one contingent on circumstances, is nevertheless answerable as to a given coal. It has been thoroughly investigated in the chief coke-producing countries of the world, and some decided results have been reached as to the best ovens for the coals of the several districts. As there is so great a variety of coals in this country, it may not be unimportant to give these results.

It seems to be quite well settled that with coals similar in character and cost to those of Durham, England, and Connellsville, Pennsylvania, the bee-hive oven, not only as to the character of the coke, but on the score of economy of operation, is the better form. The yield of these coals in coke is no doubt greater in the close distilling ovens on the so-called Belgian plans, where the time of coking and consequent exposure is shorter than it is in the bee-hive ovens, and the coke, in burning, is more or less exposed to the action of highly-heated atmospheric air, but it has been found in blast-furnace practice that this greater yield is more than compensated for by the larger amount necessary to make a ton of iron. This is a somewhat remarkable statement, but it has the sanction of the best authority. Mr. I. Lowthian Bell, the distinguished English manufacturer and writer on blast-furnace phenomena, while acknowledging, in speaking of the Belgian and bee-hive oven, (*a*) that the yield was much greater in the latter, "almost the whole of the fixed carbon being obtained as a coke, the exception being a very minute loss incurred in drawing,"(*b*) nevertheless found the useful effect in the furnaces inferior to that obtained from the coke made in the ordinary oven. In consequence of this all his more recently erected ovens have been constructed upon the old fashion.

Mr. Bell also stated, at a meeting of the British Iron and Steel Institute at Paris in 1878, (*c*) that his firm, among many others, undertook, at considerable expense, the inquiry as to whether it was possible to treat English coal in the same way as coal was treated in France in the manufacture of coke. Both the Knab and the Appolt ovens were tried, and while in both these systems the yield obtained was quite equal to their expectations, they found in practice that whatever advantage was gained in yield was so much lost in the blast-furnace; that the quantity of coal actually consumed in the manufacture of a ton of iron remained pretty much the same in each case. In other words, he found if 30 hundred-weight of coal made 20 hundred-weight of coke in a bee-hive oven and 22½ in an Appolt, that it would require the 22½ hundred-weight of Appolt coke to do the same work in the blast-furnace as the 20 hundred-weight of bee-hive coke. They were compelled, therefore, to go back to the old bee-hive oven, and, as a result, were using a considerably greater quantity of fuel than ought to be the case if the coke made in the better description of ovens had produced an article equal in quality to that produced in the bee-hive oven. He suggested, as one reason for this fact, that the extra coke was consumed in great part in the upper part of the blast-furnace, but another and more simple reason was that as they invariably used a much greater quantity of water in quenching the coke made in the Coppée and Appolt ovens than they did with the bee-hive, a portion of the increased yield was due to the presence of water, and therefore more apparent than real.

There is perhaps another reason for this greater consumption of the coke made in Belgian ovens than of that made in bee-hive ovens. The flued ovens make a denser coke than the bee-hive, and it takes more of it to smelt a ton of pig-iron than of the more cellular coke of the bee-hive. In a word, the difference of consumption may be largely due to the physical condition of the coke; and here it may be pertinent to say that the physical condition of the coke produced with the several ovens is not receiving the attention its importance demands. (*d*)

Mr. A. L. Steavenson, a North of England engineer and writer on coke, went further than Mr. Bell, and claimed that coke was made in bee-hive ovens in the Cleveland district of England that it would be impossible to produce in any of the Belgian ovens. After a study of coke-making in England extending over a period of twenty-five years, he was quite sure that there was not any oven equal to the old-fashioned round oven for producing coke economically for the manufacture of iron. (*e*)

These statements are fully borne out, so far as relates to the cokes made from our Broad Top and Connellsville coals, by the careful and thorough experiments of Mr. John Fulton, mining engineer of the Cambria Iron Company. (*f*) Speaking of the Connellsville coal, Mr. Fulton says: (*g*)

> The best quality of Connellsville coke treated in the Belgian ovens of the Cambria Iron Company produced a coke of very objectionable density, especially in the bottom and middle of the charge.

A direct test to determine the relative calorific values of cokes made in bee-hive and Gobeit ovens, using the same quality of coal in each kind, was made at the furnaces of the Kemble Coal and Iron Company, in the Broad Top coal region, Pennsylvania, by William Lauder, the general superintendent. The furnace in which

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a *Chemical Phenomena of Iron Smelting*, I. Lowthian Bell, London, 1872, pages 314, 315.

b *Transactions Institute of Mechanical Engineers*, 1871.

c *Journal of the Iron and Steel Institute*, No. 2, 1878, pages 346, 347.

d Mr. Fulton suggests that the denser coke may not be as vigorous a fuel as the more cellular, or, in other words, that as many tons of pig-iron could not be made in a week in a furnace using the denser coke as in one using the cellular. A comparison between the makes of furnaces using Connellsville coke and those using anthracite, which is practically a dense coke, will illustrate what is meant by a "vigorous fuel".

e *Journal of the Iron and Steel Institute*, page 354.

f See *Second Geological Survey of Pennsylvania*, Report G (Harrisburg, 1878), pages 235 *et seq.* Also Report L, pages 117 *et seq.*

g Report G, page 248.

the tests were made is 14 by 60 feet, with modern blowing machinery and hot-blast oven. The ores are from the Clinton group (No. V), well known as the Juniata fossil ore, containing 30± per cent. of metallic iron. The increased density of coke made in the Gobeit was very manifest. It was found that with careful management in both trials it required 2,300 pounds of Gobeit coke to carry the same furnace burden as 1,900 pounds of bee-hive coke. Mr. Lauder confesses his surprise at the results. While this coke was in the furnace it took 5,196 pounds to 1 ton of pig-iron; with the bee-hive coke 4,156 pounds for the same work. The loss, per ton of pig-iron made, is 1,040 pounds of coke, or 20 per cent. If the furnace makes 250 tons a week, the loss will be 115½ tons of coke, at $2 25=$259 87 per week.

This testimony in favor of the use of the bee-hive oven for coking the coals of western Pennsylvania is further strengthened by the action of certain coke manufacturers in that region, who, after having thoroughly tried certain forms of the Belgian oven, have, on increasing their coke-plant, built nothing but bee-hive ovens.

It may be assumed that, for coking, the character of coals, of which the Durham and the Connellsville may be taken as the type, and having in consideration the fact that the use to which coke is most largely put is in blast-furnace work, the bee-hive oven is the best. It may be possible that in the development of the iron business and the increased demand for coke, coupled with the exhaustion of coal-beds and the necessity of going deeper and further into the hills for coal; in a word, with the increased cost of the character of coal which is so admirably adapted to the manufacture of coke, some modification of the bee-hive oven that will give a similar character of coke without so great waste will be adopted; but we are speaking, of course, of the present and the present conditions.

In noting these results and opinions it is scarcely necessary to state that in the experiments recorded all forms of the so-called Belgian oven have not been tested and the results compared with those obtained in the bee-hive ovens. It is fair to presume, however, that tests made by such eminent engineers as Messrs. Bell and Steavenson in England and Mr. Fulton in this country would be carefully and thoroughly made, and that the Belgian oven selected for trial would be regarded as the best form for the coal used with which they were acquainted at the time the test was made.

It should also be noted that in these statements the coke is considered only as to its value as a blast-furnace fuel; the economy of coking is not taken into account.

It is also fair to state that the experience of Messrs. Laughlin & Co., of the Eliza furnaces at Pittsburgh, is favorable to the use of the Belgian ovens. The oven they use is the old François oven, improved by Mr. Henry Laughlin, and are 22 feet long, 18 inches wide, and 5 feet high, flues being arranged vertically in the side walls, which are 13 inches thick. Mr. Laughlin states that he has used Connellsville coal in these ovens with very good results, the time of coking being very much shorter and the coke produced equally as good as that made from the same coal in bee-hive ovens, but the yield was greater. They also use at times a mixture of Connellsville coal and the fine slack from the Monongahela river, but for the most part use the latter alone after careful washing, it making a lighter and more porous coke than the Connellsville coal. They get every 24 hours about 2,000 pounds of coke from each oven. A remarkable difference between their practice and that ordinarily used with the Belgian oven is that the coke is watered in the oven as in the bee-hive and is pushed out cold, and it may be possible that the better quality of the coke from these Belgian ovens is in part due to this watering inside.

So far this question of the relative value of different forms of ovens has been considered only with reference to the coking of coals similar to those of Durham, England, and of Connellsville, in this country, and it seems well established that with these coals the bee-hive oven has so far given the best results; but all coals are not of the character of these, nor are they so easily coked. Mr. E. Windsor Richards, of Blockow, Vaughan & Co.'s steel works at Eston, England, very aptly remarked of the Durham coal: "It would be very difficult not to make good coke with it;" (*a*) and a similar statement may be made of the Connellsville coal. The question arises, regarding those coals that in the bee-hive oven have made inferior coke, or, as they are termed, the "inferior coking coals": Are any better results obtained with these coals in the Belgian oven than in the bee-hive or similar forms?

The evidence seems conclusive that, with certain inferior coals, the Belgian oven produces a better coke than the ovens of which the bee-hive is the type. In a word, certain inferior coking coals can be coked in the Coppée or some other form of Belgian oven which cannot be coked in the bee-hive. Many coals do not contain sufficient hydrogenous matter to thoroughly ignite and agglutinate in the bee-hive; they lack the pitchy matter to supply heat and bind the coal together in coking. In the Belgian oven, however, by reason of the greater heat, these coals catch more readily, and, the process being quicker, they bind together better. In many cases where the Belgian oven is used on these dry coals it is found advisable to mix them with coals containing more "pitch". This has been done at the works of the Cambria Iron Company with their Belgian ovens. At the same time, however, it seems to be a fact that the invention of the Belgian oven was the result of necessity, not of advanced scientific method. The European coals for which this oven was designed were very dry material for coke—could not well be "stuck" together in the old circular oven, and hence a costly appliance had to be used to make it possible to use these inferior coals in coke-making.

Up to 1852 coke was made in Belgium in bee-hive ovens, or in others with solid walls, somewhat similar in

a *Journal Iron and Steel Institute*, No. 2, 1878, page 348.

construction to the bee-hive. At this time the cost of the bituminous coal used increased to such a figure that it was necessary to use inferior coal for coking or to abandon iron-making. Out of this have grown the many forms of the so-called Belgian oven, the principles of which are described in the chapter treating of ovens.

The fact that the old forms of oven have been entirely abandoned in Belgium is the most convincing evidence that for the Belgian coals they are not the best form. The testimony as to which of the many forms of the Belgian is the best is not conclusive, but it seems generally conceded in Belgium, as the result of careful and long-continued experiments and comparisons, that almost any form of the oven is better than the bee-hive for their coal.

A similar statement is true of France. The French coals chiefly used for coking are not typical coking coals, being dry and quite impure, and consequently high in ash. In that country the coke is generally made in the Coppée or Appolt forms of the Belgian oven. In the discussion of Professor Jordan's paper, which has been before referred to, Mr. Windsor Richards stated that his impression was that without the Coppée or Appolt oven coke-making in France would be impossible. (*a*) In discussing this further, Professor Jordan said: (*b*)

The improved coke ovens, Belgian or Appolt system, yield with the same quantity of coal a higher percentage of coke than the old bee-hive ovens, because there was a smaller loss by combustion in the oven, and also because the proportion of small coke or cinders was smaller, as was also the cost of working. It is a fact universally known to be true by the French and Belgian coke manufacturers that the cost of production of a ton of coke in a Belgian or an Appolt oven is smaller than in a bee-hive oven. There is less coal and less labor required. For the blast-furnace process, coke must be considered as to its percentage of ash, and as to its porosity and friability. A percentage of ash can be obtained as low in the improved coke ovens as in the old form; indeed, by using the same coal, a purer coke is produced in the new ovens, since the yield is higher. As to the porosity and friability, which depend above all on the quality and the physical state of the coal used, and also on the thickness of the layer of coal in the coke oven, the French manufacturers certainly obtain in their improved ovens coke as dense and as hard, indeed, perhaps more dense and more hard, than in the old bee-hive ovens.(*c*) Therefore, Professor Jordan said he could not find an explanation of the fact recorded by Mr. Bell. He was not aware of any trial made by iron-masters for comparing the two kinds of coke for blast-furnace use, but all the blast-furnaces in the Loire district had formerly used coke made in bee-hive ovens, and actually now used coke manufactured in improved ovens, and they had never had any disadvantage resulting from the change.

Professor Jordan, referring to Mr. Richards' remarks, agreed with them. The only coals to be got by French iron-masters were generally inferior to those of Durham for coke-making. In old times, when the consumption of coke was not very extensive in France, it was manufactured from caking coals in bee-hive ovens; this, for example, was the case with the Loire coal-field. Now, however, that the wants of the iron trade have increased other kinds of coal are largely employed.

Professor Jordan believed (*d*) that, in spite of the unfavorable results referred to by Mr. Bell, the Durham coke-makers would adopt in due time the improved systems of coke ovens used in France, Belgium, and Westphalia. The failures reported by Mr. Bell had also been incurred by German manufacturers in the Loire coal-field, where formerly coke was made only from caking coal in bee-hive ovens. There the improved systems had been introduced in practice later and more slowly than elsewhere, because the first trials had been made with systems of ovens which, though having merits for other qualities of coal, were somewhat inappropriate for that used. He ventured to say that the same had perhaps happened to Mr. Bell. It should always be remembered that when making trials with coke ovens of the Smet, Coppée, Appolt, or other class failure might result instead of success, in consequence of a difference of some inches, more or less, in the breadth of the oven or the dimensions of a flue, or probably of some units too much or too little in the percentage of humidity of the coals prepared for carbonization. These improved ovens required also more attention and care than the old ones.

In Westphalia, though the coal is superior to the French for coking, being somewhat similar to the Welsh steam-coal, it has been found that better results are secured by the use of the Belgian ovens than by the old style of bee-hive ovens. The details and experience in the use of these ovens in this part of Germany have not been procured, but the relative number is conclusive evidence as to which form is deemed best. Of the 5,300 ovens reported in the Westphalia district, the far greater number are of the Coppée system. Dr. Gustav Natorp, in his paper read before the British Iron and Steel Institute, says:

Although it is the opinion of some engineers that the coke produced in the bee-hive ovens is superior in many respects to that of the Coppée ovens, the former have, nevertheless, not been generally adopted, since a coke can be far more cheaply produced in the Coppée ovens, which answers all the requirements, not alone of our native iron industry, but of that of Belgium, Luxembourg, and France as well.

Even in England itself there is strong evidence of the superiority of the Belgian ovens of the Coppée system for the manufacture of coke from certain of the British coals, especially those of South Wales.

Mr. Richard Meade, in his recent work on *The Coal and Iron Industries of the United Kingdom*, page 201, says:

The coke manufactured in the ordinary way in South Wales, although exceedingly hard and dense, does not appear to have attained all the economical results possible. Experience has shown that the carbonization of the coal is not complete, the long, deep fissures in the coke thus manufactured exhibiting, on examination, a considerable amount of dark carbonaceous matter not carbonized.

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a *Journal Iron and Steel Institute*, No. 2, 1875, page 348.

b *Idem*, pages 349, 350.

c A confusion of denseness and hardness of coke may exist in some of these cases. Dense coke is not desirable; hard coke is. As is explained under "Properties and composition of coke", a hard coke is one in which the cell-walls in the fuel are hard; a dense coke is one in which the number of cells in the coke is small.

d *Journal Iron and Steel Institute*, No. 2, 1878, pages 352, 353.

At the Ebbw Vale iron works, in South Wales, 60 ovens were constructed on the Coppée system in 1874, and so successful has been their use with the coals at these works that 60 more were erected in 1880. In the same year the Dowlais iron works decided to erect two blocks of 72 ovens each, and it was also reported that the Barrow Hematite Company had decided to make a trial of their coal, which is a very much poorer coking coal than even the Welsh, in these ovens. In Pembrokeshire, where the coal is not at all caking, good coke was obtained in the Coppée oven with the mixture of 50 per cent. of anthracite dust with bituminous coal and some pitch.

At the Dowlais works the first block of 72 ovens on this system was put into full operation early in 1881, at which time they produced 1,000 tons a week of excellent coke from a coal containing but in a slight degree those qualities that are considered necessary for coke-making. The success of these ovens at Dowlais led to the erection, in 1881, of a block of 72 similar ovens by the Rhymney Iron Company. (*a*)

From what has been said we think it is evident that while for coals similar to those of Durham, England, and Connellsville, Pennsylvania, under the present conditions as to prices and demand, the bee-hive oven is the best form for coking. We think it is also evident that for other coals, which may be termed inferior coking coals, similar to those of France, Belgium, Westphalia, those mentioned in South Wales, and the Cumberland district, the Belgian system, or some form of the Belgian system, is better than the bee-hive or a solid-walled oven.

As to the relative cost and results of the two systems, many comparisons have been instituted. Mr. Emerson Bainbridge, who has gone very fully into the respective merits of the bee-hive and Coppée systems of coke manufacture, has prepared the following summary of the chief points of comparison, which exhibit some interesting features: (*b*)

	Bee-hive.	Coppée.
First cost per 2 tons of coke per day	£119 7*s*.	£100.
Time of burning	48 to 120 hours	24 hours.
Area per ton of coke daily	1,218 square feet	234 square feet.
Per cent. of yield	45 per cent	59 per cent.
Outside cooling-surface per 2 tons	1,002 square feet	175 square feet.
Time in emptying and refilling	60 minutes	8 minutes.
Units of heat in waste gases per oven	966.710	1,401.584.
Labor charge per ton	1*s*. 3*d*.	11*d*.

Mr. Fulton, in discussing this point, says: (*c*)

The relative cost of making coke in each kind of oven is hereby given, with original cost of ovens and annual cost of repairs. The estimate contemplates banks of ovens to produce 100 tons of coke per day, or 30,000 tons per year. Coal at $1 per ton delivered at ovens.

BEE-HIVE OVENS.

80 ovens, at $200	$16,000
Interest on investment, 10 per cent. per annum	1,600
Annual repairs and renewals, at $10	800

Then $\frac{\$2{,}400}{30{,}000 \text{ tons.}}$ = 8 cents per ton of coke.

COST OF COAL AND COKING.

1.60 tons of coal, at $1 per ton	$1 60
Labor at ovens, charging and drawing	27
Interest on cost of ovens and annual repairs	8
Coal, $1 60; coking, etc., 35 cents	1 95

BELGIAN OVENS.

65 ovens		$45,200
Engine for pushing coke out of ovens		3,000
Annual repairs to engine		50
Tracks for engine		300
Annual repairs to ovens		310
Annual interest on investment ($48,800), at 10 per cent	4,880	

Then $4,880+$310+$50 = $\frac{\$5{,}240}{30{,}000 \text{ tons.}}$ = 17½ cents, nearly.

a Mr. Edward P. Martin, manager of the Dowlais iron works, writes me under date of November 23, 1882:

With regard to the question of yield of coke, we consider that the yield in the Coppée oven is better than in ordinary ovens; how much, it is difficult to say, as we do not weigh the products. With regard to the question of cost, taking into consideration the greater output per oven, we do not think that the cost per oven per ton of coke made is in excess of ovens built on the ordinary plan. The time of coking with us is 24 hours. The coke, if we use a fair quality of coal, is good and hard, but it has not that silvery appearance so taking to the eye which we get from good coal from ordinary ovens. Chemically and mechanically there is no difference in the quality, as far as we are able to judge, on the blast-furnaces. The cost per oven in this country is about £100 each, including roads, foundations, etc. The labor expense is less than in operating ordinary ovens. We have 72 ovens, and these 72 ovens burn out about 1,000 tons per week, or 14 tons per oven per week.

b Ure's *Dictionary of Arts, Manufactures, and Mines*, vol. iv, page 262.

c *Second Geological Survey of Pennsylvania*, Report G, pages 249, 250.

COST OF COAL AND COKING.

Coal, 1.42 tons, at $1 per ton	$1 42
Labor at ovens, charging, luting, pushing, etc	23½
Interest on cost of ovens and annual repairs	17½
Coal, $1 42; coking, etc., 41 cents	1 83

The Belgian plant of ovens is the more costly in construction, but less expensive in repairs and coking.

The economy in this class of ovens consists in the saving in coal to make 1 ton of coke, the saving in the work of discharging the coke out of ovens, and in their annual repairs.

The bee-hive oven is less costly in construction, but more expensive in annual repairs. Regarding the two systems in the aspect of absolute economy, embracing the interest of invested capital in their construction with annual repairs of each, and without any reference to the value of the coke made by each kind of oven, the Belgian exhibits an economy of 12 cents per ton of coke in its favor.

Mr. Fulton sums up the whole question as follows: (*a*)

The inquiry as to the best oven will be confined to a comparison of the bee-hive and Belgian, the Appolt being regarded as planned for peculiar cases which are not embraced in the limits of the present investigation.

The advantages of the bee-hive are mainly as follows: first, it produces from the coal the best possible physical structure of coke; second, it yields a uniform quality of coke; third, its coke watered out in the oven is produced in the driest condition; fourth, in rabbling it out it is separated into diminutive pieces; and fifth, the operation of coking in it is simple, and the cost of oven and repairs moderate.

The Belgian or François oven has its advantages: first, it produces a uniform quality of coke; and second, it is the most economical method of coking.

Its disadvantages consist mainly with the ordinary coking coals in making a dense coke. It requires skill in its coking operations; it requires its coke to be quenched outside in a clumsy manner, producing a damp fuel; its cost is large, but its repairs moderate.

It is only especially adapted to the family of coals demanding pressure in coking, to prevent too inflated a physical structure, and to the peculiar cases hitherto noticed consisting of coals holding a minimum of volatile matter and requiring washing.

Perhaps at present it is possible to secure coke made in the bee-hive ovens from the excellent coals of the Allegheny mountains at such rates as would not justify the attempt to coke what might be termed the "inferior coking coals" of the states of the Mississippi and Ohio valleys outside of the Allegheny region, but in the near future the question of the coking of these inferior coals will be one of considerable moment, and it is for this reason that it has been discussed at length here.

THE UTILIZATION OF WASTE PRODUCTS.

The enormous waste in coking has been a subject of earnest consideration on the part of coke-makers for many years, and various methods have been suggested and tried for saving this waste. The waste heat has been partially utilized—

First, by changes in the construction of the ovens, building them in banks or blocks, and by the use of flues in their sides and bottoms.

Second, by carrying the heated gases under boilers and utilizing them for raising steam.

This waste of heat, however, is a mere bagatelle to the waste of the by-products that pass off during the distillation of coal. In the manufacture of gas one of the principal sources of income is the sale of tar and ammoniacal liquors, and the amount and the value of these by-products in gas-making would scarcely be credited did it not have the sanction of such high authority. (*b*)

The color industry utilizes practically all the benzine, a large proportion of the solvent naphtha, all the anthracene, and a portion of the naphthaline resulting from the distillation of coal-tar, and the value of the coloring matter thus produced was given as £3,350,000. The present production of 1,000,000 tons of liquor yields 95,000 tons of sulphate of ammonia, which, taken at £20 10*s*. a ton, represents an annual value of £1,947,500. The total annual value of the by-products of the gas-works of the United Kingdom may therefore be estimated as follows:

Coloring matter	£3,350,000
Sulphate of ammonia	1,947,500
Pitch (325,000 gallons)	365,000
Creosote (25,000,000 gallons)	208,000
Crude carbolic acid (1,000,000 gallons)	100,000
Gas coke, 4,000,000 tons (after allowing 2,000,000 tons consumption in working the retorts) at 12*s*	2,400,000
Total	8,370,500

Taking the coal used, 9,000,000 tons, at 12*s*., as equal to £5,400,000, it follows that the by-products exceed in value the coal used by very nearly £3,000,000. In using raw coal for heating purposes these valuable products are absolutely lost.

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a *Second Geological Survey of Pennsylvania*, Report G, pages 248, 249.

b Dr. Siemens, in his address as president before the British Association at Southampton, August, 1882, estimates that 9,000,000 tons of coal were used annually in the gas-works of the United Kingdom, producing 500,000 tons of tar, 1,000,000 tons of ammoniacal liquors, and 120,000 tons of sulphur.

It is evident from this that the value of these products wasted in coke-making, which is essentially the same as gas-making, is enormous. On the basis of the above estimate, assuming a consumption of 7,000,000 tons of coke annually in the blast-furnaces of Great Britain, there would be a loss of by-products to the value of nearly £4,643,333⅓. Dr. Angus Smith, the English inspector under the alkali acts, estimates that 20 pounds of ammonia are given off in the combustion of every ton of coal manufactured into coke. This would equal 27,524 net tons of ammonia as the product of coke-making in the United States in the census year. It is well known that there exists an almost unlimited demand for sulphate of ammonia for agricultural purposes, all the more so as the natural manures, such as guano, saltpeter, etc., are getting scarcer and scarcer, or deteriorating with respect to the quantity of nitrogen they contain. Latterly the ammoniacal liquor has also been used in the manufacture of soda under the Solvay patents.

A number of attempts have been made in England, extending through a series of years, to utilize these by-products, and ovens have been built and appliances attached to the ordinary bee-hive ovens for this purpose, but with very little success until recently. While no difficulty was experienced in collecting these waste products in the earlier trials, the coke was inferior, and there was some trouble in maintaining the necessary flues. Messrs. Pease & Partners, in the north of England, have quite recently started a block of 25 ovens, (*a*) to which they have applied the Carvès plan, of whose success they speak very favorably. This plan has reached its best development at Bessèges, France, at the works of the Terrenoire Company, though it is in successful operation at other places on the continent of Europe. On pages 102 and 103 will be found drawings of these ovens as modified by Mr. Henry Simon, with a full statement of the working of the ovens and the results attained. (*b*)

In this oven the coal is rapidly carbonized by subjecting a comparatively thin layer to a high temperature in a closed and retort-like vessel, the volatile products being burned around the outside of this vessel after they are deprived of the tar and ammoniacal liquor.

Each oven is in the form of a long, high, narrow chamber of brick-work—a Belgian oven in fact—a number being built side by side, with partition walls between them sufficiently thick to contain horizontal flues. Flues are also formed under the floor of each oven, and at one end of these is a small fireplace, consisting of a fire-grate and ash-pit, with suitable door, the fire-door having fitted above it a nozzle, through which gas produced from the coking is admitted to form a flame over some fuel burning on the grate. Only a very trifling amount of such fuel, consisting exclusively of the small refuse coke, is used here, its function being really more that of igniting the gas than that of giving off heat. These grates when in regular work are not charged with fuel more than twice every twenty-four hours.

The products of combustion pass from the fireplace along a flue under the oven floor to the end farthest from the fire, and return along another flue under the floor to the fire end. They then ascend by a flue in the partition wall to the uppermost of several horizontal flues formed therein, and descend in a zigzag direction along these flues, finally passing into a horizontal channel leading to a chimney. Thus the coke oven is heated not only at the bottom in the usual manner, but also evenly at the sides, and the coal with which it is charged becomes rapidly and completely coked. No air is allowed to enter the ovens. These ovens are fed with coal through openings in the roof, over which coal-trucks are run on rails; and the coal is evenly distributed by rakes introduced at end openings provided with doors faced with refractory material, which doors are closed and kept tightly luted while the oven is in operation. The feed-holes in the roof are also provided with covers. Through the middle of the roof rises a gas-pipe provided with a hydraulic valve, which closes the passage by a lip projecting down from it into an annular cavity surrounding its seating, in which it is immersed in a quantity of tar and ammoniacal liquor lodged there during previous distillations. The volatile products of the coal-distillation rise by the gas-pipe and are led through a range of pipes kept cool by external wetting, so that the tar and ammoniacal liquor become condensed and separated from the combustible gas.

The quantity of these by-products depends, of course, mostly on the nature of the coal used, as the richer the coal is in bitumen or gas the greater the value of the by-products.

Much also depends on the proper conduct of the temperature at the different stages of the coking process, for it is quite possible to obtain even from the same coal different proportions, quantities, and qualities both of the coke and the by-products. Practical experience must in each case determine what is best adapted to local requirements and circumstances.

The cooling-pipes are conveniently arranged in pyramidal form, surmounted by a water-pipe having numerous holes, so that a shower of water descending on the uppermost and the outermost is scattered over all their surfaces.

The gas, when thus separated from the condensed materials, is further passed through scrubbers or vessels containing coke moistened by the ammoniacal liquor, which, on being repeatedly used, becomes stronger and stronger, until it reaches saturation, when it may be run off into reservoirs, to be treated in the ordinary way for

a Now (December, 1882) building additional ovens.

b Partly from a paper read before the British Iron and Steel Institute by Mr. Henry Simon, and partly from Dr. Angus Smith's fourteenth and fifteenth reports under the alkali acts.

the preparation of ammoniacal compounds, or sold in its crude state for the manufacture of soda. All valuable by-products having thus been withdrawn from the gas, it is led by pipes to the nozzles at the fireplaces under the sole of the ovens, where it is burnt.

SIEMENS-CARVÈS OVEN.

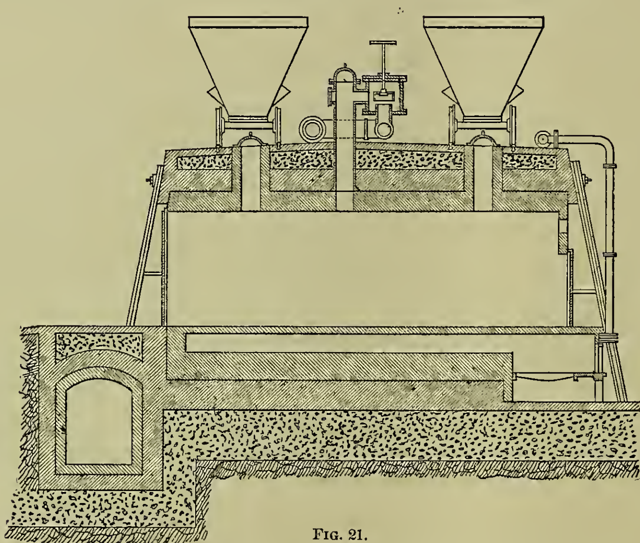

Fig. 21.

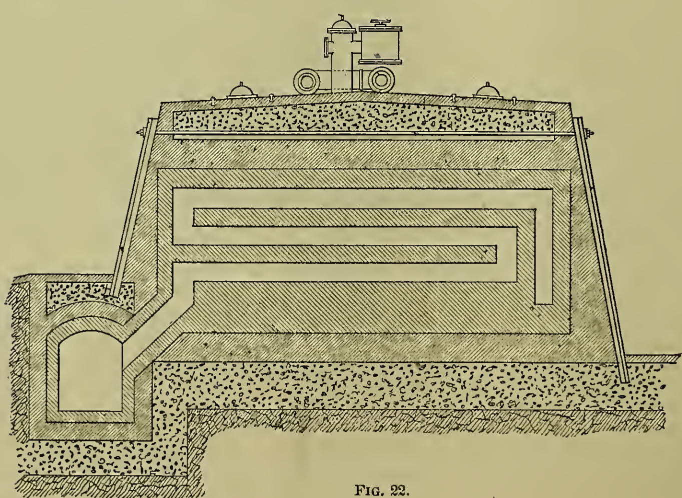

Fig. 22.

It has been found that the extraction of the gas from the ovens by artificial means (say a Beal's exhauster, similar to those used in gas-works) is more regular, and therefore preferable to extraction by the natural draught of the chimney only, as the latter varies often according to wind and temperature.

When a charge is nearly finished and ready to be taken from the oven some trucks full of coal are placed ready on the rails going along on the top of the ovens and over the charging-holes. The two end doors are then opened. The mass of coke, measuring about 30 feet long by 2 feet thick and 6 feet high, is pushed out at the

SIEMENS-CARVES OVEN.

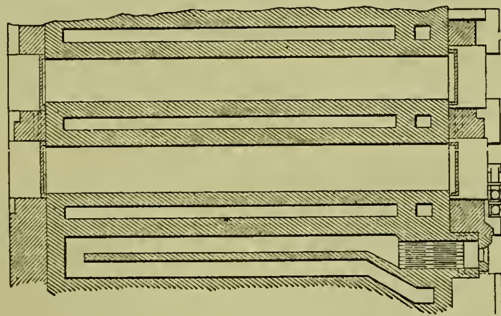

FIG. 23.

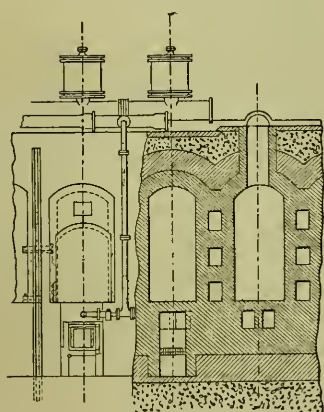

FIG. 24.

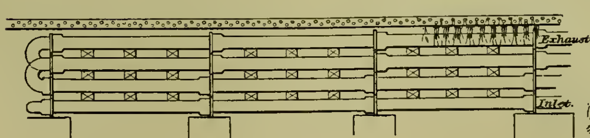

FIG. 25.

Fig. 6.

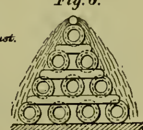

FIG. 26.

back of the oven and upon the bank by means of a ram or piston, worked by a portable steam-engine running on rails in front, and similar to the well-known arrangement used with the Coppée ovens. The ram can be brought opposite to each oven in turn. The coke is then quenched as usual.

Immediately after the discharge of an oven the tops are opened, and the coal from trucks emptied into the hot oven and raked level. The doors and top openings are then closed again, and the process begun afresh. The operations of discharging and refilling, when well conducted, need not take more than ten or fifteen minutes.

The Terrenoire Company, in France, originally introduced this process in the year 1867, and has since then, from time to time, increased the number of ovens at their different works; but their proportions and method of construction have, during these years, undergone continued and considerable alteration and improvement.

Experience has shown that a great deal depends upon the dimensions of the vertical sections of these ovens. At the outset they were made too wide and too low, and the density or hardness of the coke was, under such circumstances, not such as was desirable; but from a width of 6 feet 6 inches, they have been gradually reduced, until at present they are 2 feet only, with a height of at least 6 or 7 feet.

The effect upon the hardness of the coke by the reduction in width has been quite beneficial. M. Jouguet, the director of the Bessèges works of the Terrenoire Company, gives the following table, showing resistance to crushing of six different kinds of coke, experimented on by him in 1880:

[Resistance per square centimeter in kilograms.]

	Kilograms.
1. Coke from Carvès ovens of 70 centimeters width ($27\frac{9}{16}$ inches)	66.46
2. Coke from Carvès ovens of 66 centimeters width (26 inches)	79.72
3. Coke from Carvès ovens of 50 centimeters width ($19\frac{11}{16}$ inches)	92.32
4. Coke from bee-hive ovens of 50 centimeters width	43.92
5. Coke from Belgian ovens of 50 centimeters width	53.12
6. Coke from Coppée ovens of 50 centimeters width	80.50

Nos. 1 to 3 show clearly that the hardness of the coke increases as the width of the oven or the thickness of the layer of coal treated decreases.

The time required for each charge varies according to the description of coal and the dimensions of the oven. In ovens of a width of 2 feet a charge is finished every 48 hours; in ovens of a width of 3 feet 60 to 70 hours are required.

At the Bessèges works steam is produced to the extent of about 45 pounds and of $4\frac{1}{4}$ atmospheres pressure per hour and per ton of coal coked, and under more favorable circumstances it is thought 59 pounds of steam should be obtained. As at Bessèges 1,400 kilograms (3,080 pounds) of coal are carbonized per oven and per 24 hours, it follows that, taking about $17\frac{1}{2}$ pounds of steam as necessary to produce one horse-power per hour, each oven gives about $3\frac{2}{3}$ horse-power of motive power, and could be driven to about $4\frac{2}{3}$ horse-power. (*a*) At Bessèges all the machinery required in the manufacture of coke and its by-products is now being driven by steam raised in this way, and there remains a large surplus, which is used in the blowing-engines for the Bessemer process for lifting charges to furnaces, etc.

At Saint-Étienne, in France, coke was for many years made upon a somewhat similar system, but the manufacture was discontinued in favor of Carvès' system, which gives greatly superior results in every way.

There can be no doubt that much of the prejudice existing against these ovens and this system as the results of early trials was just. The latter results also seem to indicate that the disadvantages of the earlier ovens have been removed. The present increased heating surface of the ovens is the principal cause of this change for the better; for whereas in the first ovens the heating surface per ton of coal charged was only 18 square feet, and was applied exclusively under the sole of the oven, in the last ovens the heating surface per ton of coal charged amounts to about three times as much, namely, 54 feet, and surrounds almost entirely the charge of coal, which is much thinner than before.

The cost of ovens varies considerably, according to local circumstances. On solid ground much less expense is occasioned in foundations.

I annex a translation of the actual expense incurred in constructing the last battery of a hundred ovens at Terrenoire, which are each 19 feet $8\frac{3}{16}$ inches (6 meters) long, 2 feet 6 inches (0.73 meter) wide, and 5 feet 7 inches (1.70 meters) high. The length of the ovens but for local circumstances would have been greater, as thereby the power of production per oven is increased, with almost no increased expense of working. Each of these ovens takes a charge of 5 tons of coal, and produces at the rate of from 1,100 to 1,400 kilograms (22 to 28 hundred-weight) of coke per 24 hours, according to the quality of coal used and the quality of coke required. The time occupied by one operation with this size of oven is from 60 to 72 hours.

a Or, to express it more clearly, a battery of 100 ovens will furnish steam for about 400 horse-power over and above the making of the coke and the rendering of the by-products.

COST OF CONSTRUCTING ONE HUNDRED COKE OVENS ON THE CARVÈS SYSTEM AT TERRENOIRE, FRANCE.

[One cubic meter=1.3 cubic yard.]

Masonry.	Number of cubic meters.	Price per cubic meter.	Total.
1. Ovens complete, including flues:		*Francs.*	*Francs.*
Digging out foundation	660.87	2.00	1,321.75
Concrete	803.75	12.00	9,645.00
Rough stones	100.00	11.00	1,100.00
Red brick	1,828.82	25.00	45,720.50
Fire-brick	1,358.00	90.00	122,220.00
2. Discharging platforms:			
Digging out foundation	32.00	2.00	64.00
Rough stones	6.40	11.00	70.40
Dressed stone	6.40	60.00	384.00
Red brick	79.40	25.00	1,985.00
3. Four chimneys:			
Digging out foundation	94.01	2.00	188.00
Rough stones	77.10	11.00	848.10
Red brick	340.08	25.00	8,502.00
Fire-brick	16.28	90.00	1,465.20
4. Flues to Beal's exhauster, pumps, and condensing pipes:			
Digging out foundation	274.55	2.00	549.10
Rough stones	119.49	11.00	1,314.40
Red brick	28.45	25.00	711.25
5. Engine-house:			
Digging out foundation	277.81	2.00	555.60
Concrete	55.12	12.00	661.45
Rough stones	143.85	11.00	1,582.35
Red brick	18.72	25.00	468.00
6. Foundation for engine:			
Digging out foundation	54.93	2.00	109.85
Concrete	27.48	12.00	329.75
Red brick	18.59	25.00	464.75
Dressed stone	3.36	60.00	201.60
7. Foundations for Beal's extractors:			
Digging out foundation	3.70	2.00	7.40
Concrete	2.69	12.00	32.30
Rough stones	3.24	11.00	35.65
Dressed stone	1.60	60.00	96.00
8. Pump foundations:			
Digging out foundation	1.65	2.00	3.30
Concrete	1.65	12.00	19.80
Rough stones	3.04	11.00	33.45
Dressed stone	1.86	60.00	111.60
9. Masonry under engine floor:			
Rough stones	2.23	11.00	24.55
Red brick	3.03	25.00	75.75
10. Masonry for Field's boilers:			
Digging out foundation	88.34	2.00	176.70
Rough stones	27.78	11.00	305.60
Red brick	36.89	25.00	922.25
Fire-brick	11.11	90.00	999.90
11. Feed-water tank:			
Red brick	2.25	25.00	56.25
12. Scrubbers:			
Digging out foundation	17.01	2.00	34.00
Rough stones	26.47	11.00	291.15
Red brick	8.43	25.00	210.75
13. Settling tank:			
Digging out foundation	100.10	2.00	200.20
Rough stones	26.32	11.00	289.50
Red brick	1.75	25.00	43.75
14. Condensing tank:			
Digging out foundation	70.68	2.00	141.35
Rough stones	1.48	11.00	16.30
Red brick	0.68	25.00	17.00
15. Other tank:			
Digging out foundation	3.68	2.00	7.35
Rough stones	23.15	11.00	254.65
Red brick	1.71	25.00	42.75
16. Tar reservoir:			
Digging out foundation	3.67	2.00	7.35
Rough stones	11.04	11.00	121.45
Red brick	0.75	25.00	18.75
17. Tank for ammoniacal water:			
Digging out foundation	3.67	2.00	7.35
Rough stones	12.23	11.00	134.55
Red brick	0.75	25.00	18.75

Masonry.	Number of cubic meters.	Price per cubic meter.	Total.
18. Woodwork, etc., for engine-house:		*Francs.*	*Francs.*
Timber for house and shafting			800.00
Four windows and two doors			304.65
Painting			455.00
Glass			78.00
Tiles			208.00
Fixing			165.00

Railway lines, doors, and fittings.	Quantities.	Price per 100 kilograms.	Total.
19. Railway lines:	*Kilograms.*	*Francs.*	*Francs.*
Rails and chairs	10,780	25.00	2,695.00
Stone underchairs	15,050		210.00
20. Doors:			
Cast-iron	30,380	25.00	7,595.00
Wrought-iron	5,200	30.00	1,560.00
21. Fittings:			
Wrought-iron	33,334	30.00	10,000.20
22. Discharging-machine or ram:			
Machine for discharging coke from ovens.			12,000.00
Sleepers	120	7.00	840.00
Rails	12,100	25.00	3,025.00
Chairs	2,250	25.00	562.50
Laying lines and fixing machinery			415.00
23. Apparatus used in collecting the by-products:			
Pipes supporting the valve-boxes, cast-iron.	21,000	25.00	5,250.00
Pipes connecting the valve-boxes, cast-iron.	2,490	25.00	622.50
Valve-boxes with covers, cast-iron	19,000	25.00	4,750.00
Valves with rods and keys, cast-iron	1,000	25.00	250.00
Cocks, cast-iron	3,700	25.00	925.00
Nozzles, cast-iron	2,900	25.00	725.00
Furnace fronts and doors, cast-iron	35,700	25.00	8,925.00
Grate-bars, cast-iron	13,200	25.00	3,300.00
Plugs for top charging holes, cast-iron.	9,000	25.00	2,250.00
Gas exhaust pipes, cast-iron	11,500	25.00	2,875.00
Pipes conducting gas back under furnace, cast-iron.	9,000	25.00	2,250.00
Pipes receiving gas from the ovens, cast-iron.	28,000	25.00	7,000.00
Return gas-pipes to furnace, cast-iron.	8,000	25.00	2,000.00
One steam-engine, 15-inch cylinder, 31½-inch stroke.			15,000.00
Two field boilers, with fittings			8,000.00
Two pumps			2,000.00
Two Beal's extractors			5,000.00
Twelve scrubbers			12,234.15
One water-tank	420	50.00	210.00
Two safety-boxes, cast-iron	2,000	25.00	500.00
Two safety-boxes, cast-iron	1,400	25.00	350.00
Lead for joints	7,693	40.00	3,077.20
Six wrought-iron tanks, each 60 cubic meters capacity.	17,940	65.00	12,831.00
Pulleys, cone pulleys, bearings, gearing, and pinions for shafting, cast-iron.	2,547	100.00	2,547.00
Brass for bearings	230	4.50	1,035.00
Wrought-iron work for shafting	1,395	100.00	1,395.00
Eleven leather belts	297	8.00	2,376.00
Bolts	1,828	80.00	1,462.40
Pipes between furnaces and exhausters and *vice versa*, pipes for pumps, steam-pipes, feed-pipes, pipes for cooling water, etc., cast-iron.	62,000	25.00	15,500.00
Packing for joints, etc., sundry expense (oil, coal, felt, laces, etc.).			2,400.00
24. Scrubbers:			
Timber-framing	2.5 cub. m.	140.00	350.00
Quartz	151,600	7.00	1,061.20
25. Laying down of pipes forming integral parts of ovens and other apparatus.			9,800.00
26. Sundries			500.00
Total			384,884.30

The table shows altogether, say, about £15,500, or £155 per oven complete, with all machinery and apparatus for collecting the by-products, and including rail connections, coke platforms, etc.

The repairs of these ovens are—care and completeness in their first erection being presupposed—very low. At Terrenoire they are given as three halfpence per ton of coke, which will compare very favorably with those incurred in other systems. At Bessèges, where there is a lot of very old ovens, the cost of repairs, materials and labor included, stands now, according to the very exact accounts of M. Jouguet, at under fourpence per ton of coke made. The principal repairs are the renewal of fire-bricks over the grates in the sole of the ovens and the renewal of the cast-iron doors, which crack and break after a time. The last lot of ovens established at Bessèges, in August, 1878, had not in 1880 required the slightest repairs. Much, of course, depends upon the temperature employed during the process, which, in its turn, depends upon the kind of coal coked and the dimensions of the ovens. Narrower ovens, with more rapid carbonization, are subject to higher temperatures, and consequently to greater extremes of temperature and liability to injury. Experience goes to show that after the first two years or so each oven may on an average lose one or two days a year through repairs. It will therefore be seen that although the original cost of the ovens is large, the outlay for repairs is very much smaller than in the bee-hive and others.

At Terrenoire the number of work-people employed on a battery of 100 ovens, producing over 100 tons of coke per day, is 48 per 24 hours. This includes 2 foremen and 2 masons for repairs. Their wages are 184½ francs, or, say, £7 10*s.* per day, being at the rate of, say, 1*s.* 6*d.* per ton of coke for labor.

On the other hand, the cost of producing the coke is given by M. Jouguet, of Bessèges, as about 3 francs, or, say, under 2*s.* 6*d.* per ton, including all labor and materials and the cost of repairs.

Mr. Simon claims the following advantages for these ovens, viz:

1. Greater yield of coke by about 10 per cent.
2. Greater purity of coke.
3. A yield of about 4*s.* worth of useful by-products per ton of coke.
4. An almost entire absence of smoke or noxious vapors.
5. In comparison with any other existing system of coke-ovens, equal facilities for utilizing the heat, and a reduced cost for repairs.

The following table shows the results obtained by the ovens at Bessèges during the last twelve years, and up to the end of 1879: (*a*)

AVERAGE RESULTS OF OVENS ON THE CARVÈS SYSTEM AT THE BESSÈGES WORKS OF THE TERRENOIRE COMPANY.

	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.
Coal consumed..........tons..	4,849	14,329	14,641	13,886	14,632	14,215	26,998	30,057	35,451	45,331	44,754	41,797	46,300
Number of coke ovens..........	25	25	25	25	25	25	53	53	(*)	85	85	(†)	96
Coke produced..........tons..	3,075	9,054	9,575	9,272	9,760	9,297	18,820	20,763	24,462	31,720	31,065	29,166	33,092
Production of coke per oven and per year..........do....	120	365	385	375	330	375	355	390	386	373	365	355	344
Tar obtained..........do....	74	263	296	327	267	228	458	562	585	778	766	851	1,099
Ammoniacal liquor obtained..........do....	60	1,073	1,120	1,113	979	794	1,683	3,256	3,214	4,459	4,396	3,995	4,393
Sulphate of ammonia made‡..........do....	....	56	60	50	46	42	67	113	97	158	172	122	....
Yield of coke according to books..........per cent..	63.5	63.2	65.3	66.7	66.7	65.2	69.7	69.0	69.0	69.9	69.4	69.8	70.5
Yield of coke after deduction of water contained in washed coal, per cent.	67.2	67.2	69.8	69.8	70.5	69.5	73.0	73.0	73.4	74.4	73.8	74.2	§ 75
Tar per ton of coal..........kilograms..	15.6	17.6	20.0	17.0	18.3	16.0	17.0	18.6	16.5	17.1	17.1	20.4	23.4
Tar per ton of coke..........do....	24.3	29.0	30.0	25.0	27.4	24.7	25.7	27.1	24.0	24.5	24.7	29.2	33.2
Ammoniacal liquor per ton of coal..........do....	....	75.8	76.0	73.0	66.9	55.7	62.5	108.5	91.0	98.3	98.2	95.6	93.6
Ammoniacal liquor per ton of coke..........do....	....	118.0	117.0	109.0	100.4	85.5	94.1	157.0	132.0	140.6	141.8	137.0	132.7
Small fuel consumed under grates per ton of coke made, kilograms.	....	46.0	28.0	16.0	17.0	18.6	20.3	21.4	22.7	11.5	11.0	15.2	15.9

* During the first eight months of 1875, 53 ovens were at work. During the last four months of 1875, 85 ovens were at work.

† During the first four months of 1878, 85 ovens were at work. During the second four months of 1878, 53 ovens were at work; during the last four months of 1878 96 ovens were at work.

‡ The making of sulphate of ammonia was given over in December, 1878; since then the ammoniacal liquor is sold direct.

§ Yield calculated after deduction of the water contained in the coke as well as of that contained in the coal after it is washed.

In all industries the subject of waste is a most important one, and in many the profit of to-day is from the waste of ten years ago, which better methods have saved. Our resources of coal to-day may be enormous, and the need of economy not apparent, but every waste of these resources is the act of a spendthrift. Dr. Angus Smith says in one of his yearly reports that "the present method of making coke in England has all the appearance of roughness and savagery which extravagance always produces". He might extend the charge to coking in this country.

a There were at the close of 1882 three works in France using the Carvès system—Tamaris, Terrenoire, and Bessèges. The total amount of coke produced by this system at these works is about 300 tons per day.

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REPORT

ON

THE BUILDING STONES

OF THE

UNITED STATES,

AND

STATISTICS OF THE QUARRY INDUSTRY

FOR 1880.

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LIST OF ILLUSTRATIONS.

* Plate LV: for *Maryland*, read "Missouri".

LETTER OF TRANSMITTAL.

WASHINGTON, D. C., *February* 19, 1883.

Hon. CHARLES W. SEATON, *Superintendent of Census.*

SIR: In accordance with your request, I have examined and revised the following report upon the building stones and quarry industries of the United States.

This work was undertaken jointly by the Census Office and the National Museum, and placed in charge of the late Dr. George W. Hawes, then curator of the department of mineralogy and lithology in the National Museum.

The work as planned by him comprised the collection of very full and complete statistics from all quarries in the United States doing business during the census year to the extent of $1,000, and the making of a collection of quarry specimens for examination for the purpose of this report and for deposit in the National Museum as a reference collection. These plans contemplated also a thorough study of the building stones with reference to their hardness, durability, beauty, chemical composition, microscopic structure, and geological relations. Dr. Hawes lived long enough to see his plans well under way, the collection practically completed, and much of the microscopic and chemical work done. His health failed in the fall of 1881, and he was obliged to give up work, when his principal assistant, Mr. F. W. Sperr, was placed in temporary charge. Dr. Hawes' health continued to fail, and at last, on June 22, 1882, he died, at Colorado Springs, Colorado.

Not long after, Mr. Sperr's health failed, and he was obliged to give up the control of the work, when it was left in charge of Mr. Thomas C. Kelly, by whom it was brought to its present stage.

As assistants in the field-work of this investigation Dr. Hawes enlisted the services of many of the most prominent geologists and mineralogists of the country, and to them is due in great measure whatever success may have been attained in this investigation. They have devoted to it much valuable time and attention, and in every way have shown the utmost interest in prosecuting it thoroughly. Many of these gentlemen have also rendered valuable services in furnishing manuscript notes regarding the quarries of their respective districts, which, from the local knowledge of the author, is of great value. The statistics and the information concerning the quarries were gathered by the following gentlemen in the areas indicated:

In Maine, Rhode Island, and that portion of Massachusetts east of the Connecticut river, Professor N. S. Shaler, of Harvard university, Cambridge, Massachusetts.

In New Hampshire, Vermont, and that portion of Massachusetts west of the Connecticut river, and of New York east of the Hudson and above the latitude of the north line of Connecticut, Professor C. H. Hitchcock, of Dartmouth college, Hanover, New Hampshire.

In Connecticut, and New York east of the Hudson and south of the latitude of the north line of Connecticut, Mr. Harrison R. Lindsley, of New Haven, Connecticut.

In Manhattan Island and cities in the immediate vicinity of New York, Professor Alexis A. Julien, of the School of Mines, Columbia college, New York city.

In the portion of New York west of the Hudson, and New Jersey outside of the immediate neighborhood of New York, Professors George H. Cook, director of the geological survey of New Jersey, and James C. Smock, of New Brunswick, New Jersey.

In Pennsylvania, Mr. Charles Allen, of Harrisburg, Professor J. P. Lesley, state geologist, and Messrs. Ashburner, Lehman, D'Invilliers, and other members of the second geological survey of that state, and Messrs. F. W. Sperr and Thomas C. Kelly.

In Maryland, Delaware, and Virginia, Professor J. H. Huntington, Boston, Massachusetts, Professor Charles E. Munroe, United States Naval Academy, and Mr. H. K. Singleton, of Mississippi.

In Ohio and Indiana, Professor Edward Orton, Columbus, Ohio.

In Kentucky, Professor J. R. Procter, state geologist, Frankfort, Kentucky.

In Michigan, Wisconsin, and Illinois, Professor Allen D. Conover, Madison, Wisconsin.

In Minnesota, Iowa, and Dakota, Professor N. H. Winchell, state geologist of Minnesota, Minneapolis, Minnesota, and Mr. W. J. McGee, Farley, Iowa.

In Missouri and Kansas, Professor G. C. Brodhead, state geologist of Missouri, Pleasant Hill, Missouri.

The statistics in the southern states were collected by Mr. Henry E. Cotton and Dr. A. Gattinger, of Nashville, Tennessee, and those of the west by Mr. William Foster, of Denver, Colorado.

A number of assistants, who also rendered much valuable service, was employed by the gentlemen above mentioned. In addition to the above list of regular assistants upon this work, a great many persons aided in extending the scope of the work, especially by bringing to notice some of the great undeveloped resources of the country.

The unfortunate death of Dr. Hawes necessitated a considerable change in the character of the report. It became necessary to curtail what might be called the scientific portion, that relating more purely to lithology, thus giving greater relative prominence to the economic side of the subject. With this exception the original plans of Dr. Hawes have been carried out as far as possible.

The following is a sketch of the topics under which the report is arranged:

Following the introduction, which consists of the discussion of general matters relating to the subject, are tables showing the number of quarries, the capital invested in them, product in the census year, and its value, and other details regarding labor, means of transportation, etc. These tables are given by states and by general classes of rocks, and form a general exhibit of the extent of the quarry business in the country. The quarries of each state which is of importance in this respect are then taken up in detail, the general facts regarding the individual quarries being given in tabular form, with location, kind of rock, structure, quality, color, geological formation, etc. Descriptive text follows each table, and is intended to fill out and complete the matter in the tables in such a way as to give the details which are desirable to be known regarding the quarries of importance. Then follow a description of the use of stone in most of the principal cities of the country, the extent to which it is employed, the kinds of stone principally used, and other matters of importance connected with this subject. This description is accompanied by a table showing the proportion of stone buildings in each city, the class of stones principally used, and their sources, and the stone employed for foundations, pavements, etc. A short table of exports and imports of stone and a brief discussion of a few notable foreign ornamental stones close the report.

In the following report it will be observed that a comparatively small portion of the work bears the name of Dr. Hawes as author, but the amount of this matter must not be taken as in any way the measure of the share which he had in the work. Not only are the inception and plan of the entire work due to him, but a large proportion of the material from which this manuscript was made was collated and drafted roughly by him, though not put in shape for publication. He plowed, sowed, and cultivated that others might reap.

The chemical work of the report and the classification of the limestones were done by Mr. F. P. Dewey, of the Smithsonian Institution, and his report upon the general methods employed by him is included in the introductory matter.

The microscopic examination of the rocks commenced by Dr. Hawes was completed by Mr. G. P. Merrill, of the Smithsonian Institution, and his report upon this subject also is included in the introductory matter.

The illustrations of polished rock surfaces, representing some of our most beautiful and serviceable rocks, were drawn in water color by Mr. Henry J. Morgan.

The chapter upon methods of quarrying, machines, and tools used in such operations was prepared by Mr. F. W. Sperr.

The great bulk of the text, consisting of descriptions of the quarry regions and individual quarries, and of the use of stone in construction in the principal cities of the country, was in the main compiled by Messrs. Sperr and

Kelly from descriptive notes furnished by the different special agents enumerated above. The degree of fullness of these notes depends, therefore, not so much upon the importance of the quarry industries in the different districts as upon the extent of the descriptive matter furnished by the different special agents; and it is doubtless true that undue prominence has on this account been given to certain regions. For example, the quarries of the state of Ohio have been described in great fullness of detail, while the marbles of Tennessee receive but a passing mention. It does not, however, appear to be advisable to throw away a large part of this information for the mere sake of producing uniformity.

The notes of Professor Shaler regarding his district are so full and elaborate that it has been thought best to present them, with little change, over his own name. The same is the case with those for Illinois, Wisconsin, and Michigan, by Professor Conover; for Iowa, by Mr. W. J. McGee, and a portion of the notes concerning Missouri, by Professor Brodhead, the state geologist.

In the chapter upon stone construction in cities New York city is treated exhaustively by Professor A. A. Julien, who in addition to this furnished a paper on the very important subject of the durability of the building stones in actual use in the country.

It should be borne in mind that the statistical tables deal in general only with quarries which produced during the census year to the value of $1,000 or upward. This excludes not only a large number of small quarries, but also many which have in years past produced very extensively, but which were worked little or not at all during the census year.

Nearly all the quarries of the southern states, with the exception of the marble quarries of Tennessee, fall within one or the other of these classes. For instance, out of a large number of quarries in North Carolina, scarcely one, under the above definition, should be represented in the tables.

In this portion of the country this industry is yet in its infancy. The slight demand for stone in construction, owing to the relative cheapness of other building material, especially wood, and the fact that the region contains but a small urban population, have combined to delay its development, and to-day the south is but beginning to realize its immense resources of this kind.

The reader will doubtless find in the text, and especially in that portion relating to stone construction in cities, many references to quarries which are not represented in the tables. These apparent omissions, in the majority of cases, fall into one or the other of the above classes of intentional omissions, that is, of quarries whose importance is not sufficiently great to give them place in the statistical tables, or where the quarries, although large and important, are worked spasmodically, as occasion requires, and were not worked extensively during the census year. Still, as this is practically the first attempt which has ever been made to obtain the statistics of this industry, it is very possible that some important quarries have escaped notice, although every precaution for obtaining completeness which had suggested itself to those having the matter in charge was taken. Wherever practicable, the local knowledge of the state geologists, and of others more or less directly interested in this industry, was utilized, and it is believed that, under the circumstances, the omissions have been reduced to as small a quantity as possible.

Very respectfully, yours,

HENRY GANNETT,

Geographer and Special Agent Tenth Census.

THE BUILDING STONES OF THE UNITED STATES AND STATISTICS OF THE QUARRY INDUSTRY.

CHAPTER I.—INTRODUCTION.

BY DR. GEORGE W. HAWES.

Materials for building may be divided into two classes, natural and artificial. Of the former class may be mentioned, as the principal members, wood and stone, and of the latter class, brick, artificial stone, and iron. The industry of extracting stone for building purposes has been, for convenience in this report, denominated the quarry industry. This term is not accurately descriptive, since all the materials extracted from quarries or open mines are not here described. Coal, metallic ores, limestone when quarried for lime or for fertilizing, and phosphate of lime when quarried for the latter purpose, may be noted as exceptions.

The importance of this investigation will be recognized when it is known that the subject has received little or no attention heretofore in this country, although immense sums are spent annually upon stone as a material in construction.

The first, and indeed the only attempt, so far as known, to bring into notice our resources in building stone was made at the late centennial exposition at Philadelphia, when a general invitation was sent to quarrymen to forward specimens for exhibition. This was generally responded to, and a beautiful collection was the result; but it was by no means exhaustive or representtive, inasmuch as it was a purely voluntary collection.

Many experiments upon the strength of building stone have been made, notably by the officers of the United states engineer corps, and the results, published only in a fragmentary way, are more or less inaccessible. Strength, however, is but one of the factors which determine the relative value of the stone. The factor, primarily, is its accessibility, as the most valuable stone is of but little use for extensive building operations if far from water or railroad transportation. Next in importance is its durability, as well as its capability of resisting climatic influences; and this is a subject upon which very little has been said or written. It is a subject upon which it is extremely difficult to experiment, and yet in this respect it is most desirable that we should possess information. Such knowledge can be gained only by experience, and in many cases dearly-bought experience, and it is therefore important that all facts relating to the durability of stone under the influences of climate should be collated and brought into juxtaposition with one another.

THE COLLECTION.

The considerations already advanced show the desirability, in connection with a work of this kind, of making a systematic collection of specimens of building stones. The popular names given to building stones vary in different parts of the country, and the same name is in some cases applied to most diverse materials. Such words as granite, trap, blue-stone, flag-stone, etc., do not designate stones in such a manner as to enable one to judge of their appearance or characteristics, and, beyond its necessity for purposes of classification, a collection is of such value to architects and builders as to justify its accumulation at government expense. At the centennial exhibition in Philadelphia in 1876 many of our best stones were placed in direct comparison with those from foreign countries, and visitors were surprised to find that our country possessed materials for which we have been in the habit of looking to other lands. This collection was made the subject of a report by Professor J. F. Newberry, of the School of Mines, Columbia College, New York city, which report forms one of the most prominent contributions to the literature upon the general resources of the country in stone.

This collection, however, did not claim to be either systematic or complete. The Census Office has aimed at system and uniformity in the collection and treatment of specimens, in order to insure fair comparison. The size of the specimens was determined by such considerations, it having been the intention that every quarry of importance in the country should be represented in the collection by a cube with edges four inches long. These specimens are dressed in the following manner:

Polished in front.

Drafted and pointed on the left-hand side.

Drafted with rock-face upon the right-hand side.

Entirely rough behind.

Rubbed or chiseled upon top and bottom.

The aim has been to show the appearances of the stone when subjected to such treatment as it will receive when applied to construction and ornamentation. The polished surfaces render prominent many peculiarities of structure and composition which are not evident upon rough surfaces. The only modification that has been allowed has been in the treatment of the front face, which, when incapable of being polished, has received the highest finish which it can be made to receive.

The specimens are of such size as to admit of easy handling and close examination, and are easily accessible to all interested in their study and comparison. The centennial collection has been united with these, and the whole forms one of the attractive features of the National Museum in Washington.

A number of treatises upon building material have been issued in European countries, and the crudeness of their statements concerning the quarries of America is most striking when one notes the size of this collection and the diversity of its specimens. The statements, however, are not to be wondered at, since the authors have had little accessible American literature. It might, however, be assumed that a country of this extent, possessing so great diversities in physical features, would possess a great variety of building stones.

It may be said in general that at this stage of the development of the stone industry in the country there are few quarries which do not produce material possessing something or other to recommend them and to give them an excuse for existing. This can scarcely be otherwise in a land which possesses such an immensity of undeveloped resources in stones of the finest quality.

The collection, however, brings one thing most prominently forward, and that is that at the very doors of buildings constructed of stones brought from great distances materials equal or superior are often found. The lack of confidence in home resources has very frequently caused stones of demonstrated good quality to be carried far and wide, and frequently to be laid down upon the outcropping ledges of material in every way their equal. Development of local resources follows in the wake of good information concerning them, for the lack of confidence in home products cannot be attributed to prejudice. The first stone house erected in San Francisco, for example, was built of stone brought from China, and at the present day the granites mostly employed there are brought from New England or from Scotland. Yet we have no stones in our collection possessing more qualities to recommend them than California granites.

Some of the results of this general ignorance of the resources that this country affords in the way of building stones is shown by the use of stones brought from the Atlantic sea-board in the public buildings of the Mississippi valley. Some of the prominent public and private buildings in Cincinnati, for instance, are constructed of stone that was carried by water and railway a distance of about 1,500 miles. Within 150 miles of Cincinnati, in the sub-Carboniferous limestone district of Kentucky, there are very extensive deposits of dolomitic limestone that afford a beautiful building stone, which can be quarried at no more expense than that of the granite of Maine. Moreover, this dolomite is easily carved; it requires not more than one-third the labor to give it a surface that is needed by granite. Experience has shown that the endurance of this stone under the influences of weather is very great. A building in Bowling Green, Kentucky, which has been standing over forty years, retains the chisel marks with all the clearness they had the day they were made. Yet, because of the want of some authority of an absolute sort, the fear to use this stone has so far kept it from finding a market and has led to the transportation of stone half-way across the continent.

In all other mining industries the product shows the fitness for its use almost at the moment of its production, so that, if the government secures the exercise of proper precaution in the carrying on of the work, the character of the products may be left to be determined by the laws of trade. But in building stones there is always the question of endurance under the action of the weather, which cannot be determined in any easy way. The external aspect of the stone may fail to give any clue to it; nor can all the tests we yet know determine to a certainty in the laboratory just how a given rock will withstand the tests of absorption of our own variable climate and the gases of our cities. The cities of northern Europe are full of failures in the stones of important structures. The most costly building erected in modern times, perhaps the most costly edifice reared since the great pyramid, the parliament-house in London, was built cf a stone taken on the recommendation of a committee representing the best scientific and technical skill of Great Britain. The stone selected was submitted to various tests, but the corroding influence of a London atmosphere was overlooked. The great structure was built, and now it seems questionable whether it can be made to endure as long as a timber building would stand, so great is the effect of the gases of the atmosphere upon the rock. This is only one of the numerous instances that might be cited in which a neglect to consider the climatic conditions of a particular locality in selecting a building material has proved disastrous. Stones having a high ratio of absorption, or which absorb water readily, are not likely to be durable in a climate subject to alternations of dampness and hard freezing; and, as before mentioned, the acid atmosphere of manufacturing cities is injurious to stones made up largely of carbonate of lime. Professor Hull, in his work on the building and ornamental stones of Great Britain and foreign countries, gives the following as the most instructive examples of "buildings in Great Britain of limestones and dolomites which have shown disintegration from the influence of rain charged with acid: Saint Mary's, Redcliffe, in Bristol; the new houses of parliament, and the chapel of Henry VIII in Westminster Abbey. The first is built of oolitic limestone, the second of dolomite, the third of Caen stone, the white limestone of Normandy, of Jurassic age". Professor Hull states further that the presence in humid or wet climates of smoke, or sulphurous, hydrochloric, and other acids, powerfully aids the destructive effects of rain or moisture, as the rain itself takes a considerable amount of the acid from the air and spreads it over the exposed surfaces of the buildings; and that, therefore, for such climates limestone of especially soft, granular, and porous kinds should as far as possible be avoided; also, sandstones which contain a notable percentage of calcareous matter in the form of cement should not be used.

Some of the "black granite" or diabase rocks of New England decay rapidly when exposed to the weather, yet they are, in appearance, of enduring quality.

In a communication to the Census Bureau, Professor N. S. Shaler, of Cambridge, Massachusetts, says:

A few years ago I found the stone from one of these diabase quarries being used for the foundations of the most costly buildings ever erected by Harvard college. A century of exposure would be sure to convert a large part of the faces of these foundation stones into dry sand. It was by a mere chance that I was able to make an effective protest against its use in this building. I know that it has been used in scores of other buildings in the same region.

There are many other stones in use in this country that are open to the same objections; they are fair looking, but have not the necessary endurance, under certain atmospheric conditions, which makes them fatal elements of weakness in any architectural work of importance.

It is not possible for the architect or the builder to make tests and accumulate information concerning the particular qualities of this or that stone; nor is it possible for any association such as the national societies of architects to do justice to the problem. The result is that it is very hard to bring a new quarry stone into use unless it is essentially like some of those already extensively employed. No one builder is willing to assume the risk that may come from the experiment, especially when he is not likely to have the profit that may arise from the use of the cheaper stone. There can be no question that in this way we are debarred from the use of many of the best and cheapest building stones that the country affords. Professor Shaler advises substantially the following plan:

In proposing to myself a method whereby a source of necessary information concerning the building stones of the country may be established, I have taken care to make the element of interference on the part of the state as small as possible. It seems to me that the following plan may serve to accomplish the end in view without undue expenditure or overregulation. There should in the first place be a national collection of building stones whereat the architect may be able to see a sufficient representation of all the building stones the country affords.

The admirable system followed by the Tenth Census has already accumulated at Washington an excellent foundation for such a collection. By the simple plan of having large specimens of the stones heretofore used in all public buildings added to this collection, and further by letting it be known that architects would confer a favor by submitting specimens of the stone used by them, a very valuable collection could be accumulated. In addition to this interior cabinet there should be an open-air collection designed to show the effects of weathering upon the various classes of building materials. This collection would necessarily occupy a good deal of ground, for in many cases several courses of stone, one on top of the other, would be necessary to show the full effect of weathering. The attitude of the wall with reference to the sun, frost, etc., is a matter of importance. It should also include water-cement, roofing materials, and various forms of terra-cotta, from common brick to decorative work. In fact such a collection should be essentially an experimental station on construction materials.

With the view of accomplishing more perfectly the large purposes that could only be accomplished by such a museum, I would suggest that the whole matter of strength of materials used in public edifices should be placed in the control of its superintendent; and that, on the payment of a small fee, the laboratory connected with the museum might examine into the composition and character of building material submitted to it. Each subsequent decennial census will give a chance to revise and extend the researches of this museum.

In addition to the ordinary specimens of building stones, quarry-owners were invited to represent their material in the National Museum by a larger specimen, dressed by themselves and forwarded at their own expense. To this invitation many quarrymen have responded by sending dressed foot cubes or slabs, pedestals, etc., many of which are very beautiful. We have not allowed the prominence thus given to individual quarries to modify or prejudice our opinion of the material. No injustice has thus been done, as no effort was made to gather these blocks, and any one had, and still has, the opportunity, if he wishes, to supplement his exhibition with such blocks. Our 4-inch cubes are, however, to us the most satisfactory specimens, as showing the nature of the material and forming a systematic collection which it would be impracticable to attempt to make of larger blocks.

One of the large halls in the National Museum at Washington has been set apart for the exhibition of this census collection of building and ornamental stones, and no trouble has been spared by the authorities in the attempt to show each specimen to the best advantage. They are placed in glass cases, in front of a suitable background; each rests on a block, and a card designating the stone and the features of particular interest in connection with it is tacked upon this block, where it can be easily read.

The centennial collection before mentioned, or so much of it as was presented to the Smithsonian Institution, is placed in the hall. The addition which it has made to the census collection is mostly composed of foreign stones.

The supervising architect of the treasury, Mr. Hill, has also kindly given a large portion of the collection which has accumulated in his office, to be used in the study and in supplementing the collection.

THE MINERALS IN BUILDING STONES.

A stone is of little consequence for purposes of construction unless it exists in large quantities, and therefore the principal constituents are the commonest of minerals and few in number. Microscopic examination increases the number of the species quite considerably, and at times those present in smallest amount are of great importance in the determination of economic properties. As these minerals are sufficiently described in any mineralogical treatise, it is only necessary to mention the names of those which occur in building stones.

The mineral compositions of stones are much simplified by the wide range of conditions under which the commonest minerals can be found, thus allowing their presence in all classes of rocks. Thus quartz, feldspar, mica, hornblende, and pyroxene can be found in a mass cooling from a state of fusion; they can be crystallized from solution, or be formed from volatilized products. They are, therefore, excluded from no classes of rocks, since there is no process of rock formation which determines their absence.

Most of the commonest minerals, like feldspar, mica, hornblende, pyroxene, and the alkaline carbonates, possess also the capacity of adapting themselves to a wide range of compositions. Feldspar, for example, can take more or less silica, lime, soda, or potash into its composition. Hornblende and pyroxene may be pure silicates of lime and magnesia, or iron and manganese may take the place of a portion of these bases. Lime carbonate may be very pure, or magnesia may take the place of any proportion of the lime.

These considerations indicate the reason of the extreme simplicity of rocks as regards their chief constituents, and that whatever may be the composition of a mass within the limits which nature allows, and whatever may be the conditions of its origin, the probabilities are that it will be essentially formed of one or more of a half dozen minerals in some of their varieties.

But however great may be the adaptability of these few minerals, they still are subject to very definite laws of chemical equivalence; there are elements which they cannot take into their composition, and there are circumstances which retard their formation while other minerals are crystallizing. Therefore, in a mass of more or less accidental composition, other minerals may always be expected to form in considerable numbers and minute quantity.

For convenience we may therefore divide the minerals into two groups: the first to contain those minerals with their varieties which compose the mass of rocks, and any one of which may be the chief ingredient of a rock; and the second to contain those which never compose the mass of a building stone, and are, when present at all, usually present in small amount.

The following is a list of the mineral constituents of most building stones:

1. Quartz.
2. Feldspar.
   - 2*a*. Orthoclase.
   - 2*b*. Microcline.
   - 2*c*. Albite.
   - 2*d*. Anorthite.
   - 2*e*. Labradorite.
   - 2*f*. Andesite.
   - 2*g*. Oligoclase.
   - 2*h*. Triclinic feldspar (undetermined species).
3. Mica.
   - 3*a*. Muscovite.
   - 3*b*. Biotite.
   - 3*c*. Phlogopite.
   - 3*d*. Lepidolite.
4. Amphibole or hornblende.
   - 4*a*. Tremolite.
   - 4*b*. Actinolite.
   - 4*c*. Common hornblende.
5. Pyroxene.
   - 5*a*. Malacolite.
   - 5*b*. Sahlite.
   - 5*c*. Diallage.
   - 5*d*. Augite.
6. Calcite.
7. Dolomite.
8. Serpentine.
9. Talc.

ELEMENTS.

10. Iron.
11. Copper.
12. Carbon.
13. Graphite.

SULPHIDES.

14. Galenite. (Lead glance.)
15. Sphalerite. (Zinc-blende.)
16. Pyrrhotite. (Magnetic pyrites.)
17. Pyrite. (Pyrites.)
18. Chalcopyrite. (Copper pyrites.)
19. Marcasite. (White pyrites.)
20. Arsenopyrite. (Mispickel, or arsenical pyrites.)

CHLORIDE.

21. Halite. (Common salt.)

FLUORIDE.

22. Fluorite. (Fluor-spar.)

OXIDES.

23. Tridymite.
24. Opal.
25. Corundum. (Emery.)
26. Hematite. (Specular iron.)
27. Menaccanite. (Titanic iron.)
28. Magnetite. (Magnetic iron.)
29. Chromite. (Chromic iron.)

OXIDES—continued.

30. Limonite. (Hydrous iron oxide, rust.)
31. Spinel.
32. Rutile.
33. Pyrolusite. (Manganese binoxide.)

ANHYDROUS SILICATES.

34. Enstatite.
35. Hypersthene.
36. Acmite.
37. Glaucophane.
38. Beryl.
39. Chrysolite. (Olivine.)
40. Danalite.
41. Garnet.
42. Zircon.
43. Epidote.
44. Allanite.
45. Zoisite.
46. Iolite. (Cordierite.)
47. Scapolite.
48. Elacolite.
49. Sodalite.
50. Cancrinite.
51. Chondrodite.
52. Tourmaline.
53. Andalusite.
54. Fibrolite.
55. Cyanite.
56. Topaz.
57. Datolite.
58. Titanite. (Sphene.)
59. Staurolite.

HYDROUS SILICATES.

60. Petalite.
61. Laumontite.
62. Prehnite.
63. Thomsonite.
64. Natrolite.
65. Analcite.
66. Chabazite.
67. Stilbite.
68. Heulandite.
69. Harmotome.
70. Kaolin.
71. Chlorite.
71*a*. Jeffersonite.
72. Ripidolite.
73. Penninite.
74. Prochlorite.

PHOSPHATE.

75. Apatite.

SULPHATE.

76. Gypsum.

CARBONATES.

77. Ankerite.
78. Siderite.
79. Rhodochrosite.
80. Aragonite.
81. Malachite.
82. Azurite.

METHODS OF STUDY.

The methods usually applied to the study of building materials are eminently practical. The required qualities of good stones are well understood, and direct processes are employed in order to ascertain the strength, hardness, and durability. Experience most of all has aided in the development of knowledge, and this sometimes has been gained at great expense. Though the results of actual practice are the final criterions, they are too slowly gained, and hence scientific and practical study can be combined to the advantage of those using stone.

On the other hand, the application of scientific methods to economic problems, while bringing the later results of study into the domain of daily life, has never been carefully performed without incidentally developing some things of interest and value to science. There are no absolute rules to lay down by which stones are to be judged, however simply such are recorded in the text-books.

Stones which have lain in the quarry for years, and which show the effects which time can produce, are usually inferior specimens that have been rejected, and quarries which have produced bad materials may also subsequently produce the best, and *vice versa.*

The methods which have been employed in the study of compositions and structures are, however, such as require some explanation.

The purposes of the work demand a determination of the compositions and structures of the various rocks, as these in combination with the location and geological features determine the applicability of the stones and explain their peculiar properties. The microscopic examination of thin sections leads most directly to the desired results. This method of study in the hands of the microscopic lithologist has been most fruitful in developing valuable and interesting knowledge of a scientific character. By its means the nature and the composition of almost all of the commonly-occurring rocks have been determined, and geological progress in later years has been modified and directed to a certain extent by the results of microscopic study. Exactly those same features which are of importance in scientific study are the ones which determine the value and appearance of building stones; and there is no distinction between the scientific and the practical.

The method will here be described with the least detail that will render the accompanying plates comprehensible to those who are interested in the results but unacquainted with the method. Any who wish to apply the method will seek fuller information in the treatises devoted to the subject.

A thin fragment of stone with a circumference equal to that of a silver quarter-dollar is knocked from the larger block with a hammer or a pitching-tool; or when difficulties are encountered in obtaining thus a favorable piece, the same is sawed off from the block with a diamond saw. When a flat, smooth surface has been ground upon one side of this chip, and which reaches the outer circumference of it at every point, the chip is glued firmly upon a slide of glass, by means of hot Canada balsam, in such a way that the new, smooth surface is very nearly in contact with the glass. The Canada balsam hardens on cooling, and the stone will adhere to the glass with great tenacity. The glass slide thus furnishes a support, by means of which the stone can be held in contact with a revolving disk supplied with wet emery, and ground away on the other side until it becomes thin and transparent. By means of graded emery the stone is reduced to a very thin film; a good section being less than one-thousandth of an inch in thickness; and under this treatment even the most opaque stones which are employed for building purposes become transparent. It will be seen that in a section thus prepared the film which remains is composed of sections through the components of the rock, and that its grains or crystals have been undisturbed. An examination of the section by means of the microscope will show not merely the various substances which compose it, but also the method according to which they are arranged and by which they are attached to one another. With a magnifying power the minutest inclusions can be recognized, and by the application of optical methods the ingredients can all be determined. It is found that the stones which we ordinarily employ are much more complex in composition than once was thought, and the minerals which compose the stones are frequently different from what would be supposed by examination with the unaided eye. For the improvement and preservation of the section it is usually transferred to a new, clean slide, and covered with a thin film of glass, which is firmly fixed by gluing with Canada balsam.

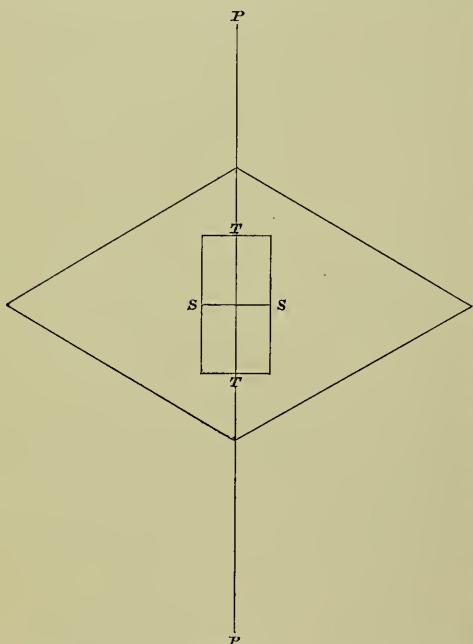

FIG. 1.

The examination of thin sections has been found most useful to botanists, zoologists, and pathologists, who have long employed the method for most important examinations. The method was recommended to the mineralogists by Cordier in 1816, but neither chemical nor optical methods were then enough advanced to render its use practicable. Thin sections were made by Mr. H. Whitham in 1831, when studying the microscopic structures of fossil plants, which necessitated making thin sections of materials practically according to the method described. Mr. H. C. Sorby first applied the microscope to lithology, and discovered many facts. Since that time a score of lithologists have occupied their time in cutting sections of all possible stones, and have developed a knowledge of their compositions, structures, and features, but as a rule with strictly scientific ends in view.

THE OPTICAL EXAMINATIONS.—If sections prepared as described are placed upon the stage of the microscope, simple observation will indicate that most stones are complex; that their ingredient minerals are more or less impure; that they possess peculiarities of cleavage, fracture, and color; that in some cases they are more or less decomposed; that they are united with one another in very different ways in different cases, and that a variety of minerals is frequently present in small amount not visible to the unaided eye.

It will also be noticed that all the sections of the same minerals do not look alike, and that there is a probable difference between many which do look alike. This is especially the case in the white minerals which are present in considerable numbers in building stones, and other minerals with weak colors become white when ground so thin. In order to identify the minerals present it is necessary to use certain optical appliances which develop more individual peculiarities. When the polished surface of a stone is examined, its appearance is determined by the character of the light which it reflects. The amount of light reflected from the outer surface determines its brilliancy, the light reflected from internal surfaces imparts iridescence and reveals structure, and the light absorbed determines the color of the stone. But when a section of a stone is examined the appearance of this section depends upon the character of the light which it transmits. The colors which are reflected from a surface may be quite different from those which are transmitted by the body, and the general appearance of a section, therefore, is entirely different from that of a surface.

When light enters from a medium of one density into a medium of another density, as, for example, when it enters from the air into water, if its direction is oblique to the surface separating the two substances it is deflected toward a perpendicular to the surface. This is called refraction, and the relative amount of the deflection which is caused when light enters different substances from the same medium is expressed by the index of refraction. Minerals possess great differences in their indices of refraction, these differences being manifested in thin sections. A mineral which possesses a high index of refraction, and which consequently deflects a beam of light to a greater degree, is apparently thicker than a mineral with a small index of refraction, since the refraction causes a retardation of the light, which is equivalent in effect to the thickening of a mineral with a less refractive index. Moreover, the surface of a section being covered with Canada balsam, the appearance of this surface is modified by the refractive properties possessed by a section. If a mineral possesses a high index of refraction there is a greater difference between its index and the index of the balsam than in the case of a mineral with a low index of refraction, and consequently its surface will appear rough, since all the asperities which this surface possesses will become evident on account of the alteration in direction and the change of velocity which will take place when the light emerges from the surface of the section. The minerals of crystalline rocks possess generally quite high indices of refraction, and the beauty of polished surfaces is much enhanced thereby. The effects of refraction are much modified by the crystalline structure of the minerals, and are dependent upon this structure.

A crystal, in the modern acceptation of the term, is a homogeneous substance, the ultimate particles of which are definitely arranged. The physical properties, such as cleavage and hardness, which are of importance in building stones, are determined by this molecular arrangement. If a crystal develops in a space surrounded by fluid or by plastic substances, it will develop into a form bounded by planes which, in position and direction, are characteristic of the substance. In rocks, as a general rule, there has been no opportunity for such crystalline development, and the substances by their mutual contact have so interfered with one another in their development as to give them forms which are arbitrary and, to a certain extent, accidental. The internal arrangement of the substances in crystalline form is, however, as perfect as if the external forms were characteristically developed. Rocks may therefore be said to be made up of crystals which, in some cases, as in porphyries, possess characteristic form, but which usually are granular and irregular in form, and are either united upon their edges or cemented together by some interposed foreign substance.

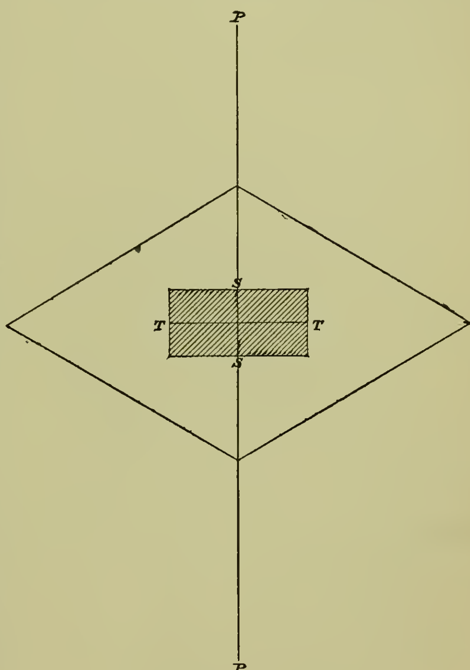

Fig. 2.

One of the fundamental properties of crystals is that the light which passes through them passes in definite directions and is submitted to definite modifications. An ordinary beam of light is composed of vibrations which differ from the vibrations of sound in that while sound is propagated by vibrations the axes of which are parallel with the direction of propagation, light is composed of vibrations which take place in all directions perpendicular to the direction of the beam. The color of a beam of light depends upon the duration of the vibration, and the intensity depends upon the amplitude. If a beam of light enters from the air into a non crystalline structure it suffers no further modification than the simple refraction; if it enters a crystal it may pass through it as through a non-crystalline substance, or it will be modified in such a way as that the vibrations which have been stated to take place in every direction about the axis of transmission will all be reduced to two planes which are at right angles to each other and are definite in direction. As to the method in which the light is modified in passing through the crystal, that depends upon the nature of the substance and the degree of symmetry which the crystal possesses. The simplest illustration of such a modification is seen by examining a dot through a piece of the ordinary calcite or Iceland spar; the dot will appear double, and the two apparent dots will have different appearances, dependent upon the difference of refraction of the two parts of the ray, which are separated in the crystal and are vibrating at right angles to each other. If a ray of light has passed through a crystal, and has had its vibrations thus all reduced to two planes, one of the two portions of light is what is called polarized; and the effects of this kind of light can be much better observed if by means of some contrivance one of the sets of vibrations can be absorbed so that a light can be obtained, all the vibrations of which take place in a single plane. Polarized light, then, as distinguished from ordinary light, is light the vibrations of which occur in one plane instead of taking place in an indefinite number of planes, as in ordinary light. Such polarization can be effected in a variety of ways. By passing through a plate of tourmaline cut parallel to the axis of the crystal the light, as previously explained, is divided into two sets of vibrations at right angles to each other, one of the sets being almost entirely absorbed, while the other is mostly transmitted as a polarized beam. Polarization is ordinarily effected by passing a beam of light into a crystal of calcite, which is cut in such a manner that one set of vibrations is allowed to pass through while another set is reflected away. A crystal so modified as to accomplish this object is called a Nicol prism, as such prisms were first made by the celebrated scientist Nicol.

Let us suppose that a beam of light is allowed to pass through a Nicol prism, and that its vibrations are all reduced to one plane, which vibrations take place parallel to the shorter diagonal of the Nicol prism, as represented in the accompanying Fig. 1; P P will then represent the plane of vibration of the light. If the aforementioned plate cut from a tourmaline crystal be now placed above this Nicol prism so that the long axis of the crystal plate shall coincide with the line P P, the crystal when looked through will be illuminated by light, the vibrations of which take place parallel to its axis, and it will appear of a color brown or blue, according to the variety of tourmaline thus examined. If upon this same Nicol prism the plate of tourmaline be laid with its long axis perpendicular to the line P P, as shown in Fig. 2, the light passing through the Nicol prism will have its vibrations confined to a plane perpendicular to the axis of the tourmaline, and in this direction, as has been before mentioned, the tourmaline allows but little light to pass. A tourmaline crystal, therefore, placed above a Nicol prism, will appear light when placed with its axis parallel to the short diagonal of the Nicol prism, and dark when placed with this axis parallel to the long diagonal; and in general the appearance of crystals may depend more or less upon the relation of their axes to the planes of vibration of the light which passes through. This difference is expressed by the word dichroism. A great many minerals are dichroic, as is abundantly illustrated in the figures.

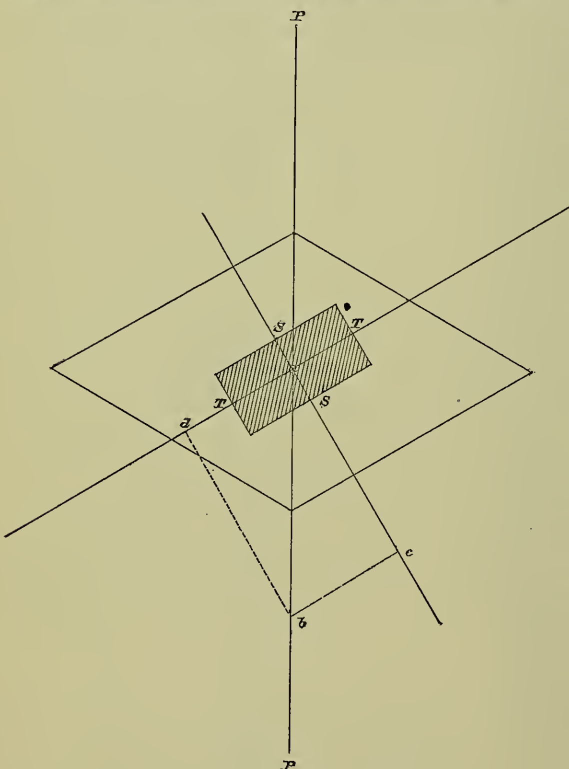

Fig. 3.

If the Nicol prism shall remain in the same position as before, and the tourmaline crystal shall be placed in a diagonal position, then the light which, after passing through the Nicol prism, vibrates in the plane P P meets the tourmaline crystal in a plane which coincides neither with its longer axis or the perpendicular thereto, as shown in Fig. 3; it therefore cannot pass through the crystal in the plane P P, since, as before explained, the only planes in which the light can pass through this crystal are a plane parallel or a plane perpendicular to the axis of the crystal. Meeting now the crystal in an oblique direction, the ray can only pass through it by resolving itself into two parts, according to the parallelogram of forces.

Let *a b* represent the intensity of the vibration as it emerges from the Nicol prism; this ray will divide itself into the part *b c*, which will pass through the crystal in the plane T T and into the part *b d*, which is perpendicular to the line T T, and which, as far as possible, will pass through the crystal in this direction. The crystal in this position will be illuminated by the light which passes parallel to the two directions at right angles to each other in the crystal, and will appear as if examined by ordinary light.

The above explanation of dichroism will explain a great many of the differences in the appearances of minerals when seen in their sections under the microscope; and it also explains a number of appearances which are commonly observed without the aid of instruments. For example, when one looks through a crystal of mica in a direction perpendicular to the laminæ, the color is determined by the light which vibrates in directions parallel with the laminæ, and is of a certain color. If one looks at a crystal of mica in a direction parallel with the laminæ the crystal is illuminated partly by light which vibrates perpendicular to the laminæ, and the color is consequently different. The dichroism of minerals, thus determining a great many of their appearances, is of both economic and scientific importance.

If the light which has passed through the Nicol prism in the plane P P, as before explained, shall be compelled to pass through another Nicol prism exactly like the first one, but placed in a direction with its short axis perpendicular to the plane P′ P′, the light will meet this Nicol prism in such a way that the light cannot pass it; for this Nicol prism, being like the first, reflects away all of the vibrations which enter it parallel to its longer diagonal. Through two Nicol prisms placed in this position light cannot therefore pass, and the portion of the field covered by both of them will appear dark; and if the tourmaline plate be interposed between them with its long axis parallel to the short diagonal of the lower Nicol prism, the light after passing through the lower Nicol prism will pass through the tourmaline as before explained, and will be cut off as before by the upper Nicol prism. The interposition of the tourmaline will therefore produce no effect, and it will appear black when thus placed between two Nicol prisms, as indicated in Fig. 4.

But let it be supposed that two Nicol prisms be placed together, with their shorter diagonals in the directions P P and P′ P′; that the crystal of tourmaline be placed between them in such a way that its axis does not correspond with the diagonal of either Nicol prism, as shown in Fig. 5, the light will, as before shown, be resolved into two parts in order to pass through the tourmaline in the planes *a c* and *a d*. If we follow the course of the ray *a c*, we find that it meets the second Nicol prism in a plane which does not correspond to either its shorter or its longer diagonal; as the light must pass into the prism parallel to one or both of these diagonals, the ray *a c* is again divided according to the parallelogram of force and enters the Nicol prism in two planes with an intensity and a direction represented by *a e* and *a g*. The light vibrating in the plane *a g* is in the upper Nicol prism reflected away, and only the light represented by *a e* passes through it. If we follow the course of the ray represented by *a d* in like manner, it is seen that it must be divided into two parts, vibrating in planes respectively parallel to the shorter and the longer diagonal of the Nicol prism, and in like manner represented in direction and intensity by the lines *a k* and *a m*; *a k* in the upper Nicol prism is lost by total reflection, and *a m* passes through. We now see that by the interposition of the crystal with its long axis placed diagonally a decomposition has been brought about by means of which two rays, represented by *a e* and *a m*, are caused to vibrate in the same plane after having passed through different experiences. The possibility of interference becomes immediately evident, for if a greater retardation has been effected by passing through the crystal in a direction parallel to the prism than in passing perpendicular to the prism, then the two parts can no longer vibrate in unison, and when they are brought back into the same plane with each other they will be sure to interfere. This interference, in fact, takes place under such circumstances, and the result is the production of most brilliant colors, the tints of which are dependent upon the nature of the substance, the thickness of the plate of the crystal interposed, and the position of the plate or section with reference to the diagonals of the Nicol prisms.

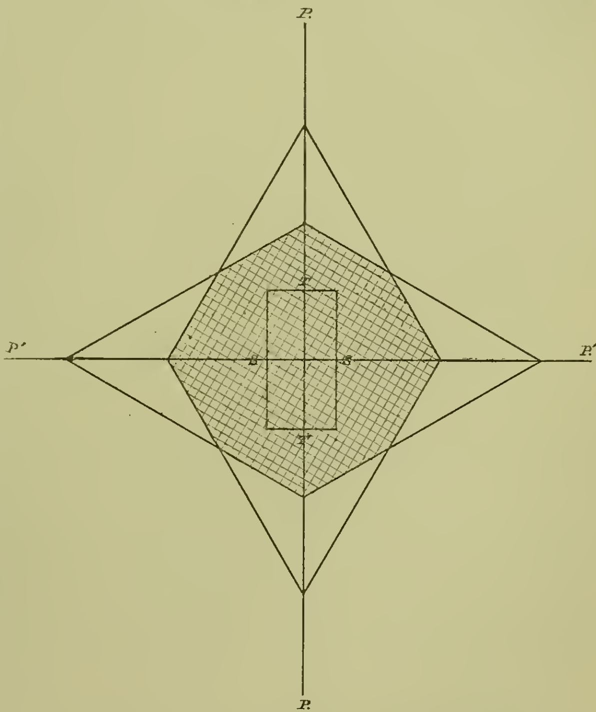

FIG. 4.

As the position with reference to the Nicol prisms brings about such modification, it is evident that the employment of polarized light will develop many peculiarities of structure and arrangement which could not otherwise be detected. In polarized light, minerals which may give no indication of their nature in ordinary light may exhibit such distinctive properties as render their determination very easy.

Those crystals through which light passes in two planes at right angles to each other, as distinguished from those substances through which the light passes without any further modification than a simple change of direction, are called double refracting crystals. These crystals show such peculiarities in their double refraction that it is possible to classify them into systems identical with those which would result from a study of their outer forms were they possessed of perfect external development.

The mode of crystallization determines, therefore, the way in which light is modified by its passage through a section, and individual substances possess in addition their own peculiarities which enable them to be determined. The optical characteristics depend upon the degree of symmetry which crystals possess, and the following are some of the properties which substances of like crystalline character will exhibit: Amorphous substances, such as glass, which occurs in the volcanic rocks, and which are without any crystalline structure, will possess the property of single refraction, will not modify the light by changing the planes of its vibration, and consequently the effects of dichroism and of color with Nicol prisms will not appear, except as they may be caused by a strain or unequal pressure which may give to such a substance a temporary structure.

A crystal belonging to the isometric or regular system is symmetrically developed about the central point. In such bodies the molecular arrangement is therefore such that sections cut in any direction are alike as regards two lines which may be drawn in the section at right angles to one another; there is consequently no double refraction, and such minerals are optically like amorphous substances, save that they may possess definite cleavage, crystalline outlines, inclusions arranged in a definite manner, or some other peculiarities which may demonstrate that they belong to the group of regular crystals. Garnet, fluor-spar, and some other substances that are found in the rocks belong to this class.

Crystals built in the form of a square or of a hexagonal prism, like tourmaline and calcite, possess, however, a different degree of symmetry. In a section of such a prism parallel to the base, any two lines drawn through the center perpendicular to each other would intersect the crystal section in the same manner, and the two lines would be therefore crystallographically identical; there would be no cause for double refraction, and the section would therefore appear between Nicol prisms like the preceding.

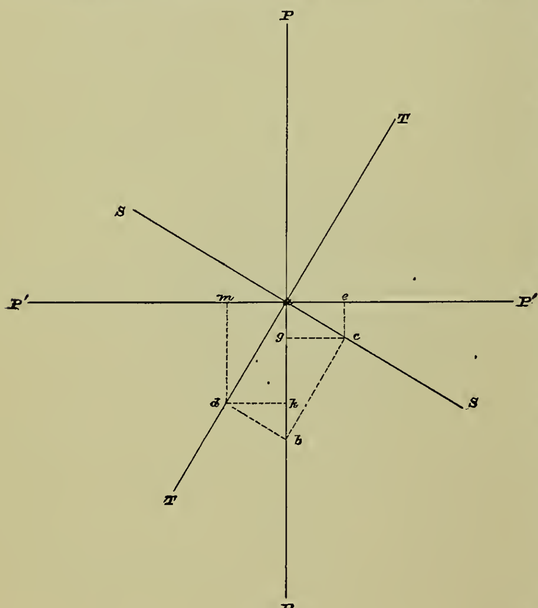

Fig. 5.

If, however, a section be cut from such a prism parallel to the long axis, two lines drawn in this section perpendicular to each other will divide the section in very different manners, and these lines will bear different relations to the crystal section. A line parallel to the longer direction of the section or a line perpendicular thereto will each divide the crystal into two symmetrical halves, which, however, in the two cases are quite different. Such a section will be double refracting, and when placed between the two Nicol prisms will modify the direction of the vibrations which will take place in two planes, one parallel and one perpendicular to the crystal, and one of these sets of vibrations will be retarded more and refracted more than the other by passing through the crystal. Such a section will therefore be colored in whatever position it may occupy between the Nicol prisms, save when its long or its short axis is parallel with one of the diagonals, as shown in Figs. 4 and 5.

If a crystal be developed in such a way that length, breadth, and height are all different, but so that the sides of the prism are perpendicular to the base, as in the case of mica, then sections cut in any direction parallel to the sides of this prism will possess the properties which have been above described as belonging to a section cut parallel to the long direction of a square prism, for such sections will possess the same degree of symmetry and therefore the same optical propertie

If a crystal is developed in such a way that one of the faces of the prism is perpendicular to the base and the others are not, as in the case of common feldspar, then sections parallel to the base and to one side would be parallelograms resembling the long section from a square prism, and would have like optical properties. Other sections cut parallel to the oblique faces of the prism would be rhomboidal in form, and would not possess such lines of symmetry. Lines parallel to the edges of the prism would not divide the section into two parts which would be alike on the two sides of the lines, and these lines would therefore no longer determine the planes in which the light will pass through the section. No two lines perpendicular to each other in such a section can be crystallographic lines, and as the light must pass through such a section, like all others, in two planes which are at right angles, these directions must be independent of the crystal edges, and will depend on the individual mineral rather than on a general system of crystallization. One single example will illustrate all these principles.

Let Fig. 6 represent a crystal of feldspar which belongs to the monoclinic system, last described, and which, if thus simply crystallized, would have the planes on the two sides of the lines *a c* and *a d* at right angles to each other, while the planes on the sides of *a b* would form an obtuse angle. Sections cut parallel to the base and the front face of this prism would then be right-angled parallelograms, and lines through the centers of these faces and parallel to the sides would be at right angles to each other, and would divide them into equal and symmetrical halves. These represent, therefore, the planes in which the light must vibrate in passing through the crystal, and are the planes which must coincide with the diagonals of the Nicol prisms, or interference and colors will be produced.

The plane on the side, however, is not a parallelogram, and lines parallel to its sides are not perpendicular to each other. The light, therefore, finds two directions, for example, *e g* and *h i*, which are at right angles to each other, in which its vibrations take place. These directions, which make a certain angle with the lines parallel to the edges *a c* and *a d*, have the same position in all crystals of like substances, and occupy different positions in crystals that belong to this system, but are of different substances. These lines are the lines which correspond with the lines parallel to the edges of the crystal in the sections parallel to the other faces, and the angle made by the optical and the crystallographic lines can be measured, and its determination may identify the species of the substance.

Only one case remains to consider. If a prism is so developed that it possesses no right angles, then sections parallel to any face are like the face on the side of the prism in our example, and therefore all its sections will have the properties attributed to sections parallel to that face, and no sections will be found in which the planes of vibration of the light are parallel to the edges of the prism.

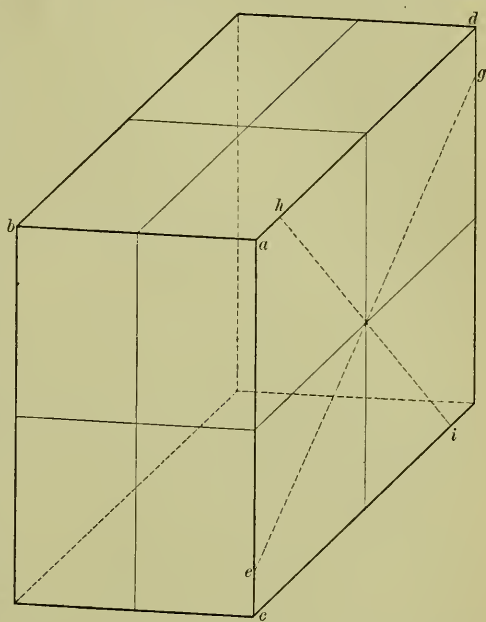

FIG. 6.

A great many more optical effects can be produced by causing other modifications in the light; for example, by making it convergent by means of lenses before it passes into the section. Effects thus obtained elucidate those that have been described, which are seen in simple parallel light. In this work only the optical features that have been described are referred to.

When these principles are applied to the microscopic examination of thin sections we are able to identify all of the constituents which the rock contains by means of the differences which the minerals exhibit either in ordinary or in polarized light. The determination is simplified by the circumstance that the number of minerals which take part in the composition of common building stones is not large.

When a section is placed upon the stage of the microscope most of the ingredient minerals are transparent, and the number which do not become transparent under this treatment is so small that there is no great difficulty in discriminating between them. To determine the opaque ingredients the light is cut off from beneath the stage of the microscope, when the color of these opaque minerals, as they appear by a reflected light, is seen; magnetite is bluish-black, pyrites yellow, etc.

Those minerals which are more or less transparent in the section exhibit the colors which they possess by transmitted light; but, in accordance with the principles already explained, sections of the same substance may be differently colored according to the directions in which their crystals are intersected. A considerable number of the minerals may be identified by their colors and appearances, and others may be identified by known peculiarities of fracture, cleavage, and decomposition.

If a Nicol prism is inserted beneath the stage of the microscope it will not essentially modify the appearance of most of the minerals, but as it will reduce the vibrations of the light which illumines the section to a plane, the phenomena of dichroism will become apparent, and by means of these phenomena some of the ingredients will be identified.

If a second Nicol prism is placed above the first, so that the section lies between the two, then all the phenomena of polarized light become evident; and if these Nicol prisms are placed in such a position that their shorter diagonals are crossed at right angles, and that the direction of these shorter diagonals is accurately known, then the relationship between the diagonals of the Nicol prisms and the planes in which the light vibrates when passing through the crystal section can be determined, and little doubt concerning the composition of any mineral in ordinary rocks will remain after the application of all these methods.

CLASSIFICATION.

The nomenclature in general use for materials of construction is very simple. It consists of a few popular names with no defined significations. These names are derived at times from certain characteristic appearances, and sometimes from the uses to which stone is applied. They answer most of the purposes of constructors; but, when examined more critically, stones which pass under the same name are frequently found to be so different as to necessitate their wide separation from one another in classification.

Some so-called granites in the United States do not contain one of the minerals which compose certain other well-known granites, and possess nothing in common with them except their granular structure. Such differences in composition essentially modify the economic properties of the stone, and there is for this reason a positive advantage in a more extended nomenclature. Closer discrimination in this direction will also necessitate a more critical consideration of the stones from different sections of the country. We hear very frequently of such things as Ohio sandstone, Maine granite, etc., which are terms that include stones that are incapable of being grouped; and the cases are not rare in which, by reason of such generalizations, the good or bad reputation of certain stones has unjustly passed over to its neighbors.

Individualities of structure and composition of the greatest scientific interest are usually identical with the features most important from a practical standpoint, and therefore for our use the scientific nomenclature of rocks can scarcely be improved. This nomenclature differs but slightly from that in common use, and this is due to the circumstance that the old popular names given by miners and quarrymen to ores and stones have always been used in mineralogical and geological studies. The great variety of practical applications which these studies find in the arts has rendered difficult and impracticable the introduction of such a system of generic and specific names as characterizes the more modern sciences, which are not so directly applied in common life; but it is noticeable that many old names, like trap, greenstone, lava, etc., which still are used in the popular nomenclature, have long since been banished from scientific works as meaningless.

The earth is covered with hard rocks and the loose products of their disintegration. If the hard rocks have resulted from a cementation and consolidation of what once was loose material, they maintain the stratified character of the original bed. When heat, moisture, or any other agencies have rendered them very compact and resistant, they still retain some traces of their original stratified character; and whenever it can be shown that a given rock was once composed of those loose products of the disintegration of older rocks, it is called stratified. The different members of the stratified group of rocks are often very unlike one another. They are sometimes composed of merely cemented masses of sand or pebbles, and their origin is very plainly seen; at other times the original constituents and the original structures are both nearly obliterated by subsequent processes of modification. Their stratification is in some cases very plain, and modifies the processes which are used in quarrying and in dressing the stones, as well as the uses to which they are applied. In other cases the stratification is with difficulty detected, and shows itself only when large masses of the stone are seen, or in the greater ease with which the stones are worked in given directions.

The process of cooling from a molten state, through which the earth has passed, has necessitated a constant change of volume and consequent strain upon its crust. Thus in every age of the world's history clefts have been formed through which materials have issued in molten condition from the interior of the earth, and have been poured forth in greater or less quantity upon its surface. Such materials cooling from a molten condition do not possess stratification, but are massive and crystalline. The modern volcanic rocks belong to this class; some of these are light, porous rocks, which are easily worked and are much used in countries where they abound. They are not employed to any extent in the United States, because there is little construction in those regions where they are abundant. The older granitic rocks of this class are hard, compact, and durable. Mechanical forces which have acted upon their surfaces for long ages have worn down and removed any soft and porous material which might have existed. They are quarried with more difficulty, and consequently are not so extensively employed as the sandstones and the limestones of the stratified group, but they possess such properties as make them favorite materials of construction. In general, the sedimentary and the volcanic rocks possess structures that render them more easily cut and worked, while the ancient massive rocks are more hard and durable. The ready accessibility of the granitic rocks in the most thickly settled portions of America has caused them to be more extensively used among us than in any other country in proportion to the amount of stone construction.

These considerations divide rocks into two principal groups, each of which may be subdivided. The further subdivision depends upon the mineralogical composition of the individual stones, as is indicated in the following classification.

If this classification is rigidly adhered to, numbers of rocks which are related by those physical properties that determine the uses to which they are applied are quite widely separated from one another. Gneiss, for example, is so much like granite that it is often used in the same way for the same purposes. The rocks which are related in composition are conveniently grouped together as being the material of one and the same industry, even though their mode of origin is recognized as different.

The following tabulation forms the basis for comparison of the industries considered in this work, and for convenience a name is given to each group, which is either that of its predominant member or that by which the stones that compose it are commonly known:

1. Granite.
   Syenite.
   Gneiss.
   Crystalline schists.
   Diabase.
   Diorite.
2. Fragmental rocks (sandstones).
   Siliceous sandstones.
   Feldspathic sandstones.
   Conglomerates.
   Breccias.
3. Carbonates (limestones).
   Common limestones and dolomites.
   Crystalline limestones and dolomites.
   Shell limestones.
   Calcareous tufa.
4. Serpentine.
5. Slate.

In this report, then, the rocks at present used for purposes of construction in the United States are for convenience divided into the following classes:

1. Crystalline siliceous rocks.
2. Sandstones.
3. Marble and limestones.
4. Serpentine.
5. Slates.

Rocks popularly known as marble and limestone are classed together, owing to the difficulty of drawing a definite line between the two; all distinctively calcareous rocks are included in this table.

The group headed "Sandstone" comprehends all the siliceous rocks not included in the tables of the crystalline siliceous rocks and serpentine. Materials commonly known as sandstone, freestone, flag-stone, some of the so-called "blue-stones", quartzite, and all the conglomerates, except the calcareous conglomerates, come under this heading.

In the class of crystalline siliceous rocks are placed those popularly known as granite, syenite, gneiss, mica-schist, trap, basalt, porphyry, and volcanic rocks.

Serpentine was quarried during the census year, to a sufficient amount to admit of tabulation, only in Pennsylvania, and even here the product was small as compared with that of previous years. The greater part of the slate product tabulated has been used for roofing, though a portion of it was employed for sidewalk paving, tiling, and other purposes of construction.

States and territories wherein any one of the classes of rocks above described are not quarried for purposes of construction are, of course, omitted in the tables devoted to that particular class, though many states and territories are rich in the undeveloped material.

DECOMPOSITION OF STONES.

There are many more factors which determine the value of stones for purposes of construction than are often considered in the elementary treatises upon this subject, and the rules laid down are often determined by the local circumstances. A more extensive study of building stones frequently vitiates the rules which apply in limited areas. It is, for example, stated that, in order to determine whether a stone will withstand the action of the weather, one should visit the quarry and observe whether the ledges that have been exposed to the weather are deeply corroded, or whether these old surfaces are still fresh. This is not a fair criterion, because the applicability of such a test is modified by geological phenomena. North of the glacial limit all the products of decomposition have been planed away and deposited as drift formation over the length and breadth of the land. The rocks are therefore in general quite fresh in appearance, and possess but a slight depth of cap or worthless rock. The same classes of rock, however, in the south are covered with the rotten products resulting from long ages of atmospheric action. They may be rotten to great depths, and the removal of the worthless rock is often difficult. This is due to the circumstance that no agencies have here operated to scrape off and remove the loose material from their surfaces in recent geological time.

There are other peculiarities of decomposition regarding which too absolute rules have been laid down. Pyrites is considered to be the enemy of the quarryman and constructor, as it decomposes with ease and stains and discolors the rock. But here, too, there are features which very seriously modify the effect of this decomposing substance. Pyrites, in sharp, well-defined crystals, sometimes decomposes with great difficulty. If a crystal or grain of pyrites is embodied in soft, porous, light-colored sandstones, like those which come from Ohio, its presence will with certainty soon demonstrate itself by the black spot which will form about it in the porous stone, and which will permanently disfigure and mar its beauty. If the same grain of pyrites is situated in a very hard, compact, non-absorbent stone, the constituent minerals of which are not rifted or cracked, this grain of pyrites may decompose and the products be washed away, leaving the stone untarnished.

We believe that the microscopic study of these stones is, even in such simple cases as this, necessary for a correct determination as regards the influence of decomposing agents upon the stone.

Again, some of the constituent elements of rocks are so frequently found in a decomposed condition that they are considered to be deleterious, when present in large quantity, on account of their well-known tendency to decompose. For example, olivine indicates a very marked tendency to decompose, as indicated by the vast accumulations of serpentine which are so frequently found to be a result of its decomposition; but the circumstances which in past time have brought about this decomposition may have been very different from those which are at present active, and the prejudice against olivine in a rock is not supported by any observations which indicate that it will decompose under the present influences. We wish to bring prominently forward that we consider that a decision as to the probable action of the agents producing decomposition in rocks should be largely dependent upon careful microscopic examination of the structure of the rock. Our experience has demonstrated that a rock of a given character, as regards ultimate composition and mineral constituents, may be easily affected by the weather if its constituent minerals, as indicated by their microscopic structure, are so fractured that they are laid open to atmospheric agencies through rifts, no matter how small, while the same stone, with the same constituents, may be eminently resistible to decomposing agencies if its constituent minerals are sound, whole, and impermeable, as indicated by the microscopic structure.

In the old world, where immense cathedrals, planned long ago, have been in the process of construction for hundreds of years, it has not been uncommon to see portions of the building fall into decay before the structure was finished, and the process of restoration often consumes large sums of money while the process of construction is yet going on. It thus very frequently happens that a variety of stones is used in the construction of the same building, because in this process of construction experience is gained indicating inapplicability of the stones used for durable structures. In this case it is experience alone which finally dictates the most suitable material; and even to this day, here in America, there is no other criterion to apply to a building stone save the test of experience; and the result is that buildings can be pointed to which, like those old, immense structures before referred to, are already crumbling while yet in the process of construction.

PRESERVATION OF STONES.

Disintegration of stone and the method by which this can be arrested has furnished a topic for considerable study. The methods which have been applied with most success are to bathe the stones in successive solutions, the chemical actions between which bring about the formation of insoluble silicates in the pores of the stone. For example: If a stone front is first washed with an alkaline fluid to remove dirt, and this subsequently followed by a bath of silicate of soda or potash and allowed partially to dry, and then bathed again; and if the surface is then bathed in a solution of chloride of lime, chlorate of sodium or of potassium, according to what is used, an insoluble lime silicate is formed. The soluble salt is then washed away and the insoluble silicate forms a durable cement and checks the disintegration. If lime water is substituted for chlorate of lime there is no soluble chlorate to wash away.

INFLUENCE OF CLIMATE.

In addition to the consideration of the humidity of the atmosphere, the influence of the purity of the atmosphere is also important in deciding on a building material. For example, in the smoke of Pittsburgh it would make very little difference what the material employed for construction might be, so far as appearances are concerned, since it would soon assume the gray color peculiar to all the buildings of the city; but the capacity of a stone to resist acid vapors would become very important, since the only point necessary to be considered in selecting a stone would be as to whether ornamental structures are defaced and disintegrated by the vapor fumes peculiar to this atmosphere.

STRENGTH OF MATERIALS.

In practice it is not common to place stones where they are obliged to bear more than one-sixth or one-tenth of the weight which their crushing strengths, as determined by experiments, indicate that they are able to bear. Beside this, there are many considerations which demonstrate that reliance upon experimental data is unsafe. A stone that will crush under a given pressure to-day may, if exposed to the weather, crush under a very much smaller or very much larger weight after the passage of years, according to the action of the weather upon it. Stones, when they crush, usually break in certain lines of weakness, which lines may be arbitrarily situated in the stone and difficult to detect, or may be definitely situated and dependent upon structure. As stones from different parts of the same quarry, and even from different places in the same layer, frequently vary greatly in strength, it is quite important to develop methods by which the strength of stones and their variability in this respect can be more easily detected than by the laborious experimental tests upon small cubes. Results of studies made upon the structure and composition of those stones which have been very accurately tested as to their strength are valuable contributions in this direction.

Chapter II.—MICROSCOPIC STRUCTURE.

By G. P. Merrill.

It is not the intention in this chapter to present a purely scientific treatise on microscopic lithology, but rather to give a short description such as together with the plates will enable any one with but a slight knowledge of the subject to appreciate the variations in structure and mineral composition of some of the more common kinds of building stones. What may be considered as typical specimens of the various kinds of rock quarried have been selected, and from the thin sections, prepared as already described, enlarged photographs have been made from which the plates have been reproduced. They therefore show the exact structure as seen under the microscope, excepting, of course, in the matter of color. In preparing the text the manuscript notes left by Dr. Hawes have been utilized so far as possible.

THE CRYSTALLINE SILICEOUS ROCKS.

Rocks that are commercially designated as granites are composed in some cases of minerals which are entirely absent in other rocks that are also designated as granites. For example, some of the so-called black granites are diabases or diorites. But the circumstance that the minerals, although different, are all very nearly of the same hardness; that the rocks therefore offer the same difficulties in cutting, in dressing, and in polishing, and that the similarities of their appearance render them applicable to like purposes, unite these rocks into a well-defined group. In it are included the various granites, syenites, trap-rocks, gneisses, and crystalline schists.

The structural differences that exist among the rocks of this class, although indicating very different modes of origin, are fully recognized in grouping these rocks thus together.

The nomenclature for these rocks in use among quarrymen shows that they are all related as economic products; for example, the gneisses are frequently called "bastard" granites or "striped" granites, as are also frequently the mica-schists. The trap-rocks, where they are quarried, are very commonly called "black" granites or "gray" granites, and as a rule no distinction whatever is made between the granites and syenites. Therefore, in a tabulation which shall indicate the extent to which the hard crystalline rocks are quarried, and shall give the data for comparing one well-defined industry with the others, these rocks are naturally associated together.

Although, as shown, these rocks do possess common characters that unite them into a well-defined group, they possess differences which allow the group to be subdivided both according to the appearances and uses of the stones. The granites and gneisses, for example, possess the common characters already referred to, but the resemblance extends no further. It is therefore a positive disadvantage to the industry to classify them, as is so frequently done, under a common name. Therefore, in the tabulation the common name by which the stones are sold will be given, accompanied by the scientific designation.

These rocks are found chiefly among the older formations and in regions where there have been such disturbances as have cleft the crust of the earth and given egress to the fused matters which underlie it. The crystallization of these molten materials which have thus been erupted has given rise to many of the rocks which, on account of their massive homogeneous structure, are most prized. Quarries of these rocks occur in all the Atlantic states, the Lake Superior states, and in the mountainous regions of the far west. Thus the great interior basin of the continent is left without rocks of this class, if we except some isolated areas in Missouri, Arkansas, and Texas.

It is not, however, to be inferred that all of the rocks of this group are as old as the rocks which characterize these regions. The gneisses and the crystalline schists are very old rocks, belonging mostly to the Archæan period. The other members of the group are eruptive rocks which have at some period in the earth's history been molten, and have been forced through clefts in these older rocks. There is, therefore, no method of determining their exact age in all cases, since the time of their eruption can only be determined as being later than the time when the rocks which they intersect were accumulated. It is, however, known that a great many of them are very old, and that the time of their eruption was probably identical with the elevation of the mountains and the disturbances which would have naturally resulted in producing the clefts through which they were erupted; and it is also known that some of them are quite modern in age, since they intersect sandstones which were accumulated in later periods of the earth's history.

GRANITE.

The essential components of the true granites are quartz and potash feldspar. Although the essential minerals are but two in number, the rocks are rendered complex by the presence of numerous accessories which essentially modify the appearances of the rocks and those properties which render them of importance as building stones. These additional minerals are either present in such amount as to be conspicuous and to exercise an influence upon the apppearance and structure of the rock, when they are called characterizing accessories, or they are present in such small amount as to be invisible to the naked eye, when they are called microscopic accessories. If all the minerals which by careful examination have been found in granites should be considered as constituents of the rock, then the latter would appear as very complex. At least two-thirds of all the known elements exist in granitic rocks, and the number of minerals that are liable to be present in special cases is very large.

The following list does not include all of those minerals which have been identified in this rock, for many have been found under circumstances which are so isolated that their occurrence is entirely exceptional. All of the minerals in this list are liable to be found at any time, and may therefore be considered as common constituents of the rock, although the presence of them all together is not to be expected, and some of them may be present in such minute amount as to be of no practical importance. Any one of them, save the two essential constituents mentioned above, may be absent from an individual specimen, or from a granite from a given locality; and any one may be present in the specimens from a given locality in such amount as to give a character to the rock. Thus almost any one of those minerals which are given as microscopic accessories may assume the character of a characterizing accessory; this is especially true of the iron oxides, which sometimes are present in such amounts as to become characteristic:

Essential:
- Quartz.
- Feldspar.
  - Orthoclase.
  - Microcline.
  - Albite.
  - Oligoclase.
  - Labradorite.

Characterizing accessories:
- Mica.
  - Muscovite.
  - Biotite.
  - Phlogopite.
  - Lepidolite.
- Hornblende.
- Pyroxene.
- Epidote.
- Chlorite.
- Tourmaline.
- Acmite.

Microscopic accessories:
- Sphene.
- Zircon.
- Garnet.
- Danalite.
- Rutile.
- Apatite.
- Pyrite.
- Pyrrhotite.
- Magnetite.
- Hematite.
- Titanic iron.

Decomposition products:
- Chlorite.
- Epidote.
- Uralite.
- Kaolin.
- Iron oxides.
- Calcite.
- Muscovite.

Inclosures in cavities:
- Water.
- Carbon dioxide.
- Sodium chloride (salt).
- Potassium chloride.

The feldspar, which is so easily recognized by its cleavage surfaces in all of the granites, is by far more complex in composition than has usually been supposed. It is exceptional to find a granite which contains but one kind of feldspar, and not merely are two or three species usually present, but the structure and condition of their crystals are far from simple. The potash feldspar sometimes exists in the form of orthoclase and sometimes in the form of microcline. Microcline is a feldspar of the same composition as orthoclase, but differs from it in crystalline form by belonging to the triclinic system, which possesses no right angle. The orthoclase is very commonly seen in crystalline grains, in each of which one-half bears the relation to the other half of one crystal revolved 180° about an axis in another. Such are called twin crystals. They render themselves conspicuous to the eye in some granites by the different positions in which one receives the bright reflections from the two sides. The microcline is divided into such a multitude of twinned parts that they are only recognized by a microscopic examination, and in addition two different systems of twinning combine to make the structure more complex. Therefore, in the thin sections, while the orthoclase at the most is divided into two parts by a straight line, the microcline as seen in polarized light possesses a reticulated structure, which is due to the interweaving of the multitude of laminæ that stand in the relation to one another of twin crystals. This structure will be noticed in the plates.

The discovery of this species of feldspar has been one of the developments of microscopic mineralogy, and examination has proved microcline to be one of the prominent constituents of granites.

The albite, oligoclase, and labradorite are identified in thin sections by the circumstance that they possess also a complex twinned structure; but one system of twinning preponderates, so that they possess a banded structure which evinces itself in the fine parallel striation that is frequently seen on its bright cleavage surfaces with the unaided eye, and in thin sections the same is much more plainly shown by the banded structure that its sections possess in polarized light when the crystals are cut in some plane that is not parallel with the plane of the lamination. The optical properties of the individual species render it possible to still further identify them; or they may be analyzed when it is possible to separate them from the rock.

The different kinds of feldspar that exist in these granites are sometimes separated from one another in distinct grains, and sometimes are interlaminated with one another, forming complex grains. For example, orthoclase and albite are frequently combined in the same crystal or grain.

All of these circumstances of composition and structure are important, for the appearances of granites depend largely upon the feldspathic ingredient. The different species are often quite differently colored, and thus at times a beautiful mottled appearance is imparted to the stone; if, for example, the orthoclase feldspar is red and the albite or oligoclase is white, the effect of this mixture of colors is strikingly manifest. If both kinds of feldspar are white, one may be opaque and the other transparent, or one may be opalescent and the other dull. In general, many of the most striking characteristics and a large proportion of the immense diversity in granitic rocks are due to this complexity in the feldspathic constituent, and its consideration is one of the most important elements of their study.

The feldspar has also an influence upon the cutting of the stone and its shade of color. The so-called hard granites consist of quartz with a compact, transparent, nearly glassy feldspar, which is quite difficult to cut, and which allows the light to enter it and be absorbed, thus imparting to the stone a dark color, as in the case of the Quincy granite. The cause of the hardness of these rocks is not entirely due to the quartz, as is often supposed Quartz is always brittle, and is not very variable under tools. The hardness of hard granites is due to the condition of their feldspathic constituent, which is variable. The soft granites, however, consist of the same constituents, but the feldspar is porous and is thereby rendered soft and less resistant to the tools. The light is reflected under these circumstances from the surface and the rock is rendered white. It bears the same relation to the feldspar of the hard granites as does the foam of the sea to the water, but of course in a less marked manner. The Concord granite may be mentioned as an example.

The structure of the feldspar modifies the resistibility of the stone to decay, the quality of the polish which may be imparted, and the ease or difficulty with which the stone may be discolored or stained.

The quartz is much more simple in structure, and is subject to many variations in form and appearance, but to none in composition.

Although belonging to what we call the infusible substances, it is evident that in the solidification of the granitic rocks such agencies were active as rendered this substance more easily fusible than the other ingredients, and it was therefore the last element to take final form in the solidification. This is shown by the way in which it occupies the interspaces which were left after the other minerals had crystallized, and it therefore, to a certain extent, acts as a kind of cementing material to the other ingredients. Some granites contain large, imperfect quartz crystals, which must have been one of the first products of the solidification, but in nearly all granites the last substance to solidify is the quartz.

The microscope indicates that the quartz almost always contains pores which are partially filled with fluids. The number and size of these pores are of considerable importance, as they tend to explode when heated, and this aids to disintegrate the rock at a high temperature. It is important to note, however, that the various minerals which compose granites possess different expansibilities, and this is a cause of the well-known tendency of granites to disintegrate in the fire. Granite usually contains about eight-tenths of one per cent. of water, and is capable of absorbing a few tenths more. The water permanently present is largely contained in these pores when the rocks are fresh, and the capacity for further absorption is due to the rifts and empty pores that are largely confined to the feldspar.

At times quartz and feldspar constitute almost the whole of the rock, and at other times the accessories become very prominent. These accessories vary with the locality, and give the characteristics to the various kinds.

Mica is the most common of the accessory ingredients, and its presence constitutes what is called mica granite. If the mica is the white muscovite, the granite may be very light in color and may be almost white, as in the case of the Hallowell granite, or the granite from Barre, Vermont. If the mica is exclusively the black variety of biotite, the granite will be dark in proportion as this mineral is present. If both species are present, as is frequently the case, the granite will be speckled with alternating black and white shining spots, as in the case of the Concord granite.

The amount of the mica present is economically important. It does not polish as easily as do quartz and feldspar, owing to its softness, and the presence of a large amount therefore renders the rock difficult to polish. When polished it does not retain its luster so long as do the other minerals, and its surfaces become dulled by exposure. Its presence in large amount is therefore deleterious to stones which are intended for exterior use as polished stones. The condition in which it exists is also important in this respect. A large amount of mica scattered in very fine crystals through the rock influences its value as a polished stone less than does the presence of large and thick crystals of mica scattered through the rock in smaller number. The method of arrangement of the mica is very important; if scattered at hap-hazard, and lying in all directions among the quartz and feldspar crystals, the rock will work nearly as easily in one direction as in another. If it is distributed through the rock in such a manner that its laminæ are arranged in one definite plane, it imparts a stratified appearance to the rock, and when this stratified appearance becomes marked, the stone is called gneiss. One or two causes may give rise to this structure, but so far as it exists in granites it is easily explained by the circumstance that slight motions in a given direction in a plastic mass will cause all of the flat and long constituents to arrange themselves in a definite plane. If, for example, some mica scales or any other thin flat scales are mixed in clay so that they lie scattered through it in all directions, and if this clay is pressed so that it is flattened out a little, a section through the clay will show that the scales have arranged themselves in a definite plane, an effect produced by the motion of the plastic mass induced by pressure.

As granite is supposed to have cooled from a condition of fusion, the circumstances must plainly have existed under which this laminated structure could have been produced, for the mica was crystallized before the rock was entirely solid, as is evident from an examination of its microscopic structure, which shows that the mica invariably crystallized before the quartz had taken form. The effects of the parallel arrangement of minerals in granites are often evident, even when this arrangement is invisible to the unaided eye. Apparently massive granites cleave more readily in one direction than in another, and this plane of more easy cleavage is always detected by quarrymen with experience.

If hornblende is the characterizing accessory, the granites are usually without any evident stratification, as this mineral exists in the granites in granular form. Hornblende is subject to as wide variations of composition as is mica, but its white and very light colored varieties do not frequently appear in the granitic rocks. Its green varieties occur and give a characteristic shade of this color to the stone, as is illustrated, for instance, in the granite of which the new Mormon temple is built. It cleaves parallel to two planes which make an angle of 124° with each other, and is thus distinguished from mica, which invariably has but one cleavage. It is easier to polish than mica, and its presence is favorable on this account. The hornblende granites are to be classed among the best.

Pyroxene as a characterizing accessory in granites is more abundant than has usually been supposed. Indeed all rocks which contain pyroxene abundantly have usually been confounded with the hornblende granites. The distinction between pyroxene and hornblende is important from an economic standpoint, as horneblende possesses a much better cleavage than pyroxene, while the pyroxene is much more brittle than horneblende, and cracks out with greater ease in working. The cracking out of little pieces from the black ingredient of the Quincy granites has been frequently noticed, and is due to the circumstance that this granite is not the hornblende granite that it has been usually supposed to be. Hornblende is very tough, but the Quincy granite contains a peculiar variety of pyroxene, which is so brittle that it is difficult to make a large surface on a Quincy granite which does not show some little pits, due to the breaking out of a portion of the black grains of pyroxene.

Although pyroxene and hornblende may be identical in composition, they are frequently associated together in the same rock, a circumstance which is very evident in thin sections, but not in the massive stones. The rocks which contain hornblende also frequently contain mica, but it is noticeable that under such circumstances the mica is always of the dark-colored variety, and an example of a granite which contains both hornblende and muscovite is not known.

Epidote is quite characteristic when present in the granite, giving to it its deep green color. Its crystals are always green so far as observed in granite, and the polishing of the stone develops the brightness of this color. It is sometimes an apparently original constituent of the rock, and at other times a decomposition product.

The Dedham, Massachusetts, granite is one of the most marked examples of an epidotic stone. It is also frequently present in all the varieties of granite previously mentioned, and more or less modifies their appearances.

The tourmaline granite usually occurs in veins of inconsiderable size. Such granites are associated with those that are extensively worked, and in themselves are often beautiful, but they do not exist in accumulations of such size as to warrant the opening of quarries to work them exclusively. The tourmaline granites must, therefore, be considered as accessory products that exist in connection with the quarried stones, but which are not extracted for economic purposes.—G. W. H. (*a*)

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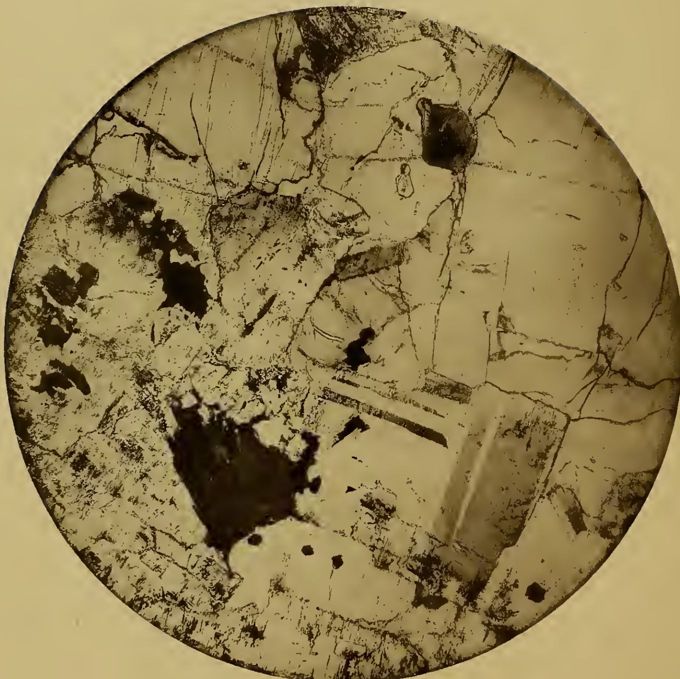
a The chapter to this point is from Dr. Hawes' notes.

PLATE I.

Muscovite Granite,

Barre, Vt.

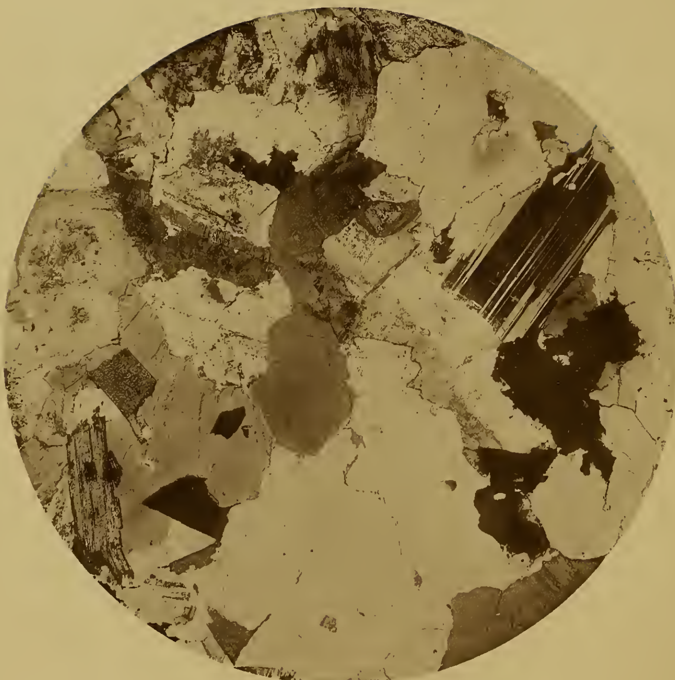
PLATE II.



Biotite Granite,

Dix Island, Me.

HELIOTYPE [illegible] CO. BOSTON



Biotite Granite,

Sullivan, Me.

The granites at present quarried throughout the United States may be classified as follows:
Muscovite granite.
Biotite granite.
Muscovite-biotite granite.
Horneblende granite.
Hornblende-biotite granite.
Epidote granite.
Granitell, or granite without any accessory.

Although it is possible to classify all the granites under these heads, the lines of distinction between them are by no means sharply drawn, but the different varieties merge into each other by continual gradations. For instance, nearly all the muscovite granites contain a little biotite, and *vice versa;* also, nearly all the hornblende granites, as those of cape Ann and other localities, contain some mica, although not in all cases enough to be visible without the aid of the microscope. In these cases the dividing line must necessarily be drawn somewhat arbitrarily, and it is the prevailing accessory which has given the specific name to the rock; or when two are present in such abundance as to be both evident to the naked eye, then the two descriptive names are employed, as in the case of the muscovite-biotite granite of Concord, New Hampshire, which contains both micas in nearly equal proportions.

MUSCOVITE GRANITE.

Since muscovite itself is very nearly colorless, the granites bearing this mica as their chief accessory are very light in color, being in fact the lightest of all our granitic rocks. Pure muscovite granites are not at present extensively quarried. That found at Barre, Vermont (*see* Plate I), is a coarse, light gray rock of almost marble whiteness, a polished surface of which presents a somewhat mottled appearance due to the presence of quartz and mica. The prevailing constituents are quartz, orthoclase, plagioclase, and white mica or muscovite. When examined in thin sections under the microscope the interstices between the larger crystalline grains are found to be filled with very many smaller grains of quartz and feldspar, together with shreds of mica and numerous accessories, giving rise to the structure known to lithologists as "drusy".

The mica as seen in ordinary light is quite colorless, but between crossed Nicol prisms it gives a most beautiful iridescence. It occurs usually in ragged shreds, but rarely in small forms with definite crystalline outline. A very little biotite is also present. The feldspars are the predominating minerals and occur in more or less perfect crystals, while the quartz grains fill the interspaces. The chief accessory mineral in this rock is epidote, which occurs in small irregular grains without definite crystalline outlines and is traversed by numerous fractures. In the thin sections it is of a very faint greenish color. Some apatite is also present in the form of small, colorless, six-sided crystals, which are never large enough to be visible to the naked eye.

A fine gray muscovite granite of a slightly darker shade, though much more even in texture, is quarried near Atlanta, Georgia. This rock is richer in both quartz and mica than its representative from Vermont, but contains less epidote. A large part of the feldspar of this rock is microcline, as is shown by its peculiar reticulated structure when viewed in polarized light.

BIOTITE GRANITE.

This constitutes the most widespread group of our granitic rocks, and presents also the most diversified color and structural peculiarities. A large proportion of all the granites at present quarried in the United States is referable to this group. In color they vary from light to dark gray and almost black, according to the amount of mica they contain and the color of the feldspar; the red granites, many of which belong here, owe their color to the flesh-red orthoclase, which is the prevailing ingredient. As a general thing these granites are much tougher and harder than those of the preceding group, and, if we except the porphyritic varieties, possess a more even texture, lacking the drusy structure characteristic of muscovite-bearing rocks. The texture, however, varies almost indefinitely, and it is obviously impossible to select rocks from any one locality as typical for the group. Perhaps the more common varieties are those represented by the granites from Dix island, Maine, Westerly, Rhode Island, and Richmond, Virginia.

The essential constituents of biotite granite are quartz, orthoclase, and biotite, but a plagioclastic feldspar is almost invariably present, together with some magnetite and apatite. The usual accessories are microcline, hornblende, muscovite, apatite, epidote, sphene, and zircon. It is stated by Rosenbusch (*a*) that the biotite granites, as a class, usually contain less quartz and a correspondingly larger proportion of plagioclase than those of the muscovite-bearing group.

As representatives of this group Plates II and III are given from sections of the granites from Dix island and Sullivan, Maine. These are both coarse, gray rocks, containing a considerable proportion of plagioclase in connection with the orthoclase. The biotite in thin sections is of a yellowish-brown color and bears numerous inclosures of apatite and magnetite. The pores in the quartz of these rocks are neither abundant nor large; in the Dix Island granite they are often arranged in fine wavy lines traversing the quartz grains in directions nearly parallel to one another.

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a Mikroskopische Physiographie der Massigen Gesteine, p. 20.

The biotite granites from Manchester, Virginia, and vicinity are practically of the same constitution as these, although differing in details of texture. Small zircon crystals and scattering flakes of muscovite, together with a few garnets, are found in these rocks.

The granites of Westerly, Rhode Island, are biotitic, but differ from those just mentioned in being usually of a finer texture and more rich in accessory minerals, containing frequently small crystals of fluor-spar, sphene, menaccanite, magnetite, apatite, epidote, and pyrite; the quartz contains also many of the small, thread-like crystals so characteristic of rutile. Many of the Westerly granites are of a flesh-red color, but otherwise than this they do not differ materially from the ordinary gray granites, the red color being as usual due to the red orthoclase they contain.

The red granites quarried at Red Beach and at Jonesboro', Maine, have biotite as their characterizing accessory. These are coarse, compact rocks of even texture, and tough and hard. They bear but few accessory minerals, a little apatite and magnetite only being observed. The mica occurs usually in small ragged shreds of a greenish color.

The red granite quarried at Lyme station, Connecticut, differs from the last in being of a still coarser texture, and in the feldspars occurring in beautiful large glassy crystals. The proportion of plagioclase is much larger than in the Maine red granites, and it contains little if any apatite and magnetic iron. The quartz contains numerous quite large pores or cavities, in many of which moving bubbles were noticed, while in others the bubbles were motionless.

The Leetes Island and Stony Creek red granites are of a much lighter shade than those of Lyme, the feldspars being only light pink or flesh-red in color, and of a more gneissoid structure. Some muscovite is present, together with the biotite and a little epidote; the quartz contains but few cavities. A part of the Leetes Island rock has a porphyritic structure, and is of a mottled pink and gray color, due to the larger pink feldspar crystals being surrounded by a finer admixture of small grains of quartz and mica.

A coarse red granite is quarried in the vicinity of Iron Mountain, Missouri, a part of which differs from any of the preceding in containing no characterizing accessory, to the unaided eye the stone appearing to consist only of quartz and feldspar. Under the microscope a few grains of magnetite are visible, as well as a few scales of hematite. Other granite from this locality contains black mica, which is usually more or less altered into chlorite. A red granite comes from Burnet county, Texas, which is of a fine, even texture, and contains much plagioclase. So far as observed this stone is lacking in tenacity, but this is very probably due to the fact that the quarries have not yet been worked to sufficient depth to bring to light the better portions of the rock, the feldspars showing signs of decomposition such as are produced by weathering.

The red biotite granite from the government quarries at Platte cañon, Colorado, is much coarser than the last, and contains many blood-red scales of hematite. The biotite is very dark and opaque.

So far as observed, all our porphyritic granites are biotitic. A part of the East Bluehill (Maine) rock is a beautiful example of this variety. This is a fine dark-gray rock, the uniformity of whose texture is broken by a plentiful sprinkling of snow-white orthoclase crystals of an inch or more in length, the crystals being usually in the form of Carlsbad twins. In many of the East Bluehill rocks the biotite is found altered into a chlorite, in which case it contains numerous inclosures of magnetite. Muscovite is also frequently present in small quantity, together with the usual colorless apatite crystals.

MUSCOVITE-BIOTITE GRANITE.

As its name denotes, this variety combines the properties of both muscovite and biotite granite, and may be considered as intermediate between the two. Transition stages between this and true muscovite or biotite granite are continually met with, and, as already stated, no sharp line of distinction can be drawn between them. The essential constituents are quartz, orthoclase, muscovite, and biotite; small transparent crystals of apatite are nearly always present, together with more or less plagioclase; zircons occur quite rarely.

Of this variety, the so-called Concord (New Hampshire) granite may be considered as typical. It is a fine-grained, light-gray rock, showing under the microscope a somewhat drusy structure. The feldspars are in nearly every case more or less turbid through decomposition and impurities, while the quartz is penetrated in every direction by small needle-like crystals of rutile. Fluidal cavities are quite small and not at all abundant. According to Dr. Hawes, (*a*) the plagioclase of this rock is oligoclase; some microcline is also present. The micas usually occur in small, irregular flakes, without definite crystalline outline, but occasionally a small, perfect crystal of muscovite can be seen.

Between the Concord and the lighter colored of the Fitzwilliam granites there is no essential difference. Microscopic particles of zircon were found in the Fitzwilliam rocks, which were not noticed in those of Concord.

The granites quarried at Allenstown, Sunapee, and Rumney offer no differences of practical value. As a general thing they are much like the Concord, presenting only slight variations in the way of color and texture. The feldspars as seen by the microscope are sometimes in a little fresher state and contain fewer impurities, while the quartz usually contains less rutile, that from Rumney having none at all, and fluid cavities are perhaps a trifle more

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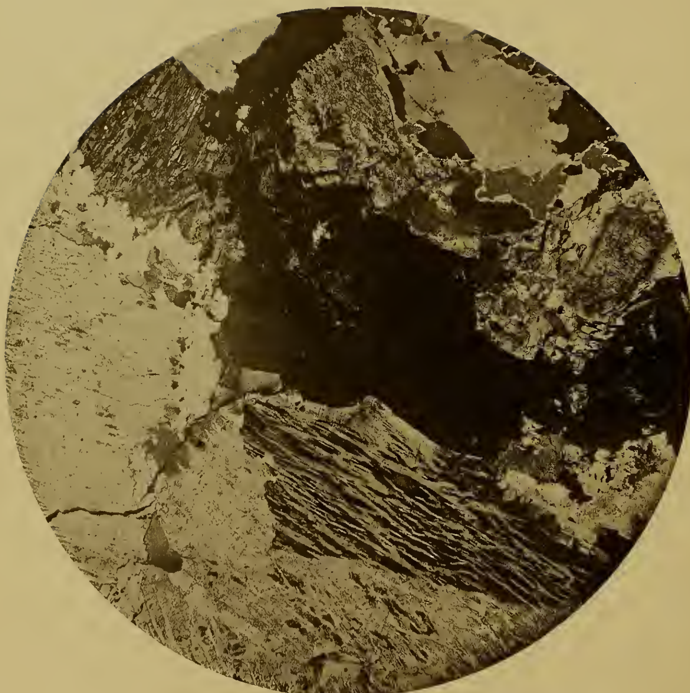
a *Min. and Lith. of N. H.*, p. 194.

PLATE IV.



Hornblende Granite,

Peabody, Mass.

abundant. The Manchester granite differs from any of the preceding in being of coarser texture, with a flesh-red color, and containing very little biotite, but a much larger proportion of microcline. The quartz frequently contains small colorless crystals resembling fibrolite; brilliantly red scales of hematite are also occasionally met with, as well as many large opaque grains of magnetite.

Outside of New Hampshire, muscovite-biotite granite is quarried quite extensively at Ryegate, Vermont, and at North Jay, Lincolnville, and Hallowell, Maine. The Ryegate rock is of coarser, more even texture, and contains a larger proportion of quartz than that of Concord. The quartz is almost entirely free from rutile inclusions and the feldspars are in a very pure condition, in both of which respects it closely resembles the Jay rock. The Hallowell and Lincolnville granites resemble the Concord closely, both in color and in structural peculiarities, even to the presence of the rutile inclusions. It contains, however, a much larger proportion of the feldspar microcline. A few garnets unobserved elsewhere are present in the Hallowell rock.

A rather coarse biotite-muscovite granite is quarried near Fredericksburg, Virginia. The feldspars in this rock are quite impure and frequently contain numerous inclosures of muscovite. Microcline is quite abundant in this rock, as is the case also with that of Hallowell and Augusta, Maine.

HORNBLENDE GRANITE.

As has already been stated, no sharp lines of separation can be drawn between the different varieties of granite, and in no case is this better illustrated than in those rocks bearing hornblende as their chief accessory, nearly all of them containing more or less black mica. This is well illustrated in the case of the granite quarried at Gloucester, Rockport, Lynnfield, and other localities in Massachusetts. From specimens of these rocks forwarded to the Museum it appears that while with one or two exceptions they would, from a simple macroscopic examination, be classed as hornblende granites, the microscope shows a constant gradation from those in which biotite is easily distinguishable in the hand specimen to those in which apparently there is none, more or less mica appearing in all. The distinction must, therefore, be somewhat arbitrary, and only those have been called hornblende granites in which no biotite was visible to the naked eye. (*a*)

As typical of this group, Plate IV is given. It is from a magnified section of the rock quarried at Peabody, Massachusetts. This rock, which agrees so closely with that quarried at the other localities named that a single description will do for all, is a coarsely crystalline rock composed essentially of quartz, orthoclase, and hornblende, the orthoclase being frequently of a faint greenish or bluish tinge, while the quartz varies from light glassy to dark smoky tints. The rock is of quite uniform texture, exceedingly hard and tough, and may be ranked as one of our most durable granites. Under the microscope it is seen that the feldspar of this rock is nearly all orthoclase in a very fresh and undecomposed condition, and as orthoclase is the hardest and toughest of all the feldspars the predominance of this variety over all others easily explains the hardness of the rock. In none of the granites quarried during the census year are the plagioclastic feldspars entirely absent, though sometimes prevalent in very minute quantities, as is well illustrated in the hornblendic granites of Gloucester, Roxbury, Lynnfield, Peabody, etc., and especially in that of the last-named locality, where it exists only as minute microscopic crystals, filling the interspaces between the larger crystals of orthoclase. The quartz, which is quite abundant, contains the usual cavities, in some of which moving bubbles occur. The hornblende is of a deep green, almost bluish, color, and never occurs in perfect crystals, but rather in broken fragments and ragged shreds bearing numerous inclusions of apatite and zircon. Zircon is especially abundant in the Gloucester granites, where it occurs usually in small, square prisms scattered irregularly about or clustered around the ragged edges of the hornblende crystals. Some magnetite is usually present, and an occasional shred of black mica.

A very beautiful deep-red hornblendic granite is quarried at Otter creek, Mount Desert, Maine. It is a very compact rock, though not quite as tough as those from cape Ann. Under the microscope the feldspar is found to be quite opaque through impurities. The hornblende is deep green, nearly black, and some chlorite and apatite are present, together with quite large epidote granules and a few zircon crystals.

Two varieties of hornblende granite, one red in color and the other gray, are quarried at Saint Cloud, Minnesota. They differ, however, from their Massachusetts representatives, being of more uneven texture and containing a larger proportion of hornblende. The hornblende, which is frequently much decomposed, is of a deep brown color in thin sections and strongly dichroic. It contains numerous inclusions, such as apatite, magnetite, and zircon, although these last are not as prevalent as in the Gloucester rock; some biotite is also present. The feldspar, as in the Massachusetts rock, is nearly all orthoclase, is quite impure and opaque, and the quartz contains many inclusions and cavities, some of which are quite large. Although of the same mineral constitution as the Cape Ann granites, these are of decidedly inferior quality, being softer and less tenacious. It is more than probable, however, that when the quarries have been worked to a sufficient depth a far better quality of rock will be produced.

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a It is very probable that much of the black mica of our granites is not biotite, but lepidomelane or annite, these being the names given by Professors Dana and Cooke to the black mica of the Cape Ann granite. Such differ from biotite in containing sesquioxide of iron in place of the protoxide, and in being more opaque and less elastic. Their optical properties are, however, identical with biotite, and in the present work no such distinction has been deemed advisable. All black dichroic micas have, therefore, been called biotite. (See *Hawes' Min. and Lith. of N. H.*, p. 82.)

A coarse, red hornblendic granite is quarried at Grindstone island, New York, in which, however, the hornblende has undergone extensive alteration, and which contains so large an amount of calcite as to effervesce distinctly when treated with a dilute acid. A little mica is present, which is of a copper-red color in the thin section, and a few small apatite crystals, together with numerous crystals of zircon. The rock contains considerable pyrite, which may be easily observed on a polished surface of the stone as small specks of a yellow metallic luster. The quartz occurs only in very small grains grouped together in the interspaces between the feldspars.

HORNBLENDE-BIOTITE GRANITE.

The rocks of this group stand intermediate between true hornblende and biotite granites, and combine to a certain extent the properties of both. The essential constituents are quartz, orthoclase, hornblende, and biotite, with the usual accessories. To this group belong some of our most beautiful granites. Plate V is from a magnified section of a granite of this class—the so-called black granite of Saint George, Maine, the black color being due to the abundance of hornblende and black mica. Under the microscope it is seen that the rock contains a small amount of quartz and a proportionately large amount of plagioclase, and that the hornblende predominates over the mica. The feldspars are very fresh in appearance, and the quartz contains but few cavities. Magnetite and pyrite are present, together with a little apatite. This rock also contains a very considerable amount of calcite, which must have an important bearing upon its weathering qualities. It is a very beautiful rock, acquiring a fine polish.

In this group must also be placed a part of the granite quarried at cape Ann, Massachusetts, although the two rocks in general appearance are totally unlike, the Cape Ann rock being coarsely granular and of a slight greenish tinge due to the orthoclase, which is the prevailing constituent. Quartz is abundant, and the black mica and hornblende are in about equal proportions. Under the microscope the feldspar is found to be moderately pure, and but little plagioclase is present, the feldspar, as is usual in rocks rich in quartz, being nearly all orthoclase. Numerous quite large microscopic zircon crystals are found intermingled with the hornblende and mica.

A third hornblende-biotite-bearing rock is quarried at Sauk Rapids, Minnesota. This is a dark gray granite, of which the general uniformity of structure is interrupted by frequent black blotches of about the size of a pea, which are caused by segregation of mica. The feldspar is of a slightly pinkish tinge, and by the microscope is seen to be very impure and murky. The quartz contains very many inclusions and cavities. The general quality of the rock is much inferior in point of beauty to those previously mentioned.

EPIDOTE GRANITE.

Although very many of our granites bear epidote in small proportions, usually visible only with the aid of a microscope, the cases in which it is of sufficient abundance to give a specific character to the rock are rare, the epidotic granite quarried at Dedham, Massachusetts, being at present almost the sole representative. This is a fine, even-grained rock of a light pink color, spotted with small specks of light green, which are due to the included epidote crystals. Under the microscope the epidote appears usually in irregular grains of a faint yellowish-green color, and is but faintly pleochroic. A little biotite is present, which has in nearly every instance become altered into a green chloritic product. The feldspar of this rock is quite impure and opaque. Owing to its fine, even texture the rock works easily and takes a good polish. The granite quarried at Lebanon, New Hampshire, contains epidote in considerable quantity, a thin section under the microscope showing innumerable small, nearly colorless, crystals scattered throughout the mass of the rock. They usually occur in groups or clusters, and are the cause of the light green blotches seen on a polished surface of the rock.

SYENITE.

If in a granite the quartz is absent, or becomes so small in amount as to become a merely accessory constituent, the rock is called syenite.

Syenite is quarried to a very small extent in the United States. In the system of classification there are just as many varieties of syenite as of granite which are characterized by the presence of the same accessory ingredients. Lithologically, many of these varieties are known to exist; mica syenites of the various kinds, hornblende syenites, augite or pyroxene syenites, and epidote syenites are all recognized; but none of the extensively-quarried building stones in the United States are syenites, although very beautiful rocks occur which would be much admired if they were introduced into the market.—G. W. H. (*a*)

GNEISS.

The gneisses or stratified granites are extensively quarried. Stratification is a circumstance very favorable to the extraction of stone for some purposes. For example, the perfection of cleavage in certain directions makes it easy to split large slabs from the mass, to be used for curbings, pavings, steps, etc. The stones can also be split in

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a This paragraph is from Dr. Hawes' notes.

PLATE V.

Hornblende Biotite Granite,

St. George, Me.

Hornblende Biotite Gneiss,

Middletown, Conn.

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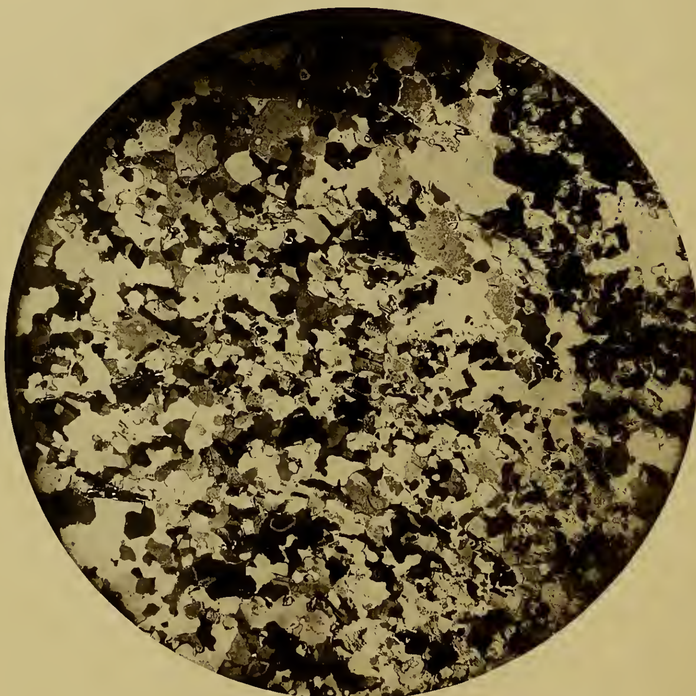
PLATE VII.



Mica Schist,

Washington, D. C.

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such a way as to always possess two parallel flat surfaces, a circumstance which simplifies the construction of walls from them. The stratification is caused principally by the arrangement of the mica with its flat cleavage planes arranged in parallel directions.

Quartz and feldspar are again the essential constituents, and the same accessories constitute a series of gneisses identical with the granite series. We thus have biotite gneiss, muscovite gneiss, hornblende gneiss, pyroxene gneiss, etc.

There are no uses to which granite is applied to which the gneissoid rocks cannot also be applied; and some of the largest quarries in the United States which are called granite quarries really produce gneiss. In common nomenclature these rocks are called granite, or at best "bastard" granite or "stratified" granite, or granite with some other adjective prefixed. There is reason for this in the circumstance that they are used for the same purposes and very often have had the same origin, and differ from one another only in that some slight movement in the mass at the proper time gave a stratification to the rock. In certain cases also the stratification is very faintly evident, so that it is difficult to recognize as stratification. Indeed, there is no line of division between the granites and the gneisses when the structure alone is considered.

There are many gneissoid rocks which are very markedly stratified, which consist of alternate layers of very different compositions, and which were apparently deposited like the limestones and sandstones, and subsequently hardened and crystallized. Even in scientific classification it is now impossible to separate gneisses that have been deposited in stratified layers from those which have become stratified, as explained, by movements in a plastic mass. In this work there is no necessity for any distinction, and rocks of the composition of granite, but stratified in structure, will all be considered as gneisses, for, from the economic standpoint, structure is of more importance than questions as to the mode by which it was produced.

MICA-SCHIST.

Mica-schist is a rock that consists essentially of quartz and mica. It usually possesses a distinct schistose structure due to the parallel arrangement of the quartz and mica, as was noted in the gneisses, from which it may be said to differ only in its lack of feldspar. It is a rock which is supposed to have been formed by the deposition and subsequent crystallization of sediments, and consequently the structure of these minerals and their arrangement are markedly stratified. The peculiarities of the schists are not such as to render them favorites for purposes of fine construction. They are, however, broken out from the ledge with great comparative ease, and for rough construction, such as foundations and bridges, they are extensively employed.

The mica of the schists may be either biotite or muscovite, or both; in short, the schists may be characterized by one or more of the same accessories as are the granites and gneisses, and we may have just as many varieties. Through a diminution of the amount of mica these rocks pass into quartz-schists, and, by an increase of feldspar, into gneisses. The relative amounts of quartz and mica vary almost indefinitely. The percentage of silica, which is dependent largely upon the amount of quartz, varies from 40 to 80 per cent. The finer grained, more compact varieties of mica-schist make very fair building material, but the coarser varieties are not to be desired, especially if the mica be biotite and in great abundance.

In accessory minerals mica-schists are particularly rich. Some of the more common of these are garnet, feldspar, epidote, cyanite, hornblende, chlorite, staurolite, magnetite, pyrite, tourmaline, and rutile. Through an increase in the amount of hornblende or chlorite the rock frequently passes gradually into hornblende and chlorite schists.

As an illustration of the microscopic structure of a biotite schist, Plate VII is given. This is from a magnified section of the schist quarried in the vicinity of Washington, District of Columbia, and popularly called "Potomac blue-stone". As will be noticed, this rock consists almost wholly of quartz and biotite, the quartz being in irregular grains, while the mica occurs in ragged shreds. The prevailing schists throughout the vicinity are, however, by no means of so simple a structure.

As a general thing the District rocks are distinctly schistose, the mica laminæ being arranged in parallel layers, and the rock consequently splitting easily in the direction of its schistosity. In some cases, however, the various mineral ingredients are so evenly commingled that all traces of schistosity are lost in small specimens, and the rocks, especially if they contain hornblende, more closely resemble basic rocks of eruptive origin, for which they have at times been mistaken.

Under the microscope the mica is seen to be frequently of a greenish color and to bear numerous inclosures of apatite, magnetite, and garnet. More or less white mica is frequently present, though never in sufficient abundance to give any distinctive character to the rock. Hornblende, when present, is usually in the form of slender rhombic prisms, which are often broken transversely. It is of a yellow or greenish-blue color, polarizing in deeper blue, or the lighter varieties in lively yellow and red, closely resembling augite. The crystals are quite imperfect, and are in many cases filled with inclosures of apatite, magnetite, and mica. It is frequently observed to have undergone an alteration into a greenish chloritic product.

One of the more abundant accessories in these schists is apatite. This occurs in small, perfect crystals which are nearly colorless in thin sections, though polarizing in faint yellow and bluish colors. The crystals are usually quite small, seldom exceeding 0.3^{mm} in length. Small, nearly transparent epidote crystals are also sometimes present, and quite often a triclinic feldspar, which is apparently oligoclase.

Another accessory of by no means so common occurrence, though quite abundant in some of these schists, is rutile. This occurs in the form of minute four- and eight-sided prisms, seldom more than one or two millimeters in length, and of a deep brownish-red color. Very small crystals are frequently found grouped together in nests of half a dozen or more, but the larger ones are always single and scattering. Geniculate forms, so characteristic of rutile, are met with but rarely. Their striking color renders them especially noticeable in spite of their small size.

Garnets are quite abundant, nearly every section showing one or more, and frequently they are so large as to be visible without the aid of the microscope. They are of rounded or irregular form, seldom with a perfect crystalline outline, and of a delicate salmon color, as seen in the section. They are sometimes quite pure, but many contain numerous inclosures of a black, opaque substance, which is probably magnetite, and also numerous quartz grains.

An accessory of more practical importance than any yet mentioned is the bisulphide of iron, or iron pyrites, which is only too abundant in much of this rock, occurring in cubical crystals and irregular grains of a brassy-yellow color and often of considerable size. On weathering, the pyrites oxidizes and disappears, but leaves its characteristic stain behind, and frequently produces the more serious result of disintegration.

DIABASE.

Under the term diabase is included a majority of the rocks commonly known as trap-rock and black granite. They consist essentially of augite and a triclinic feldspar, which is usually labradorite, though oligoclase and anorthite are not uncommon. As microscopic accessories they nearly always contain magnetite, titanic iron, and frequently apatite and black mica; hornblende and chlorite are not rare as products of alteration, a process to which these rocks, owing to their basic nature, are extremely liable. In texture the diabases are usually too fine to allow a determination of their mineral constituents with the naked eye, although porphyritic varieties are not rare. The color varies from dark gray to nearly black or greenish, according to the varying proportions of the different constituents.

These rocks are frequently called by the quarrymen and others black granite, although, as will be noticed, they differ from granite most decidedly, in containing no quartz, and in the feldspars being all triclinic; orthoclase, which is usually the predominating ingredient in the granites, being here entirely wanting. They are basic eruptive rocks of ante-Tertiary origin, and generally occur in well-defined dikes, cutting the surrounding formations in a manner very noticeable even to the most careless observer.

Plate VIII is from a magnified section of the diabase quarried at Weehawken, New Jersey. Identical (practically) with this are the trap-rocks quarried at various localities in New Jersey, Pennsylvania, and Virginia; and a similar rock, but of finer texture, comes from New Haven, Connecticut. The diabase quarried at Medford, Massachusetts, differs from those just mentioned in being of much coarser texture and in containing a pinkish feldspar and an abundance of black mica. An abundance of apatite is also present, and considerable chlorite. The feldspars in this rock are much decomposed, frequently so much so as to be almost unrecognizable. A micaceous diabase is also quarried under the name of black granite at Addison, Maine. This rock has a very complex structure. Besides mica, considerable hornblende is present, which results from the alteration of the augite, it being not infrequent to find a crystal the boundaries of which are unmistakably hornblende, while the center is still unaltered augite. A very similar rock, but containing olivine, is found at Indian River, Addison township, Maine. Olivine, however, is a mineral of very unstable composition, and is rarely found in an unchanged condition. In the present case almost the entire mineral has become changed to a serpentinous product, leaving but a small portion of the original substance near the center of the crystal still unaltered. Both of these diabases contain two varieties of plagioclase, and in addition to the minerals already named there are present chlorite, biotite, apatite, magnetite, and titanic iron, the last named being usually much decomposed and taking on very fantastic forms. A section of this rock is given on Plate IX.

An olivine-bearing diabase is also quarried at Vinal Haven, Maine, though in this case the olivine is much less altered than in the Addison rock. A little chlorite is present, and some biotite, but the composition of the rock is much less complex than is that of the stone from Addison.

BASALT.

True basalt is but little used for building purposes. Like diabase, it consists essentially of a triclinic feldspar, augite, and titanic iron or magnetite, or both. Olivine is also almost invariably present, while nepheline, leucite, hauyne, apatite, and mica are common accessories. It differs, however, from diabase in being usually of finer texture, and of more recent origin.

Of the same composition as diabase we would naturally expect to find the included minerals undergoing the same processes of alteration, which is often the case. Calcite, zeolites, chalcedony, and carbonate of iron often

Diabase,

Weehawken, N. J.

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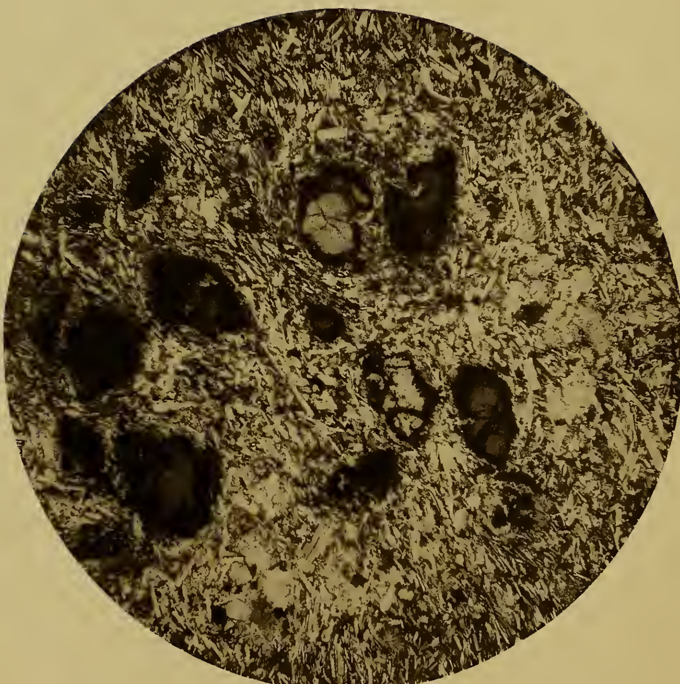
PLATE X.

Olivine Diabase,

Addison, Me.

PLATE X.



Basalt,

Bridgeport, Cal.

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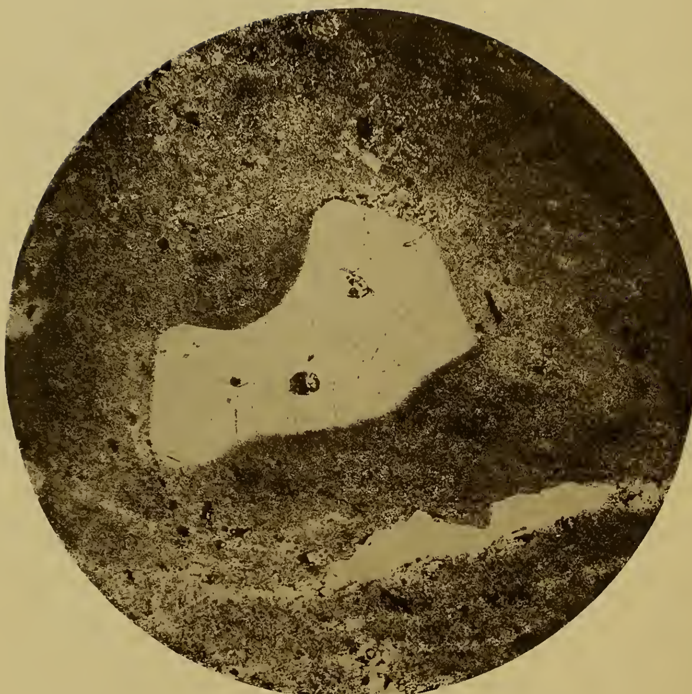
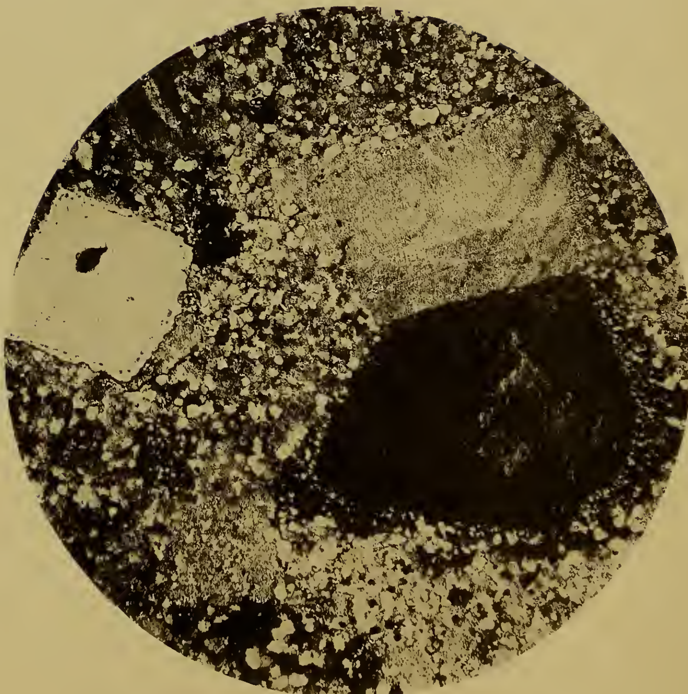
PLATE XI.



Quartz Porphyry,

Fairfield, Pa.

PLATE XII.



Orthoclase Porphyry,

Stone Mountain, Mo.

occur as secondary products, lining the walls of the small cavities or amygdules with which the rock is frequently filled. The feldspar of basalt can be either oligoclase, andesite, anorthite, or labradorite, and it is usually the prevailing ingredient; the spaces between the individual crystals are frequently filled with an uncrystalline, glassy magma, containing often numerous opaque, elongated, hair-like bodies, called "trichites".

Microscopic sections of basalt present many interesting features. The plagioclase usually occurs in small, slender crystals, showing in polarized light the customary banded structure, due to twinning. It is usually quite pure and free from all inclusions or cavities. The olivine appears rarely in well-defined crystals, but rather in rounded grains, traversed by many irregular curvilinear lines. They are sometimes of considerable size, so as to be easily distinguished by the naked eye. The augite in basalts is generally rich in inclosures of glassy matter, and in rocks which have undergone considerable decomposition both the augite and olivine are often represented merely by pseudomorphs of a green matter, either serpentine or some other hydrous silicate. Plate X is from a basalt quarried at Bridgeport, California. This is a fine-grained, brownish-gray rock, in which the included olivine crystals appear as small, greenish, rounded grains, often the size of a pin's head, scattered throughout the fine gray ground mass, the separate ingredients of which cannot be detected by the unaided eye. In the plate they appear as large, rounded, dark grains, surrounded by the smaller crystals of augite and plagioclase, like islands around which the semi-fluid mass has flowed.

PORPHYRY (PORPHYRITIC FELSITE).

Under the term porphyry it is usual to include a class of fine-grained, compact, felsitic rocks, the composition of which is not determinable by the naked eye, owing to the minuteness of the constituent minerals. The rocks consist essentially of quartz and orthoclase feldspar, one or both of which substances is frequently, though not always, present in crystals of considerable size, which lie embedded in the close, compact ground mass.

Under the microscope these rocks, as represented by the building-stone collection, can be divided into two classes, (1) those in which the ground mass is easily resolved into a crystalline aggregate of quartz and feldspar grains, and (2) those in which the ground mass gives between crossed Nicol prisms the polarization colors of an aggregate, which, even by high powers, cannot be resolved into its constituent minerals, owing to their minuteness. In both classes larger crystals of either quartz or orthoclase may or may not be developed to give rise to the well-known structure called porphyritic. According to which of these minerals is thus developed we have two kinds of porphyry—quartz porphyry and orthoclase porphyry. These two varieties are shown on Plates XI and XII. Plate XI is a quartz porphyry from Fairfield, Pennsylvania. The large white body in the center of the field is quartz, while the surrounding material is an intimate mixture of the same mineral and feldspar, but in so finely divided a state as to be inseparable by even the highest powers. Plate XII is of an orthoclase porphyry from Stone mountain, Missouri. In this rock it will be noticed that the ground mass is distinctly granular, and the porphyritic structure is due to large crystals of orthoclase, in place of the quartz as in the preceding. Both rocks are much alike in general appearance, although differing so decidedly in microscopic structure.

Porphyries are usually of eruptive origin, occurring in dikes, after the manner of what are popularly called trap rocks. The well-known porphyries in the vicinity of Boston are, however, according to some authorities, metamorphosed sedimentary deposits. (*a*)

Porphyries present considerable variation in color; whitish, flesh-colored, red, blue-black, black, and green are common varieties. They are very close-grained, compact rocks, and take an excellent polish. They are also almost indestructible, withstanding for ages the effects of weathering without appreciable change. Their hardness and lack of stratification, however, are great drawbacks to their extensive use, since they can be taken from the quarries only in small, very irregular blocks, and are cut with extreme difficulty. They are at present but little used for building purposes in this country. In Great Britain they are used chiefly for causeway stones and road metal, for which their hardness and toughness render them especially suitable.

SANDSTONES.

Sandstones are composed principally of rounded and angular grains of sand that have become cemented together through the aid of heat and pressure, forming a solid rock. The cementing material may be either silica, carbonate of lime, or an iron oxide. Upon the character of this cementing material is dependent to a considerable extent the color of the rock and its adaptability to architectural purposes. If silica alone is present the rock is light colored, and frequently so intensely hard that it can be worked only with great difficulty. Such stones are among the most durable of all rocks, but their light colors and poor working qualities are something of a drawback to their extensive use. The cutting of such stones often subjects the workmen to serious inconvenience on account of a sharp and very fine dust or powder made by the tools, and which is so light as to remain suspended for some time in the air. The hard Potsdam sandstones of New York state have been the subject of complaint on this score. Professor

a T. T. Bouvé, *Proc. of Boston Soc. of Nat. History*, 1862, p. 57; 1876, p. 217.

Geike, in writing on the decay of rocks, (*a*) mentions an instance in which a fine siliceous sandstone, erected as a tombstone in an English church-yard in 1662, and afterward defaced by order of the government, had retained the marks of the defacing chisel upon its polished surface perfectly distinct after a lapse of over two hundred years.

On the other hand, those rocks in which carbonate of lime is the cementing material, although soft enough to work well, are frequently too soft and crumble easily, beside disintegrating rapidly when exposed to the weather. On many accounts the rocks containing the ferruginous cement are preferable, since they are neither too hard to work readily nor are they liable to so unfavorable alteration when exposed to atmospheric agencies. These rocks also have a brown or reddish color, which is usually considered as something in their favor. The celebrated Portland brownstone, used so extensively for building purposes in New York city, is a good representative of this variety.

Sandstones are of a great variety of colors; light gray (almost white), gray, buff, drab or blue, light brown, brown, and red are common varieties, and, as already stated, the color is largely due to the iron contained by them. According to Mr. G. Man (*b*) the red and brownish-red colors are due to the presence of iron in the anhydrous sesquioxide state; the yellow color to iron in the hydrous sesquioxide state, and the blue and gray tints to the carbonate or the protoxide of iron. It is also stated that the blue color is caused sometimes by finely-disseminated iron pyrites, and rarely by an iron phosphate. (*c*)

In texture sandstones vary widely, from an almost impalpable fine grained stone to one in which the individual grains are the size of a pea. The looser varieties, in which the grains sometimes reach an inch or more in diameter, are called conglomerates, or if the pebbles are angular instead of rounded, a breccia.

Sandstones are not always composed wholly of quartz grains, but frequently contain a variety of minerals. The brown sandstones from Connecticut, New Jersey, and Pennsylvania are found on microscopic and chemical examination to contain one or more kinds of feldspar and frequently mica, (*d*) having in fact the same composition as granite or gneiss, from which they were doubtless originally derived. According to Dr. P. Schweitzer, (*e*) a fine-grained sandstone from the so-called palisade range in New Jersey contains from 30 to 60 per cent. of the feldspar albite. That quarried at Newark contains, according to his analyses, albite 50.46 per cent., quartz 45.49 per cent., soluble silica 0.30 per cent., bases soluble in hydrochloric acid 2.19 per cent., and water 1.14 per cent. This, however, must be regarded as an exceptional case, as very many sandstones contain no feldspar at all, being probably derived from a quartzose rather than from a granitic rock. Some sandstones are thought to originate from chemical deposition rather than from the disintegration of pre-existing rocks. Certain of the crystalline sandstones of Ohio are of this class. (*f*)

The minute cavities and moving bubbles so frequently seen in the quartz grains of granite are, as would naturally be expected, also occasionally found in sandstone, as is well shown in a white Potsdam sandstone quarried at Fort Ann, in the state of New York. The cavities in this case are extremely small, but the imprisoned bubble, as it glides unceasingly from side to side of its minute chamber, is readily seen with a microscope of high magnifying power.

Iron pyrites is a common ingredient of many sandstones, occurring frequently in cubical crystals or irregular grains of considerable size, and of a brassy-yellow color. Unless quite abundant, however, the chief danger to be apprehended from the use of such stone is the change of color it undergoes through the oxidation of the pyrites, which causes rust-colored or dark stains to appear wherever it exists. The beauty of many fine buildings has been sadly marred through the discoloration of the stone used for cappings and cornices by the oxidation of the included pyrites. Stone for such purposes should be subjected to careful examination, and all pieces in which the pyrites occur promptly rejected.

Nearly all sandstones are more or less porous, and hence permeable to a certain extent by water and moisture. Manifestly, then, in localities subject to any extremes of temperature, only those stones in which this porosity is reduced to the minimum should be used for buildings, since disintegration must certainly result if, after the pores of a stone become filled with water, freezing ensues. It is on account of the destructive effects of freezing water that such porous limestones as those of Bermuda and of Florida are totally unfit for use in countries in which the temperature falls frequently below the freezing point, although very durable in warmer climates. All sandstones absorb water most readily in the direction of their lamination or grain. It therefore follows, as every stonemason knows, that stone to weather well should be laid with its bedding (lamination) horizontal, as it was first laid down by nature in the quarry; the stone will also offer the greatest amount of resistance to pressure if laid in this manner, and, it is said, will stand a greater amount of heat without disintegrating; an important fact in cities, where any building is liable to have its walls highly heated by neighboring burning structures. The porosity of some sandstones is characteristically shown by their manner of drying after a rain; some will dry very quickly, while others containing a larger amount of water in their pores will remain moist a long time. Ordinary sandstones will absorb from 3 to

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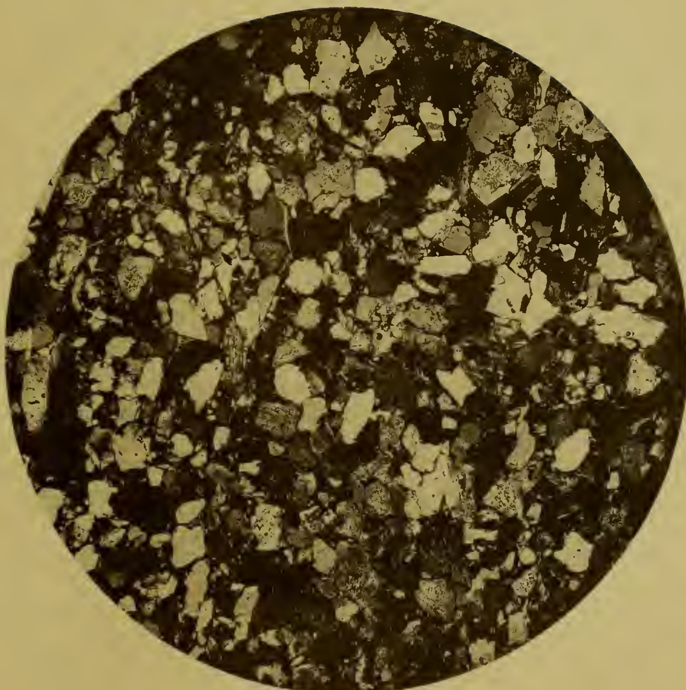
a *Geological Sketches at Home and Abroad*, p. 87.
b *Quarterly Journal of the Geological Soc.*, xxiv, p. 355.
c *Notes on Building Construction*, Part III (South Kensington series), p. 35.
d See Plates XIII and XIV.
e *American Chemist*, July, 1871, p. 23.
f J. Brainard, *Proc. Am. Soc.*, 1860.

PLATE XIII



Sandstone,

Portland, Conn.

PLATE XIV.

Siliceous Sandstone,

Potsdam, N. Y.

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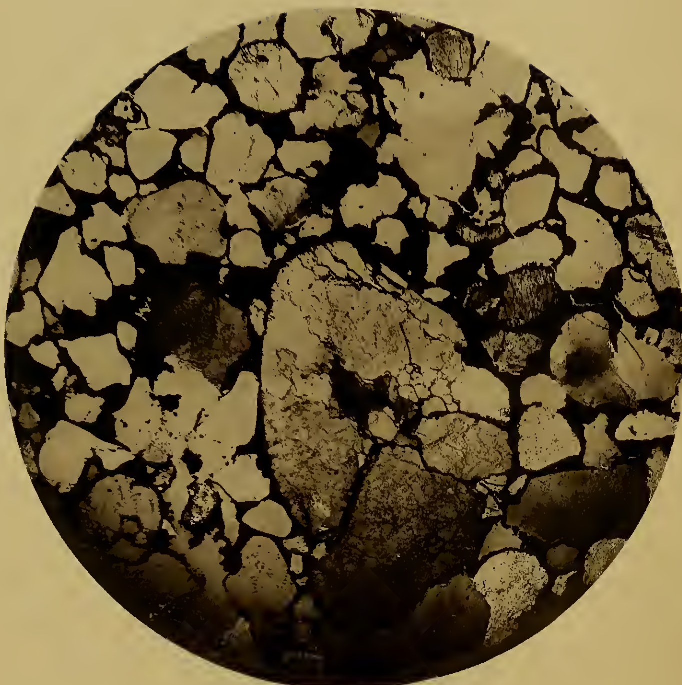

Conglomerate,

Estelville, N. J.

HELIOTYPE PRINTING CO. BOSTON

PLATE XVI.

Quartz Schist,

Berks Co., Penna.

HELIOTYPE PRINTING CO., BOSTON.

10 per cent., by weight, of water in 24 hours. Stone weighing less than 130 pounds per cubic foot and absorbing more than 5 per cent. of its weight of water in 24 hours, and effervescing somewhat actively with acid, is likely to be a second-class stone as regards durability. (*a*)

Some stones liable to the destructive effects of frost on first being taken from the quarries are no longer so after having been exposed for some time to the air, having lost their quarry water through evaporation. This difference is very manifest between stones quarried in summer and those quarried in winter. It frequently happens that stones of very good quality are entirely ruined by hard freezing immediately after being taken from the quarry (this being particularly the case with some marbles and limestones), while if they are quarried during the warm season of the year and have an opportunity to lose their quarry water by evaporation prior to cold weather they withstand freezing perfectly well. This phenomenon is easily accounted for if we admit the claim put forward by some that the quarry water of these stones carries in solution carbonate of lime and silica, which is deposited in the cavities of the rock as evaporation proceeds, thus furnishing additional cementing material and rendering the rock more compact. This will also account for the remarkable hardening of some stones after being quarried a short time, long since noted by those engaged upon stone work. When first quarried they are so soft as to be easily sawed and worked into any desirable shape, but after the evaporation of their quarry water they become hard and very durable. (*b*)

Conglomerate differs from sandstone only in point of structure, being coarser and of more uneven texture. This structure is well illustrated in Plate XV, which is from a magnified section of a conglomerate from Estelville, New Jersey. The large white grains are of silica and the dark cementing material is an iron oxide. These rocks are but little used for building purposes.

Quartzite is a hard, siliceous sandstone occurring in regions of metamorphic rock, and partially metamorphosed. It differs from ordinary sandstone in being harder and less friable. It sometimes possesses a well-defined schistose structure. Plate XVI is from a magnified section of a schistose quartzite from Berks county, Pennsylvania. Such rocks are very hard and compact, and would make very desirable building material.

LIMESTONES AND MARBLES.

Limestones consist essentially of carbonate of lime, though they are often more or less impure through the presence of organic matter and clay. It is usual to apply the name marble to those limestones that are highly crystalline in structure and susceptible of taking a good polish. The term is, however, very loosely applied, being sometimes made to include even siliceous crystalline rocks like granite. Limestones are mainly of organic origin; that is, they result from the deposition of organic remains, as shells, corals, etc. In many limestones these remains are still plainly evident, while in others they have become almost or entirely obliterated through metamorphism. The shell and coral limestones of Florida and of Bermuda are good examples of the first kind. In these the broken and water-worn fragments are simply cemented together by the same material in a more finely divided state without a trace of crystalline structure; and from these to a perfectly crystalline marble, without a trace of fossil remains, there is a constant gradation. The red-mottled and black marbles of Tennessee and of Isle La Motte, Vermont, are good examples of the semi-crystalline varieties. In these the microscope shows very plainly the remains of minute organisms, while at the same time the surrounding portions of the rock are crystalline. The oolitic limestones used so extensively for building purposes in Kentucky, Indiana, and Iowa are composed of the rounded grains of shells and corals closely cemented, and forming a very durable stone. They are generally quite soft and easily worked when first quarried, but become harder by exposure. The size of the individual grains is usually about that of a fish-egg, though they sometimes are larger, reaching the size of a small pea, when the stone is called pisolite. Some limestones are scarcely at all crystalline, nor do they show any trace of organic remains, but are perfectly homogeneous throughout. The stones quarried at Huntingdon, Pennsylvania, and at Kokomo, Illinois, are good examples of this variety. These stones are sometimes quite easy to work, though, being dull in color and not capable of receiving a good polish, they are not very desirable. They are usually very impure through the presence of clay and earthy matter.

Of the perfectly crystalline limestones, the white and the blue marbles quarried so extensively at Sutherland Falls and Rutland, Vermont, are the best examples. These are supposed to have been originally common fossiliferous limestones, and to have become crystalline and had all their fossils obliterated through the aid of heat and pressure. In some of these marbles the process of metamorphism was incomplete, and the traces of fossils still remain. According to some authorities (*c*) many limestones result not from fossil remains of animals, but from chemical precipitates from sea-water.

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a *Notes on Building Construction*, South Kensington series, Part III, p. 36.
b See Chateau, Vol. I, p. 265.
c T. S. Hunt, *Chemical and Geological Essays*, pp. 82 and 311.

The white crystalline marbles vary greatly in texture, the finest being found in Vermont, and coarser varieties farther south and west. According to Dana (a) the texture is less coarsely crystalline in Vermont than in Massachusetts, the crystallization of the limestone as well as of associated schists increasing in coarseness from north to south, or rather southwest, which is the trend of the limestone belt. The whitest marble of Rutland is not as firm as that mottled with gray, owing apparently to the fact that it was made white by the heat that crystallized it burning out any carbonaceous matter, while at Pittsford, 16 miles to the north of Rutland, it is very firm, and is white, probably because it was made with less heat from a whiter limestone.

Statuary marble is a pure white crystalline marble of very even texture; it is sometimes called saccharoidal, from the resemblance of its grain to that of pure loaf-sugar. Ophiolite or verd-antique is a mixture of limestone and serpentine, as will be noticed further on.

Carbonate of magnesia is a common ingredient of many limestones in varying proportions, and such stones are called magnesian limestones. When, however, the substances are present in the proportion of 54.35 parts of calcium carbonate to 45.65 parts of carbonate of magnesia, the stone is no longer called a limestone, but a dolomite. These stones are highly valued for building purposes, and "the best varieties are those in which there is at least 40 per cent. of carbonate of magnesia with 4 or 5 per cent. of silica". The nearer a magnesian limestone approaches a dolomite in constitution, the more durable it is likely to be.

It is not merely the nature of the constituents or their mechanical mixture that gives dolomite its good qualities; there is some peculiarity in the crystallization which is all important.

In the formation of dolomites, some peculiar combination takes place between the molecules of each substance; they possess some inherent power by which the invisible or minutest particles intermix or unite with each other so intimately as to be inseparable by mechanical means. On examining with a highly magnifying power a specimen of genuine magnesian limestone * * * it will be found not composed of two sorts of crystals, some formed of carbonate of lime and others of carbonate of magnesia, but the entire mass of stone is made up of rhomboids, each of which contains both the earths homogeneously crystallized together. When this is the case, we know by practical observation that the stone is extremely durable. (b)

The impurities in limestones are numerous. Many contain sand, which greatly injures their weathering properties; others contain clay and earthy matter, which are also elements of weakness, since they possess no strength in themselves, and, in addition, absorb water with the greatest ease, which renders the stone more liable to disintegration by freezing. Iron pyrites is a common impurity of many limestones, and such are to be avoided. Many of the Pennsylvania marbles contain talc or mica. A beautiful, coarse, rose-red marble from Danville, New Jersey, contains an abundance of black mica, which occurs in small hexagonal crystals. A limestone in the vicinity of Chicago, Illinois, contains petroleum to such an extent that blocks of it which have been used for building, become discolored by its exudation after a short exposure to the air, and this becoming mixed with the dust of the air forms a very unsightly tarry coating on the surface of the stone. "This rock, though porous and discolored by petroleum, is, when freed from this substance, a nearly white, granular, crystalline, and very pure dolomite, yielding 54.6 per cent. of carbonate of lime." (c) This oil is not always noticeable at first, but its presence can easily be detected by the well-known odor of petroleum which a sample of the rock gives off when struck with a hammer.

Oxide of iron is a common ingredient of many limestones, and to this substance is due the red color of the Tennessee, Mallett's Bay, and other red marbles. The blue or black color so common in limestones and marbles is due to carbonaceous matter derived from the decomposition of plants and animals in the waters in which the stones were originally deposited. Its carbonaceous nature is made very evident when the stone is subject to a high temperature by its becoming pure white through the burning out of this substance.

Limestones and marbles, owing to their beautiful colors and the ease with which they may be worked, are much esteemed for building and monumental work. They are not, however, the most durable of rocks, especially in cities where the air contains any considerable amount of carbonic, sulphuric, or chlorhydric acid, since these, even in very small amounts, readily attack the surface of the rock and cause it to crumble. A great deal naturally depends upon the texture of the stone. The most durable are those which are compact and homogeneous in structure and composition and not too coarsely crystalline. As a general thing the blue and gray colors denote a more durable rock than the pure white, for reasons already noted.

Limestones weigh from 112 to 185 pounds per cubic foot, the lighter weight being that of a shell limestone from Saint Augustine, Florida, and the heavier a compact, fossiliferous, semi-crystalline rock from Doughertyville, Tennessee. As would naturally be supposed, the heavier stone is much the more durable, being more compact and therefore less liable to injurious atmospheric influences. But few experiments have been made in this country upon the absorptive properties of stones, but according to the results of various experiments made in England, limestones vary in the amount of water they will absorb from 1 to 12 per cent., by weight, in 24 hours. The microscopic structure of a crystalline white marble from Rutland, Vermont, is shown on Plate XVII.

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a *Manual of Mineralogy and Lithology*, p. 433.

b *Notes on Building Construction*, South Kensington series, Part III, p. 58.

c T. S. Hunt, *Chemical and Geological Essays*, p. 172.

PLATE XVII

Marble,

Rutland, Vt.

HE IOTYPE PRINTING CO., BOSTON.

PLATE XVIII.

Serpentine,

Chester Co., Penna.

SERPENTINE.

Serpentine is essentially a hydrous silicate of magnesia, consisting, when pure, of nearly equal proportions of silica and magnesia, with some 12 or 13 per cent. of water. The massive varieties used for architectural purposes are, however, always more or less impure, containing frequently from 10 to 12 per cent. of iron protoxide, together with small amounts of chrome iron, iron pyrites, clayey matter, and the carbonates of lime and magnesia. It is a tough, compact rock of quite variable color, usually greenish, though sometimes yellow, yellowish-green, brownish-green, or, more rarely, red, its colors depending, according to Delesse, (*a*) upon the degree of oxidation undergone by the included ferruginous material.

The origin of serpentinous rocks has been a matter of considerable dispute. Formerly they were supposed to be eruptive, but later investigations have tended to show that this is not the case, but that they result from the metamorphism of magnesian sediments, (*b*) or from the decomposition or alteration of gabbro, diorite, and other hornblendic rocks, or from rocks rich in olivine, as lherzolite. We have already noted the extent to which the olivine in the diabase of Indian River, Maine, had become altered into a serpentinous product, and it is hence easy to understand how large masses might be derived from the alteration of rocks in which olivine was the prevailing ingredient. Plate XVIII is from a magnified section of the impure serpentine from Chester county, Pennsylvania. It is a fine-grained, porous, dull green rock, and so soft as to be easily cut with a knife. In thin sections under the microscope it is of a faint yellowish-green color, showing in polarized light a somewhat fibrous structure, the fibers forming an irregular network, the interspaces of which are filled in many cases with calcite. Many black grains are present, which in some cases are magnetite and in others chromite; the chromite usually occurs in small black kernels, which are quite opaque, or at best but faintly translucent upon the thin edges, where they show a faint reddish color. It is strongly magnetic; the magnetite is distinguished from the chromite by its entire opacity and its metallic blue luster as seen by reflected light.

Serpentine is sufficiently soft to be easily carved into any desirable shape, and can be readily turned on a lathe. It acquires a good polish, and is one of our most beautiful stones for mantels, table-tops, and all manner of indoor work. For outdoor work the polished stone is entirely unsuited, since when exposed to atmospheric influences, especially in cities, it soon loses its gloss, and, the surface weathering unevenly, it soon becomes as unsightly as it was once beautiful. Verd-antique is a marble or limestone through which green or yellowish veins of serpentine are disseminated. According to Hunt (*c*) the verd-antique marble of Roxbury, Vermont, is a mixture of serpentine with talc and a ferriferous carbonate of magnesia.

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a Zirkel, *Petrography*, Vol. I, p. 320.
b T. S. Hunt on Ophiolites, *Am. Jour. Sci.*, Vol. XXIII, p. 239; also *Chemical and Geological Essays*, p. 317.
c *Silliman's Journal*, 2d, xxv, p. 226.

CHAPTER III.—CHEMICAL EXAMINATION.

BY FRED. P. DEWEY, *Smithsonian Institution.*

The optical method of study is not suited to solve all of the problems of lithology, and it becomes necessary to supplement it by chemical examinations. Even when the optical properties of a mineral have been thoroughly worked out, it can generally be determined with certainty only when sections of known relations to its crystalline form can be prepared. The sections of minerals ordinarily obtained in the preparation of microscopic sections of rocks are, however, hap-hazard in their relations to the crystalline forms, and it is only by ascertaining these relations as far as possible, by an examination of outlines, cleavages, and other crystalline properties, that mineral species can be determined in rocks. The degree of accuracy which is thus obtained is sometimes insufficient for the desired purpose; for example, it can be determined that the feldspar in a rock is either the monoclinic orthoclase, the triclinic microline, or some one of the other species of triclinic feldspar, but which one of these it may be cannot with certainty be determined by optical examination. This is sometimes an important point. Again, in the case of minerals which can be determined with the greatest certainty, it is sometimes quite desirable to know the chemical composition of the species; for example, hornblende can, with almost entire certainty, be determined in thin sections of rocks, but this mineral is variable in its composition, and its properties as a constituent of a building stone may be quite different according as its composition varies, and especially according to the percentage of protoxide of iron it may contain. The composition of a rock as a whole, although important geologically, is of much less importance from an economic standpoint than the composition of individual ingredients, for the properties of the stone which fit or unfit it for use as a constructive material depend much more upon the peculiarities of its special ingredients than upon the ultimate composition of the whole. As is well known, a rock of a given ultimate composition may be a granite, a gneiss, a schist, a slate, or a sandstone, according to the circumstances of its origin and its subsequent transformation, and may be composed of very different mineral species; therefore, rocks of the same composition may be very different in their physical properties, and hence, in their capacities for resisting decomposing agencies and disintegration. It is therefore desirable to subject many of the stones which are to be considered as materials of construction to processes by which their individual mineral constituents can be separated from one another and analyzed. This indeed has been the object of those who are interested in the science of lithology, and various extremely complicated methods have been proposed to accomplish the result. A method has recently been proposed, however, which is much more efficacious than any previously applied, and as some of our results have been achieved by this method it will be briefly described:

The red iodide of mercury (HgI_2), possessing the high specific gravity of 6, is but slightly soluble in water; it is, however, very soluble in a solution of the iodide of potassium (KI), which has a specific gravity of 3.08. If, therefore, a saturated solution of the iodide of potassium is subsequently saturated with the iodide of mercury, a very heavy fluid is obtained, and the specific gravity of this fluid is such that many of the common minerals present in a rock will readily float upon it. This method of separation by means of a heavy fluid is said to have been proposed by Fleurian de Bellevue et Cordier at the beginning of this century. The solution of the double iodide of potassium and mercury was proposed by Church, in 1877, for use in the separation of minerals from one another. (*a*) The method was improved and new apparatus was proposed to be used with it by Thoulet, (*b*) who applied it with considerable success in the separation of minerals from granite and in determining the relative proportion of the various species in rocks of this nature. A further advance in the perfection of this solution was made by Goldschmidt, (*c*) who succeeded, by a careful study of the most favorable proportions between the two salts, in increasing the specific gravity of the solution and in extending the utility of its application. He also fully studied its properties and demonstrated its great advantages as a separating fluid. According to Goldschmidt, the heaviest fluid is not obtained by saturating with iodide of mercury a previously-saturated solution of iodide of potassium, but by dissolving the two salts simultaneously in water, using a smaller proportion of iodide of potassium than that found by analyzing such a saturated solution. After some experimenting, the method of preparing this solution adopted by myself, and which gives a solution of the very high specific gravity of 3.28, is as follows: One part of iodide of potassium is weighed out and placed in a beaker, and one and one-fourth parts of iodide of mercury weighed out and placed on top of the iodide of potassium; then water is added in the proportion of 10 c.c. per 100 grams of the mixed salts; in the course of a few hours, with frequent stirrings, the salts will go completely into solution. After filtering from the impurities of the salts, the solution is gently evaporated on a water-bath

a *Mineralogical Magazine*, November, 1877.

b *Bulletin de la Soc. Min. de France*, 1879, No. 1.

c *Inaugural—Dissertation, Philosophsche Facultät der Universetät Heidelberg*, Victor Goldschmidt. Stuttgart, 1880.

until crystals just begin to separate upon the surface; it is then removed from the water-bath and allowed to become thoroughly cold, by which means a considerable crop of crystals separates and a fluid of between 3.10 and 3.20 is obtained. By pouring off the fluid from the crystals and again heating gently upon the water-bath until crystals begin to separate, a further portion of water is driven off from the solution, and upon cooling there is a further separation of crystals, and a fluid of the gravity of 3.28 is obtained. My experience in using this solution indicates that there is a double salt formed of the formula $(HgI_2)\ (KI)_2$ soluble in water, much more soluble, however, in water containing a small amount of iodide of potassium; but any increase of iodide of potassium beyond a certain small amount decreases its solubility, and consequently the specific gravity of the solutions obtained. This solution is a very remarkable one, and besides its use as a separating fluid it finds many other applications; especially is it used by the physicists on account of its high index of refraction.

For use in separating the mineral constituents of rocks it possesses peculiar advantages besides its high specific gravity, the most important being that it can be mixed with water without suffering any change in volume, thus allowing fluids of any desired specific gravity to be prepared; and also by a simple calculation the reduction of any known volume of fluid of any specific gravity to any desired specific gravity, the formula for this reduction being $V_1 = \frac{V(D - \triangle)}{\triangle - 1}$, in which V equals volume of fluid, D its specific gravity, V_1 the volume of water to be added, and $\triangle$ the specific gravity which it is desired the final fluid shall have. There are, however, some disadvantages connected with the use of the fluid, the most important being its poisonous and corrosive properties.

In order to separate the mineral constituents of a rock by the use of this fluid, the rock is first pulverized so that the particles will pass through a fine sieve, the size of the mesh being governed by the fineness or coarseness of the texture of the rock. It is desirable to reduce the rock to as fine a powder as possible to avoid the presence of composite grains; at the same time it is not practicable to reduce it to anything like the fineness of dust, as that would remain for a long time suspended in the fluid without either sinking or rising. The powder thus obtained is washed with water in order to separate from it the exceedingly fine portion which of necessity is formed during the pulverization; when the mass has been so long washed with water that the particles all settle very quickly to the bottom, it is dried and placed in a tube with two stop-cocks at the bottom, provided with a perforated india-rubber cork at the top, with a bent glass tube and an india-rubber tube for making connections, and also a capillary tube from between the two stop-cocks rising nearly to the top of the tube; the tube is also graduated to admit of the ready measurement and consequent calculations of the fluids during the separation; the double iodide solution is added, and the whole throroughly mixed, preferably by drawing a current of air through the apparatus by means of the Bunsen pump; after remaining at rest for some time all those minerals present in the rock which have a higher specific gravity than that of the fluid fall to the bottom, and all that are lighter rise to the top; by opening the stop-cocks the portion which has settled to the bottom is drawn off; by closing the upper stop cock and drawing water into the lower portion of the tube by means of the capillary tube, the powder can be thoroughly washed from the apparatus; by adding water in successively calculated amounts to the fluid which remains in the tube, the other ingredients can be caused to fall to the bottom and be drawn off one by one—not, it is true, in a state of perfect purity, but in such a condition that the analysis of certain ones will very frequently lead to very important and desired results. The material which falls to the bottom when the fluid is at its highest specific gravity, generally complex in its nature, can be further analyzed by a variety of methods; a separation can very frequently be effected upon the ferruginous minerals by employing electro-magnets of successively increasing power. In some cases a separation can be effected by employing a mixture of chloride of lead of the specific gravity of 5 and chloride of zinc of specific gravity of 2.5, which fuses at a low temperature. A suitable mixture of the two chlorides can be fused in an elongated crucible and kept fluid at the lowest possible temperature; the heavy portion of the rock is then introduced and thoroughly incorporated with the liquid. After allowing a sufficient time for the rock materials to range themselves according to gravity, the heat is removed and the crucible is allowed to cool; by taking successive layers of the contents of the crucible and dissolving away the mixed chlorides a satisfactory separation can frequently be made.

The utility and the faults of the method will both be clearly recognized. As an example of its faults it may be mentioned that in the pulverization of the complex crystalline rock, no matter to what degree the pulverization be carried, some of the grains will of necessity be complex and float in the fluid in positions where they are not desired. The control, however, is kept upon the material intended for analysis by microscopic examination; and, although the full weight of the objection above mentioned is recognized, still results can be accomplished by the use of this solution which have been heretofore impossible.

There are cases of considerable importance in which the application of this method is especially satisfactory; for example, it is sometimes desired to separate from a rock one of its constituents which is either much heavier or much lighter than the other, and this can be done with the greatest ease. There are, on the other hand, cases in which the method is entirely inapplicable on account of the manifest impossibility of freeing the mineral constituents from one another, or o. separating them from one another, on account of the presence of minerals with nearly identical specific gravities; and in general the perfection or the imperfection of the separations that may be effected and the consequent value of the results can be determined by a consideration of the special cases as regards the minerals involved and the method of their combination, and by microscopic examinations of the sections and the separated products.

In the examination of the group of carbonates the chemical method has been almost exclusively used, and the classification is based upon this examination.

Of course the most satisfactory method would have been to make a quantitative analysis of each one, but with the large number to examine this was manifestly impossible, and a careful qualitative analysis giving an approximation to the relative amounts of the principal constituents was all that could be attempted. The method adopted was as follows: Measured portions of the powdered samples were introduced into test-tubes of the same size, and cold dilute hydrochloric acid was added, and the evolution of carbonic acid noted; the solutions were then boiled, allowed to settle, and the amount and character of the insoluble portion were carefully noted, and, when necessary, further examined. In a large majority of cases, however, the solutions were immediately precipitated by ammonia, and the amount and character of this precipitate noted; the solutions were then diluted with boiling water, measured portions of solution of oxalate of ammonia added to each, and the whole thoroughly shaken; they were then allowed to stand over night; the next morning the amount of precipitate of oxalate of lime was noted in each case; the solutions were then decanted into a second set of test-tubes, measured portions of phosphate of soda solution were added, and the whole rendered strongly alkaline by ammonia. After a thorough shaking they were allowed to stand twenty-four hours, when the amount of precipitate was noted.

In this way a tolerably fair idea of the approximate composition of the samples was obtained, and while there must necessarily be more or less variation in individual cases, it is thought as a whole the names adopted are just. In this connection it may be well to state that this work presupposes that the samples sent are truly representative samples as judged by the collectors, and that variations in separate quarries represented by specimens from one quarry, or even variations in the different parts of the same quarry, cannot justly be taken into consideration; and it must be borne in mind, too, that no classification of material so variable in composition as the carbonates can be rigidly exact. The system of names adopted is as follows:

Limestone, consisting of carbonate of lime.

Magnesian limestone, consisting of carbonate of lime with from 5 to 30 per cent. of carbonate of magnesia.

Calcareous dolomites, consisting of two portions, one of which is a true dolomite and the other effervescing freely in cold dilute hydrochloric acid.

Dolomite, consisting of carbonate of lime and magnesia, containing 30 per cent. or more of carbonate of magnesia.

Beside these, the following qualifying terms have been used:

Arenaceous, containing sand.

Argillaceous, containing clay.

Bituminous, containing carbonaceous matter.

CHAPTER IV.—QUARRY METHODS.

BY F. W. SPERR.

For quarrying each different class of rocks there is a characteristic method employed, which is, however, varied in detail in nearly every different quarry. The minor details of quarry methods are as various as the differences existing in the textures, structures, and modes of occurrence of the rocks quarried.

The methods of draining the quarries and the methods of ordinary rock drilling are the same as those employed in mines.

Machines in great number and variety for quarrying and dressing stones have been invented, but reference is made in this report only to such machines as are actually in use.

THE USE OF EXPLOSIVES.

All building-stone deposits have usually a certain amount of covering, consisting either of a portion of the same deposit which has been disintegrated by atmospheric influences or of a later deposit. This covering is called the "cap-rock" or "stripping"; the solid portions of it are broken up by blasting, and the whole is carted out of the way.

After a sufficient space is stripped, the next step necessary, when the quarry rock does not stand out in cliffs or escarpments, is to excavate a narrow space on one side for a quarry face, either by blasting or by some of the methods of channeling described herein.

For the purposes of stripping the cap-rock and "forcing" the face, the result to be attained by the use of explosives is the breaking up of the rock so that it may be taken out of the way with as little expense as possible, regardless of the shapes into which the pieces are broken; for this no special skill is required in the manipulation of the blast. Much, however, depends upon how the blast is made for quarrying the stone which is to be used. In the first place, the directions in which a blast will break any kind of rock from the drill-hole are but two or three, and sometimes four, unless the explosive be too quick and forcible in its action. The limited number of directions in which the rock is most liable to break is determined by the structure of the rock and the shape of the drill-hole. Quick-acting explosives, like dynamite, have a tendency to shatter the stone and break it in many directions, the texture being affected by the sudden explosion in the same manner as by the blow of a hammer. Coarse gunpowder is generally preferred for quarrying stone; and this is seldom used further than for detaching large masses, which are subsequently worked up by means of wedges. The drill-holes are put down to the depth to which the rock is to be split, and the requisite amount of powder is put in, covered with sand, and fired by means of a fuse. Sometimes numerous charges in a line of drill-holes are fired simultaneously by means of electricity.

Light charges of powder lightly covered with sand are better than heavy charges tamped in tight; and experience goes to show that better work is done by repeated light blasts in the same hole than by one heavy blast. By means of light charges often repeated a mass of rock may be detached without breaking up, which would be badly shattered by a single charge strong enough to detach the block.

At Conshohocken, Pennsylvania, a peculiarly stratified limestone, containing some schistose seams or layers, is quarried by first detaching large masses by repeated charges of powder. The rift or stratification is nearly vertical. Holes are drilled for the blast, sometimes 20 feet or more in depth, as nearly as possible with the rift. After the rock is quite well opened (or "drawn") by the light charges, a charge of several kegs of powder is put in to throw out the mass, sometimes containing several thousand cubic feet. If a heavy charge is at first put in, the break, instead of taking the direction of the rift, is liable to go in three directions, as determined by the triangular shape of the bottom of the hole. It will always be observed that a hole when drilled with a steel-bitted percussion drill is never round at the bottom; and when the hand-drill is used the hole is always triangular at the bottom, and a blast in such a hole breaks the rock in three directions. The influence of the shape of the hole upon the effects of the blast was observed in the brownstone (sandstone) quarries of Portland, Connecticut, many years ago; and the following devices for controlling the blast have long been in use there:

Deep holes, from 10 to 12 inches in diameter, are drilled by machinery, and the charges of powder are made to have definite shapes by being put in canisters, which are placed in the drill-holes and tamped in with sand, so that the effects of the blast are the same as though the holes were drilled of the shape of the canisters. To make one break across in a straight line the charge is made to have a horizontal cross-section bounded by two minor segments of a circle, the canister being made of two pieces of sheet tin, with the edges unsoldered and the ends made of paper or cloth. The plane passing through the edges of the canister is that in which the rock is broken by the blast.

Two breaks may be made with a single blast in planes crossing at right angles to each other by using a canister which is a square prism.

The holes are drilled from 10 to 20 feet or more in depth. Sometimes two holes are drilled close together, so that the core between may be chipped out; and canisters 2 feet across from edge to edge are used with tremendous effect.

In many of the large quarries of sandstone in this country explosives are not used for quarrying the stone; but in nearly all the smaller quarries gunpowder is used. The influence of the shape of the drill-hole upon the effects of the blast does not seem to be generally known, and a great waste of material necessarily follows.

Granitic rocks are less liable to be injured by the use of explosives than the softer rocks; but even for quarrying granite powder is used no further than for detaching large blocks, except in rare instances. In every quarry of this class of stones there is found to be a certain direction in which the stone splits more easily than in others, even when the structure is most decidedly granitic, though quarries are often worked a long time before the cleavage plane is discovered. When the cleavage is not very marked it is called "the grain" by quarrymen; and when it is more decided, as in gneissoid and schistose rock, it is called the "rift". In rifted rock there is a secondary cleavage plane at right angles to the rift, and this is called "the grain". "Across the grain" is in a plane at right angles to the grain and rift, or to the two cleavage planes. When the rift is horizontal, or nearly so, it is said to be "with the lift".

In every different locality the structure of the rock must be carefully studied with a view to take advantage of the cleavage planes and natural joints in the management of the blast. There must be at least one free end to allow the block to move out toward the face; and the ends are often cut off by natural joints called "end joints". Horizontal joints, called "bottom joints", occur in most cases.

To detach a block a bore-hole is put down to the first bottom joint, and light charges of powder, usually of about four pounds each, are repeatedly put in and fired to "draw the break"; and after the rock is well opened a heavy charge of one or more kegs of powder is made to move out the mass. In this manner blocks from 15 to 20 feet in width and 100 feet or more in length may be detached. When the rift is vertical, as in the quarries at Monson, Massachusetts, a blast put in a simple bore-hole will break the rock with the rift, in one direction to the free end, and in the opposite direction to an end joint; or, if there be no end joint in that direction, the break turns out more or less abruptly across the rift to the face.

When the vertical bore-holes for the blast cross the rift the shape of the hole controls the directions of the break as in other classes of rock. A hole with an elliptical, horizontal cross-section will always insure a single straight break in a plane passing through the long diameter of this cross-section. These holes are made by drilling two holes as close to each other as practicable, and then chipping out the core with a chisel-bar. They are called "lewis-holes" from their resemblance in shape to the lewis-hole made in the top of the dressed blocks of stone to receive the clamp or lewis by which the blocks are lifted.

It sometimes happens that there are no bottom joints, except at great intervals. The method adopted for detaching the blocks in a case of this kind at the Penryn quarries, California, has been described to me by Mr. William Foster, who was employed as special agent of the Tenth Census to collect the building-stone statistics in the western states and territories. An undercut is blasted out along the first bottom joint and from one end joint to another; a lewis-hole or line of lewis-holes 20 feet in depth is put down from 15 to 20 feet from the face, and the blast breaks out the block between the end joints and down to the bottom joint, which is about 80 feet from the top. Blasts put into rock in this manner act more nearly like wedges than the ordinary blasts, and are capable of splitting off blocks containing 100,000 cubic feet of stone.

The trap-rock quarried so largely at Weehawken, New Jersey, for paving blocks is blasted out without regard to the shape or the size of the blocks obtained; the main object of the blast being to throw out and break up as much rock as possible. Heavy charges heavily tamped with sand are the most effectual for this kind of work. The detached blocks are drilled again and blasted with smaller charges till they are reduced to about the size of 2 by 3 feet by 1 foot, and these are broken into paving blocks by means of hammers. Sometimes a groove is "chased" across a block and a fire is built on the line of the groove to break open the block.

Such limestones as the massive oolitic limestones of Indiana and the soft limestones of Kansas are quarried by channeling and wedging; but most limestones are used for rubble, cellar walls, and ordinary dimension work, for which cheapness is the first prerequisite; and therefore the stones are quarried by blasting. Undoubtedly the cheapest method of quarrying small blocks is by the use of explosives, unless the rock is quite soft; and for this reason explosives are most generally used in the newest portions of the country for quarrying building stones. In the case of limestones the badly shattered portions of the rock are usually burned for lime. Thin-bedded limestones are often quarried by raising the sheets with iron or steel bars. In a new country, if there are loose bowlders upon the surface, these furnish the first building stones used, and are usually broken up with powder or with fire. Such was the condition of quarrying at Quincy, Massachusetts, one hundred and fifty or two hundred years ago, where are now some of the largest and most systematically worked quarries in the country. The method of breaking up bowlders by heating them with fire, and then striking them with heavy hammers or pouring water upon them, is perhaps the rudest and cheapest, and is certainly the most disastrous in its effect upon the quality of the stone.

THE QUARRYING OF STONE BY CHANNELING AND WEDGING.

By channeling is meant the process of cutting long narrow channels in rock to free the sides of large blocks of stone. The method of cutting the channel depends upon the nature of the rock. Marble was, until quite recently, channeled by hand, using a long steel bar, chisel-shaped at one end, cutting a channel about 1½ inches wide. This method is still in use to some extent, but it has been largely superseded by the use of machinery.

Quite a large number of machines for quarrying stone have been patented in this country, but only the Wardwell channeling-machine and the Sullivan diamond channeling-machine have as yet proved successful. Each of these machines has its special merits for certain kinds of work, and both of them are often used in the same quarry for different portions of the work. In marble, these machines taken together are capable of doing all kinds of channeling required.

The machine illustrated in the cut, Plate VII, is a double-gang Wardwell channeler, it being the one mostly in use and adopted for all kinds of stone, except grit sandstone, and is represented mounted upon a steel-rail track on the bed of a quarry. The frame which supports the boiler, engine, and other machinery consists of one piece of forged iron weighing nearly a ton, thus furnishing great durability. The engine is of six horse-power, its shaft carrying a balance-wheel on each end, to which is attached an adjustable wrist-pin plate. The levers which operate the gangs of cutters are pivoted at their rear ends to an extension of the frame. The free end of the upper lever passes through a sliding stirrup or swivel attached to the wrist-pin plate (not shown), giving an up-and-down motion to that end of the lever as the balance-wheel revolves. The free end of the lower lever passes through a mortise in the back side of the lower clamp. Motion is communicated from the upper to the lower lever by means of clasps, between which the rubber springs are placed, as shown in the cut. The free end of the lower lever actuates the gang of cutters, which consists of five bars of steel sharpened at their lower ends and clamped together by head and foot clamps, the whole sliding freely on the standard. Of the five cutters, two have diagonal cutting edges and three have their edges transverse. The object of the diagonal cutting edges is to insure an even bottom to the channel. The center cutter extends the lowest, and they all together form a stepped arrangement each way from the center; thus when the machine is moving forward the center and two forward cutters operate upon the stone, and when moving in the opposite direction the other two with the center one perform the work. These bars of steel are from 7 to 14 feet in length, according to the depth of the channel to be cut. The upper ends of these bars are grooved to match corresponding grooves in the head clamp, for the purpose of preventing displacement of the cutters. The worm on the main shaft actuates the worm-gear upon the feed-shaft. The feed-shaft extends diagonally downward to the rear of the machine, where it terminates in a bevel pinion; upon the rear axle are placed two bevel gears, and, by means of the lever shown, either of these bevel gears may be thrown into action with the pinion. The motion thus communicated serves to turn the axle either forward or backward, according to which wheel engages the pinion. When the machine is required to be stationary the gears are so placed that neither engages the pinion. The short lever locks the gears in any of the required positions. The windlasses on each side of the machine are for raising the gangs of cutters out of the channels. The opposite side of the machine is exactly the same as the one already described. Channels are usually cut from 4 to 6 feet deep and 1¼ inches wide, except that in sandstone they are cut 2 inches wide; and they can be cut within 3 inches of a vertical wall.

It requires three men to operate the double-gang machine; from 300 to 400 pounds of coal are used per day, and the cost of operating is from $6 to $9 per day. This machine is calculated to cut from 75 to 150 square feet of channel in marble and limestone, and from 150 to 200 square feet in sandstone, per day, doing the work of fifty men.

One form of the Sullivan diamond channeling-machine is illustrated on Plate VIII. The principle here involved is the communication of rotary and feed motions to drill-rods on spindles; and the special advantages held by the machine are that it is capable of cutting channels vertically or at any angle of inclination, and, with the machine detached from the boiler, that channels may be cut under an overhanging wall. At one end of the drill-rod is the drill-head, 1¾ inches in diameter, armed with carbon or black-diamond points, and supplied with small apertures or outlets for water, which is forced through the spindle and drill-head. The pump which supplies the boiler also supplies the drills, the feed to the different parts being regulated by stop-cocks. The jets of water wash out the borings and keep the drill-head from heating. The drill-rods are made of varying lengths adapted to make any required depth of channel to 9½ feet.

A continuous open channel is cut in the rock by two operations. By the first, a series of holes is drilled, distant from each other a little less than the diameter of the drill-head. The rock partitions thus left between the holes are drilled out by the second operation.

Holes are bored by the first operation, uniformity of distance between them being secured by a guide, and a short plain sleeve is used on the drill-rod just above the boring-head. For the second operation this sleeve is replaced by a double guide, whereby the action of the boring-head is confined to the rock partition between the holes previously bored.

In the above figure the machine is supposed to move back and forth so as to cut a separate channel with each spindle, while on Plate VIII the machine is so mounted as to move sidewise and cut a single channel with the two spindles.

For cutting vertical channels the Wardwell machine is considered the most economical, but for cutting oblique channels the Sullivan machine is used. When the excavation is carried with the inclination of the strata, as illustrated on Plate II, the Sullivan machine is utilized to cut the oblique channel and portions of the vertical channels next to the overhanging wall. In such quarries the blocks do not come out rectangular in shape, and there is some waste of material, which becomes greater as the inclination of the strata becomes less. When the dip is not less than 50° the advantages of a horizontal quarry floor are sufficient to compensate for this loss of material; but when the dip is less than from 45° to 50° the channels are cut perpendicular to the plane of stratification with the Sullivan machine, and the blocks are quarried out rectangular in shape. A quarry with an inclined floor is illustrated on Plate IV.

After the requisite channel cuts are made about a block of stone it is necessary to undercut the block in order to release it. This is accomplished by drilling a series of holes about 8 inches apart along the bottom, and then splitting the block from its bed by means of wedges.

The work of drilling the holes is by quarrymen called "gadding". In most of the large marble quarries of this country this is accomplished by means of a machine, using the diamond spindle drill on the same principle as the Sullivan channeling-machine, and called a "gadding-machine". The holes are drilled to varying depths, depending upon the width of the block to be raised. In many quarries the blocks are made from 4 to 6 feet in width, and the bottom holes are gadded from 18 to 36 inches deep. The split is made with the common plug-and-feather wedges, which consist of two half-round pieces of iron (called feathers), tapering to a point at one end, and a wedge-shaped piece of steel called the plug. The length of the plugs is a little greater than the depth of the drill-holes in which they are to be used. The feathers are a little shorter than the plugs, and when two of them are placed with their flat sides together the large end just fits into the drill-hole, in which they are so placed that the points are left protruding slightly and the large end nearly reaching the bottom of the hole. The plugs are inserted between the points of the feathers, and when they are all thus set they are driven simultaneously till the block splits from its bed. A few of the wedges are then overdriven to loosen the others, in order that they may be withdrawn and used elsewhere.

In the Cockeysville marble quarries, near Baltimore, Maryland, the blocks are channeled from 8 to 15 feet in width by using one side of the Wardwell machine and cutting single instead of double channels. To raise these blocks the bottom holes are drilled 2, 4, and 6 feet in depth, and a wooden plug about 2 inches in length is put into the bottom of each hole. The wedges or plugs are round bars of steel of a diameter a little less than that of the drill-holes, and their lengths exceed the depth of the holes in which they are to be used by about 3 inches. The portion of the bar which is wedge-shaped is about 8 inches in length, and to this the feathers, of about the same length, are tied, the large end projecting a little beyond the end of the wedge. The feathers and wedges thus tied together are placed in the holes against the wooden plugs, which allow the wedges to be driven through and beyond the feathers if necessary. A block 8 feet thick, 15 feet wide, and of any length may thus be raised. The gadding-machine is further used for gadding the holes for splitting the large blocks into sizes suitable for handling. This operation is illustrated on Plate II. When the machine is adjusted for work it is braced by driving the pointed legs near the trunk-wheels hard upon the quarry floor. The boring apparatus is attached by a swivel to a perpendicular guide-bar, which is secured to the boiler and forms the main support of the machine. The boring apparatus may be raised and lowered upon the guide-bar and turned upon the swivel so as to bore in any direction within the plane of the swivel-plate.

Steel-bitted machines have not yet been improved so as to cut or gad the holes along the bottom of the blocks sufficiently close to the floor, but for gadding the side holes such machines are used to good advantage. They are not capable of doing as much work as the diamond machines, but the high price of the carbon points places the latter machines at a disadvantage.

In Rutland marble an ordinary day's work for one man is to channel by hand 3 square feet; to gad by hand, in depth, 12 feet. An ordinary day's work for the Wardwell channeler is 50 square feet; an ordinary day's work for the diamond channeler is 60 square feet, for the gadder 180 feet, and for the steel-bitted machine (*a*) 100 feet.

The above figures do not indicate the capacities of the machines under wholly favorable circumstances, but only their usual work with the usual contingent delays.

Guides cannot be attached to percussion drills so as to confine the action of the tool to a narrow rock partition between the holes, as is done with the diamond drill; though in some granite quarries continuous open channels are cut with percussion drills by first drilling a series of holes, with a 2- or $2\frac{1}{2}$-inch drill-bit, about three-quarters of an inch apart, which is as close as they can be cut without running into each other and wedging the tool. The cores are then chipped out by replacing the drill-bit by a tool of the same diameter, having a circular cutting rim and a diametrical cutting edge. The tendency to run off the core is partly obviated by the shape of the tool and partly by placing in the holes, on each side of the core, strips of hard wood of a thickness that will just allow the tool to go down between them. This seems to be the only practical method yet devised for channeling granite, though very little of this kind of work is done for the reason that the operation is very expensive on account of the hardness of the rock and because granite sustains less injury than the softer rocks by the use of explosives, which, therefore, may be employed for detaching large blocks without serious objection.

a The Ingersol rock-drill is the steel-bitted machine used for gadding in the Rutland quarries. The Rand drill is used in some other marble quarries.

The work of breaking the large blocks of granite into smaller sizes is accomplished altogether by means of plug-and-feather wedges. To break the largest blocks of gneiss or gneissoid granite with the rift plug-holes from 4 to 6 inches deep and 8 inches apart are sufficient; but to break such blocks across the rift, or to split blocks having a truly granitic structure, about every third or fourth hole is drilled to a depth depending upon the thickness of the block and firmness of the texture, by which a more perfect fracture is insured. These deep holes are drilled with a striking-drill operated by three men, one holding and turning the tool and two men striking with heavy hammers or sledges. The other holes are drilled with small hand-drills. The feathers or half-rounds and plugs or wedges are smaller than those used in the softer kinds of stone. The 4-inch plug-holes, about three-quarters of an inch in diameter, and wedges and half-rounds 3 inches in length, are used for splitting blocks of considerable size. The wedges draw more perfectly if they are oiled before they are driven.

In most of the large sandstone quarries, except those in the hardest kind of sand-rock, channel cuts are made to some extent. Usually in the softer sandstones channels about 18 inches in width and from 4 to 6 feet and sometimes even 15 or 20 feet in depth are dug around the sides of the quarry with sharp steel picks, and the loosened material is thrown out with shovels. Other similar channels are often made, especially in large quarries, to cut off a certain portion of rock. Sometimes these channels are cut only on three sides of a quarry, to give a face and free ends. In the brownstone quarries of Portland, Connecticut, the channel necessary for a quarry face is made and the ends are broken off by blasting, as already described.

Having a face and free ends in a bedded, stratified, or unstratified sand-rock, a groove parallel to the face is cut across the top. The distance of this groove from the face may depend somewhat upon the thickness of the bed. A row of wedges is set in this groove and simultaneously driven till the rock breaks open. A long rectangular block is thus detached, and afterward cut into smaller sizes by means of wedges. For splitting small blocks, instead of the continuous groove a short groove is cut for each wedge.

When wedges alone are not sufficient to split off a block, holes are drilled at intervals and to depths as may be required, and plugs and feathers are used in connection with the wedges. When the rock is stratified, but not bedded, a row of wedges with or without plugs and feathers, as the case may require, is driven along the bottom to raise the block at the same time that the top row of wedges is driven. When the rock is neither bedded nor stratified it is best to channel off blocks of such width that they can be raised by wedging along the bottom.

The process of quarrying sandstone by the methods most commonly employed is illustrated on Plate V.

The Wardwell channeling-machine has recently come into considerable use for quarrying sandstone. The cutting-bars for this purpose are made to cut a channel 2 inches wide and 4 feet deep, and are sharpened at both ends so that they may be reversed when one end is dull. These cutting-bars need to be sharpened more frequently in sandstone than in marble.

The work of channeling with picks and shovels is very injurious to the health of the workmen on account of the sand-dust inhaled into the lungs.

In the North River blue-stone quarries the rock is bedded and so jointed that no artificial channels are necessary for freeing the sides of large blocks. A quarry face is secured by excavating the rock between two parallel joints, which may usually be found but a few feet apart. This is called "forcing", and is done by drilling holes and blasting out the rock with powder.

The blocks are raised by driving wedges into the bed joints, unless the beds are too thick, in which case a row of plug-holes for splitting the block is put in along a line of stratification. The lines of stratification are called "reeds", and mark the planes along which the stone can be split up into thin slabs; they usually occur at intervals of from 2 to 6 inches, though sometimes at greater intervals, when the stone cannot be split up into flagging, but is suitable for dimension work.

After the blocks are raised from their beds they are broken across by means of plug-holes, about 8 inches apart, drilled across the top. Small point-holes are also made between the plug-holes. The quarryman first drives the plugs tight and then drives the point into one point-hole after another all along the line, the object of this being to assist the wedges and to secure a straight fracture. The wedges and point are driven alternately till the stone breaks. Small blocks can usually be split along the planes of stratification by simply driving the point in along a reed.

Where the rock lies in thin beds or sheets the blocks are pried up with long steel bars. If slabs of less thickness than that of the natural beds are desired the blocks are split before they are broken across.

A peculiar method of reducing large blocks by means of wedges is employed in the limestone quarries at Conshohocken, Pennsylvania. This limestone is magnesian in composition, has a rifted or foliated structure, is capable of withstanding a great transverse strain, and works in a manner peculiar to itself. The large blocks are detached by blasting, as described on page 33, and are made to lie with the rift horizontal; lines of holes are drilled from the top as nearly through the blocks as possible without chipping out a piece at the bottom, and from one side horizontal rows of holes are gadded to a depth of from 1 foot to 3 feet, depending upon the size of the blocks. In this manner all the drill-holes necessary for reducing a large block with plug-and-feather wedges to blocks of required dimensions are drilled; the holes from the top crossing the rift (or "split") are drilled about 8 inches apart, and those from the side several feet apart. The blocks are first split with the rift and then across it.

In the soft-limestone quarries at Winfield, Kansas, a common auger, not pointed, is used for boring holes for the plug-and-feather wedges. A $1\frac{1}{2}$-inch auger bores 6 inches in depth per minute.

In soap-stone quarries the blocks are at once cut up by the channels into sizes suitable for handling, wedges being used for cutting off the bottom only. A wedge fracture in soap-stone is somewhat ragged. The channel is cut to its full depth at one end, from which it is then cut back by paring off successive increments from top to bottom with a long steel bar having the cutting end beveled from one side. These bars are called chisel-bars or channeling-bars.

As all the softer rocks are more or less shattered when quarried by the use of explosives, the process of channeling has largely superseded that of blasting in this country for quarrying all kinds of rocks for building purposes, except slate and granitic rocks. It is the improved methods employed in quarrying that give the American marbles a claim to superiority over the Italian or Carrara marble.

At Carrara, Italy, the marble stands in immense cliffs on the sides of steep and rough mountains, and masses weighing many tons are blasted off and allowed to fall sometimes from 400 to 500 feet before striking. The jar sustained, both by the blast and by the fall, injures the texture of the stone, and causes, what is noticed everywhere in our cemeteries, the cracking of Italian marble after a few years' exposure. (*a*)

The worst feature attending the use of explosives for quarrying stone is that incipient cracks are produced, which do not open while the stone is being handled and dressed. Costly buildings are often marred and sometimes ruined by the cracking of some of the stones used in their construction. This disintegration is usually attributed to the non-resistance of the material to atmospheric influences, but it is more often due to the incipient cracks started in the quarry.

THE WORKING OF SLATE.

As slate is distinct in structure from all other rocks, so is the working of it essentially different. A few of the technical terms used by slate-workers it will be necessary to explain before proceeding with the discussion of the manner of working.

The SPLIT is the cleavage.

The GRAIN is a secondary cleavage at right angles to the split, and usually to a regular system of natural joints.

FLINT is a term applied to hard clay stones, quartz, or any hard rock which may be interstratified with the slate rock or occur in veins or concretions.

A QUARRY is where good slate rock exists developed or undeveloped.

STOCK is the useful rock taken out of a quarry.

The BUTT of a quarry is where the overlying rock comes in contact with an inclined stratum of slate rock.

The NOSE of a quarry is the line of contact between the underlying rock and an inclined stratum of slate rock.

END JOINTS are vertical joints running back from and perpendicular to the quarry face.

BACK JOINTS run parallel to the quarry face.

BOTTOM JOINTS are horizontal or nearly so.

The ENDS of a block are the surfaces which cross the split and are perpendicular to the grain.

The SIDES of a block are the surfaces which cross the split and are parallel with the grain.

To SCULP is to split a block with the grain by driving a chisel into a notch made in the end of the block.

To PLUG is to drill a hole near the middle of and through a block, and drive in a plug-and-feather wedge or put in a blast of powder to split the block with the grain.

To BREAK ACROSS is to break a block in a plane perpendicular to the grain and split by cutting a notch in one edge and then supporting the block at each end on this edge and striking with a heavy wooden mallet on the other edge and directly opposite the notch, or the block may be supported near the notch and struck near the ends on the opposite edge.

To SPLIT is to separate the slate along the cleavage planes.

In this country the slate is all taken out of open quarries, and the successive steps to be taken in quarrying slate are similar to those taken in quarrying other kinds of rock: The weathered material near the surface is removed; a quarry face is made by excavating a narrow channel down into the solid rock; large blocks are detached, and these are worked up into sizes suitable for handling, hoisted out of the quarry, and worked up by different processes for different uses.

The method of working a quarry depends chiefly upon the inclination of the cleavage plane and upon the direction of the grain; a quarry should always, however, be worked from the butt toward the nose.

In the Maine slate region the cleavage or split is nearly vertical and corresponds very nearly with the stratification. The grain in some of the quarries is vertical, and in others it is horizontal. The slate veins or strata occur alternately with flint veins, the former varying in thickness from 2 to 10 feet, the latter being less, but

a Mr. Edwin Greble, a marble dealer of Philadelphia, says that when he visited the Carrara marble quarries the scene reminded him of the bombardment of a fort; that he has examined blocks of marble in some of the old ruins of Rome and found that the stone was somewhat worn but not cracked, but that scarcely a block of marble quarried since the introduction of gunpowder can be found free from cracks.

also variable in thickness. The quarries are worked from the butt, a slate vein is excavated for the face, and the flint vein on the upper side is allowed to stand for a wall. The face is excavated from 20 to 30 feet in depth and about the same in length before any stock is taken out. The flint vein on the lower side is then blasted out with powder and the next slate vein will usually be found cut up into blocks of greater or less size by end joints and bottom joints, and may be detached by driving in wedges at the top. Sometimes a hole is drilled in from the top so as to strike the next lower flint vein at a depth of 8 or 10 feet, light blasts are made to loosen the back joints, which in this case are joints along the cleavage, and the blocks are pried off with bars. Whenever no bottom joint is available at or near the floor of the quarry, an undercut must be made, and this is called blasting off the roots. When the grain is horizontal the excavation is carried down in steps, each from 20 to 40 feet or more in height. When the grain is vertical the step system is not uniformly adopted; but each underlying bed or vein is allowed to stand until a bottom joint is reached, which is seldom at any great depth; and, if the end joints are so far apart that the rock between them cannot be detached at once from the top, a space is blasted out at one end in the same manner as the roots are blasted off when the grain is horizontal; a hole is drilled half way between the top and bottom and from 10 to 20 feet from the free end, and a blast put in this hole splits the block from top to bottom. For splitting (or "plugging") off blocks in this manner the drill-hole must go through to a back joint; though such a joint may be made at any depth by putting a small charge of powder in the bottom of the hole and tamping it in tightly with sand, and the effect of the blast will be to cleave the rock along the cleavage plane passing through the bottom of the hole. If the hole is filled nearly full with powder and covered lightly with sand, the effect of the blast will be to make a clean break along the grain from top to bottom without shattering the rock; but if the powder is made to fill but half the hole and is heavily tamped, the effect of the blast is to break up and shatter the rock.

Experienced slate quarrymen show unusual sagacity by the manner in which they take advantage of the position of the rock as determined by the cleavage, grain, and natural joints, and by manipulating the blast so that it will produce just the effects desired. In the Vermont slate region the cleavage dips at an angle of about 45°, and, if the quarries are opened in the butt, one face cut will be sufficient for taking out all the rock which can be obtained without carrying the excavation under the overlying strata; but small quarries are often opened near the nose, where there is but a small amount of slate above the underlying strata, and when this is taken out a new face cut must be started from the top. There are a great number of small quarries opened in this region without regard to future workings and without any idea apparently of developing large operations. The débris is thrown on good slate rock, and the progress of large quarries has already in some instances been stopped by these piles of débris.

In the different Pennsylvania slate quarries may be found every different inclination of cleavage, direction of grain, and manner of jointing, but the general principles of quarrying are the same in all; that is, a face and free end are first made, after which large blocks are wedged off, pried off with levers, or plugged off with powder, and these blocks are plugged, split, and broken across till they are reduced to such sizes that they may be hoisted out of the quarry with derricks. If a block is small and less than one foot in thickness, it can be split by driving the sculp or paring-chisel into the edge of the block along a cleavage line; if the block is large, and it is necessary to use wedges for splitting, a series of wedge-shaped holes is cut along a cleavage line with the paring-chisel, two thin strips of iron are placed in each hole, and the wedges are placed between the strips of iron and driven.

Slate is used for a great variety of purposes, and if the blocks are to be worked up into roofing slate they are taken from the quarry to the splitters' shanties on small cars run on rail tracks between the quarry and the shanties. At each shanty are a splitter and two assistants. The first assistant takes the block upon its arrival and reduces it to pieces of about 2 inches in thickness and of a length and breadth a little greater than those of the slates to be made. The splitter cleaves these pieces into slates with the splitting-chisel. The second assistant trims the slates with irregular edges into rectangular shape and to definite sizes.

The process of sculping, which is carried out by the first assistant, is as follows: A notch is cut in one end of the block with the sculping chisel, and the edge of the notch is trimmed out with the gouge to a smooth groove extending across the end of the block and perpendicular to the upper and lower surfaces; the sculping chisel is set into this groove and driven with a mallet, and thereupon a cleft soon starts, which by skillful manipulation is guided directly across the block. The upper surface of the block is wet with water so that the crack may be more readily seen. If the block were perfectly uniform in shape and texture, and the blows upon the sculp directed straight with the grain, the crack would follow the grain in a straight line across the block. Almost invariably, however, the crack will deviate to the right or to the left, and must be brought back by directing the blow on the sculp in the direction in which it is desired to turn the break, or by striking with a heavy mallet against the right-hand side of the notch, if the break is to be turned in that direction, and *vice versa*. Some slate rock can be sculped across the grain, but most of it has to be broken across the grain.

The splitter uses a broad thin chisel for his work. He always splits the piece of slate through the middle, and continues to divide the pieces into equal halves until they are reduced to the required thinness. The edges of the blocks must be kept moist from the time the rock is taken from the quarry until it is split up, and when it is necessary to allow the blocks to lie a day or more some precautions must be taken to keep the edges moist. In some quarries the blocks split best from the side and in others from the end, and in some qualities of slate the splitting chisel may be driven in its whole length at once without danger of breaking the slate, while in others it is necessary to lead the split by driving the chisel slightly all around the edges of the block before driving it in at any one point.

There are many other little peculiarities which need to be watched by the splitter, and almost every different quarry presents some characteristic features which modify the working of the slate.

To trim slate by hand a straight-edged strip of iron or steel is fastened horizontally on one of the upper edges of a rectangular block about 18 inches in height; the trimmer lays the slate upon the block, allowing one of the irregular edges to project over the iron plate, and cutting it off by a chopping stroke with a heavy knife; in this manner he trims two edges at right angles to each other and then marks out the other two edges with a measuring stick before trimming them. The measuring stick has a nail through one end and notches or steps toward the other end at distances from the point of the nail corresponding with the lengths and breadths of slates made.

The machine for trimming slates consists of a horizontal steel plate, with a beveled edge upward, past which a heavy curved knife is made to pass by being revolved on an axle like that of an ordinary straw-cutter, or by being hung on a hinge and pulled up by a spring and down by a treadle operated by the trimmer. Projecting at right angles from the plate, a little upward and toward the operator, is an iron arm upon which there are steps at distances from the knife-edge corresponding with the lengths and breadths of slates made, and which thus serves as a guide for making the slates both rectangular and of definite sizes. The trimmed slates are set on end outside of the shanties, each different size in a row or pile by itself. Each square, which is the number of slates that will cover 100 square feet of roof, is set off in the piles by allowing one slate to project over the sides of the others.

For many purposes slate is worked up principally by machinery. The blocks are taken from the quarries to the slate-mills and there split into slabs about 2 inches in thickness and sawed into the required sizes with circular saws. If thinner slabs are required the sawed pieces are split. The sawed slabs are planed on one side or on both sides, as may be required, with a planing-machine like the machines used for planing iron. The planer-chisels vary in width from 2 to 6 inches, according to the softness of the slate. The planed slabs are laid on the rubbing-bed and rubbed with sand put on with water. The rubbing-bed is a flat, circular piece of cast-iron, from 8 to 10 feet in diameter, revolving horizontally on a shaft. The sand is put in a trough above the rubbing-bed. One end of the trough is a little lower than the other, and is near the shaft above the center of the bed, so that a small stream of water entering the upper end of the trough washes the sand slowly upon the bed and near its center. The sand gradually works to the outer edge of the bed, and is finally washed off as silt. The slabs of slates are prevented from being carried around with the bed by stationary arms or timbers extending across the bed, and within about one-quarter of an inch of its surface.

Slate does not receive a gloss polish, but if a finer surface is desired than that which can be given by the rubbing-bed it is rubbed by hand with fine sand or emery. Slates for billiard-table tops are jointed after being rubbed, the slabs being fastened to a table moving back and forth before a large revolving grindstone.

For mantels, table-tops, etc., and all kinds of marbleized work, the softer varieties of slate are preferred; they can be sawed with both circular and band saws, and are easily planed and rubbed. For tiling and other uses in which the slate is subjected to considerable wear the harder varieties are employed; the slate from the quarries at Chapmanville, Pennsylvania, is especially applicable for these purposes, and has to be sawed with diamond band-saws and diamond reciprocating saws. These saws are made by setting in teeth of black diamond or carbon points to do the cutting. In the quarries at Chapmanville steel drills are used, but at the mills all the drilling is done with diamond-set tools.

School slates are manufactured quite extensively at some of the quarries in the vicinity of Slatington, Pennsylvania. A large part of the work is done by machinery, and the improvements which have been made in this line are important. The slates are quarried and split the same as for roofing.

The following table shows the different steps taken in finishing the slates after they are split, and the number of persons required for one set of machinery capable of turning out about 20,000 slates per day:

Operations.	Number of men.	Number of boys.	Number of women.
TRIMMING THE SLATES.			
Marking into rectangles and sawing with small circular saws	2		
Shaving the surfaces smooth with draw-knives	6		
FRAMING THE SLATES.			
Sawing boards into lengths for frame-pieces	1		
Sawing and grooving frame-pieces	1		
Tenoning and mortising frame-pieces	1		
Gluing tenons, mortises, and grooves, and sticking together an end and two side pieces		1	
Placing the frames on the slates		1	
Pressing the frames firmly on the slates with a machine-press		1	
Trimming the corners of the frames	2		
Planing the frames	1		
Printing rules on the inner edges of the frames			2
Punching holes in the frames			2
Sewing cloth upon the frames with shoe-strings			24
Packing and boxing the slates		1	
Total	14	4	28

The machine for printing the rules on the frames is a recent and valuable invention. The rules are divided into inches, half inches, and quarter inches.

These slates now supply almost the entire market of this country, and are quite extensively shipped to England, Germany, and other foreign countries.

THE GENERAL METHODS OF DRESSING THE VARIOUS CLASSES OF ROCKS.

1. The tools employed in dressing granite are the set, the spalling-hammer, the pean-hammer, the bush-hammer, the chisel, the bush-chisel, and the hand-hammer. The set is used for dressing the edges of a block to a line. The spalling-hammer is sometimes used for taking off larger projections than can be dressed off with the set; but such projections are commonly taken off with wedges (or "plugged off"). The point is used for roughing out the contour of surfaces. With the pean-hammer the projections left by the point are cut down. The bush-hammer imparts a finish according to the number of cuts employed. The chisel is used for finishing moldings, for cutting drafts around rock-faced and pointed work, and for lettering and tracing. The bush-chisel is used for dressing portions of surfaces not accessible with the bush-hammer. The set, point, and chisels are driven with the hand-hammer.

The steps in the process of dressing a granite surface are: 1st, dressing the edges to a line with the set; 2d, roughing out the surface with the point; 3d, cutting down the irregularities left by the point with the pean-hammer; and, 4th, dressing down, with the 4-cut, 6-cut, 8-cut, 10-cut, and 12-cut bush-hammers successively, the irregularities left by each preceding tool.

This process is carried out to different degrees for the different kinds of finished dressing known as rock-faced work, pointed work, single-cut or pean-hammer work, and 4-cut, 6-cut, 8-cut, 10-cut, and 12-cut work. For pointed work there is usually a draft chiseled around the face, after which the space within is dressed to a level with the draft or is given a certain projection, and may be rough-pointed or fine-pointed. Rock-faced work is sometimes drafted. The surfaces which come against other surfaces in masonry are dressed to a degree of fineness depending upon the closeness of joint required. Exposed surfaces are not often finished with the pean-hammer, the principal use of the single-cut being to prepare the surface for the next finer cut.

The condition of the surface at the completion of any particular cut work should be such that each cut in the hammer traces a line its full length on the stone at every blow. The single-cut should leave no unevenness exceeding one-eighth of an inch, and each finer cut reduces the amount of unevenness; and the 12-cut should leave no irregularities other than the indentations made by the impinging of the cuts in the hammer upon the surface of the stone. The lines of the cuts are made to be vertical on exposed vertical faces, and on the horizontal and unexposed faces they are made straight across in the direction which is most convenient.

For fine and accurate work all the tools designated in the complete process are used, except that a 5-cut hammer is often substituted for the 4-cut and the 6-cut hammers; but some of the tools are ordinarily omitted, the 6-cut being made to follow the pean-hammer, and the 10-cut to follow the 6-cut, etc.

A machine operating a bush-hammer by steam has been used, but not extensively. The hammer can be made to strike with any force up to a certain degree, but it cannot be guided with the delicate accuracy with which the bush-hammers are manipulated by hand. There are two other inventions for dressing granite by machinery not yet extensively tried. One of these inventions is the sawing of granite with gang-saws by the aid of chilled-iron globules.

Granite has been sawed with gang-saws by the aid of sand and with diamond-toothed saws; but the former process is too slow and the latter is too expensive to be profitable.

The essential feature of the other invention above referred to is a tool- or cutter-holder called the "chuck", which is furnished with three or more circular cutters set at an angle to the plane of their track or the path described by the edges of the cutters as they are carried round in a circle by the revolution of the chuck upon its axis.

Machines are made with the chucks and cutters variously adjusted for dressing plain and curved surfaces, the top and sides of blocks, different kinds of stone, and for turning columns.

The principal objections which have heretofore been urged against these machines are that the sand made by the dressing gets into the journals and between all the rubbing surfaces of the machinery, producing rapid wearing of these parts, and that the cutters are liable to chip out the edges of the blocks of stone. To overcome the latter objection an arrangement has recently been invented for producing more perfect arrises.

Granite is now used rock-faced in all cases where this mode of dressing is at all applicable. The use of granite for tombstones and ornamental work in general has greatly increased since the introduction of machinery for polishing. The cost of preparing a granite surface for polishing is, however, still great.

Before the introduction of machinery for polishing a polished granite surface was seldom seen; but now the polishing of granite is an extensive industry. The surfaces are prepared for polishing with the 10-cut or the 12-cut bush-hammer. The process of polishing consists in: 1st, rubbing with sand; 2d, with emery; and 3d, with putty-powder. All these polishing materials are put on with just sufficient water to make a paste which is not gummy. The process is commenced with rather coarse sand. The sand constantly works off and is caught on a shelf or in a pit, and for a time fresh sand is supplied; but as the surface becomes smoother the sand is taken from the shelf or pit and put back upon the stone, the sand being ground finer and finer at the same time that a finer surface is produced. The impalpable powder or mud produced is carried off by the water. Emery is applied in the same manner as sand after as fine a finish as possible has been given by the latter. Putty-powder is rubbed on with a felt-covered block to give the surface a gloss finish. Flat surfaces are brought to a horizontal position, and the sand and emery are rubbed on with a horizontally-revolving iron wheel made of several concentric rings. The rubbing-wheels are usually from 12 to 18 inches in diameter; the machines are constructed on various plans, so that the wheels may be carried about over the whole surface to be polished, and so that the vertical shaft upon which the wheels are carried may be raised or lowered within certain limits by the operator to give different degrees of pressure. The felt-covered block for rubbing on the putty-powder is attached to the bottom of the wheel. Straight moldings are polished with blocks made to fit them, and worked back and forth by machines called "pendulum machines". Granite columns are polished in lathes.

2. The steps taken in the process of cutting marble are: 1st, shaping up the block with the spalling-hammer and pitching-tool; 2d, roughing out the surface with the point; 3d, cutting down the projection left by the point with the tooth-chisel; and 4th, cutting the surface smooth with the drove.

The spalling-hammer is used for breaking off the larger projections, and the pitching-tool is used for dressing the edges to a line. Chisels having a bit more than one inch in width are called "droves"; smaller sizes are called "tools".

A finished surface is usually drove, tooled, or polished. Rock-faced, pointed, and tooth-chiseled work are seldom employed. A tooled surface is made with the chisel, and has a ridged or wavy appearance due to the lines of indentations made by the tool. Surfaces are drove preparatory to polishing. The steps involved in the process of polishing are: 1st, rubbing with coarse sand; 2d, with finer sand; 3d, with coarse grit; 4th, with finer grit; 5th, with pumice-stone; 6th, polishing with Scotch hone; and 7th, glossing with putty-powder, with sometimes an addition of oxalic acid. Water is applied in every step of the process.

It is usually specified in contracts for polished work that no oxalic acid shall be used, because a more durable polish is obtained by the use of the putty-powder alone.

Small blocks are rubbed with sand on the rubbing-bed; otherwise, machines similar to those used for polishing granite are used for applying the sand and putty-powder. The grit consists of spalls from sand-rock which has a texture suitable for grindstones. The grit and pumice-stone and Scotch hone are applied by hand. Each step in this process must eradicate all traces of the preceding step; skillful workmen are required, and the work of imparting the gloss finish cannot proceed so long as there are any scratches whatever left in the surface.

A dressed surface of most colored marbles will have cavities, which must be filled before the marble is polished. This filling is done with a wax made of shellac and colored with any non-oily substance, which is applied with a red-hot strip of iron, and before the wax cools a little of the marble-dust is rubbed into it. The same material is also used for cementing pieces of colored marble together. There is yet no substance known with which white marbles can be filled; and, fortunately, the need of filling them is not often felt. White marbles are usually compact and colored marbles vesicular in structure.

Marble is quite extensively sawed with machines called "gang-saws", employing horizontally reciprocating saws which are aided by sand. The saws are plates of iron from 3 to 4 inches wide and one-eighth of an inch thick; their edges are smooth, and the actual cutting is done by the sand. As many saws are used at once on a block of stone as there are parallel cuts to be made. The saw-frames are supported by iron rods working on hinge-joints at both ends. Some machines are so constructed that the pressure on the saws is simply the weight of the saws and frame; but in other machines the frame is let down a certain amount at each stroke by screws worked by the machinery. By the latter arrangement the feed can be regulated to suit the texture of the stone.

The sand is placed on the top of the stone and fed into the kerfs with a water-drip. The sludge from the ends of the saws is caught in a pit, the silt is carried off by the water, and the sand is shoveled back upon the stone.

Iron plates, the cutting edges of which are segments of a circle, are revolved by a vertical shaft for sawing circular pieces out of marble slabs for sinks, wash-stands, etc. The saw prepares the surface for the process of polishing.

Various machines have been invented for doing different kinds of work in marble dressing, but only a few of them are found at all in use, excepting those referred to above.

In many localities in this country thinly-bedded limestones are the only stone material near at hand for purposes of construction. The beds of these stones are usually smooth enough to be used in ordinary masonry without dressing; the ends are jointed with the pitching-tool and point, and the faces are commonly dressed rock-face. Such stones are not used to any extent for superstructures, except for church edifices, their principal use being for building foundations, bridge piers and abutments, and other like structures.

Heavily-bedded limestones are commonly sawed with gang-saws, and the various kinds of finish given the faces are rock-face, pointed, tooled, drove, or rubbed. On some limestones the tooth-ax is used after the point, after that the ax-hammer, and then the diamond hammer.

For carving marble and other stones, as for carving wood, chisels, gouges, and drills, of various sizes, and special tools for special kinds of work, are used.

3. The steps in the process of cutting sandstone are similar to those in the process of cutting marble, except that the crandal takes the place of the tooth-chisel on large surfaces. The diamond-hammer is used after the crandal on some kinds of sandstone, and the bush-hammer is used on hard, compact, argillaceous sandstones like the North River blue-stone.

Blocks of sandstone are sawed with gang-saws, like blocks of marble. Some sandstones are so soft when first taken from the quarry that they can be sawed with gang-saws without the aid of sand. Diamond-toothed saws have been successfully used for sawing the Portland (Connecticut) brownstone. These saws, while they cut the harder varieties of sandstones more rapidly, are much more expensive than the ordinary gang-saws.

A rubbed surface is the finest finish of which sandstone is susceptible. The surfaces may be rubbed with sand alone, or with sand followed by grit.

Slabs of North River blue-stone are planed, like slabs of slate, before they are rubbed.

4. The greenstone, or serpentine, which has been used so largely for the construction of dwellings and other buildings in Philadelphia, and to some extent in other eastern cities, is dressed rock-face. The rock is considerably broken up in quarries by natural joints, and is still more broken up by the powder used in quarrying. A greenstone building standing among other buildings presents a pleasing appearance, but many greenstone buildings together present a less agreeable appearance; there is a harshness which has become more apparent with the increased use of the stone, and which has finally driven the stone almost entirely out of use. But the greenstone is certainly capable of producing beautiful architectural effects by contrast. Thus far the quarries have been worked in the outcrop only. Upon the further development of the quarries, and more systematic working, larger blocks applicable to a greater variety of purposes, and a material more susceptible of dressing, may be produced.

For carving stones, as for carving wood, chisels, gouges, and drills of various sizes, and special tools for special kinds of work, are used.

There can hardly be said to have been any advance made in the method of carving stone since the stone age, when the savage chipped one stone with another; but the sand-blast method bids fair to supersede the old method for some kinds of work.

The sand-blast has been most extensively used for engraving glass, but it has been to some extent used for carving stones. At a high velocity of impact, grains of sand will cut or wear away substances much harder than themselves. For engraving or carving, sand, grains of quartz, or any other hard material is rapidly driven against the surface to be cut by any propelling force; a rapid jet or current of steam, air, water, or other suitable gaseous or liquid medium is preferred.

A peculiarity of the sand-blast is that the grinding or cutting action may be made to take place upon irregular surfaces, cavities, corners, and recesses hardly accessible to ordinary methods.

The business of carving stones is yet in its infancy in this country, but it is rapidly increasing; buildings, both public and private, being more ornamented with carved stones as the wealth of the country increases.

DESCRIPTION OF PLATES ILLUSTRATING QUARRIES AND QUARRY METHODS.

PLATE XIX.—Portions of several more or less connected excavations, worked independently of each other. Posts or pillars are left to support the hanging wall or roof. On the floor, in the foreground, is a Wardwell channeling-machine for cutting the marble into long rectangular blocks. Whenever it is necessary to make the quarry deeper (to "go down in the floor"), one of the long blocks is cut into short, nearly cubical pieces, called "key-blocks". The first key-block may be broken off more or less near the bottom by driving wedges into one of the channels. After the first key-block is completely removed (the bottom may have to be dug out in fragments) a row of holes is drilled along the bottom of the second key-block, and wedges are driven into these holes to raise the block from its bed. In this manner each succeeding key-block is taken out. A long block is then raised by driving wedges into holes drilled along the bottom. The long blocks are split, along the lines of stratification, into pieces which can be handled by the hoisting machinery. The small, waste material is raised to the surface in cages, which are shown attached to the derricks.

PLATE XX.—Small portion of the second excavation of Plate XIX, as seen from the opposite direction. The inclined channels on the hanging-wall side are cut with the diamond channeling-machine. The machine in operation is a diamond gadding-machine, by which the necessary holes for splitting up a long block are being drilled. The quarried blocks are attached to the derrick ropes, as shown in the foreground, and hoisted to the surface.

PLATE XXI.—Portion of the second excavation of Plate XIX, at an earlier period, when the excavation was just being cut through under the pillar. The excavations are usually carried down by steps, as shown on this plate.

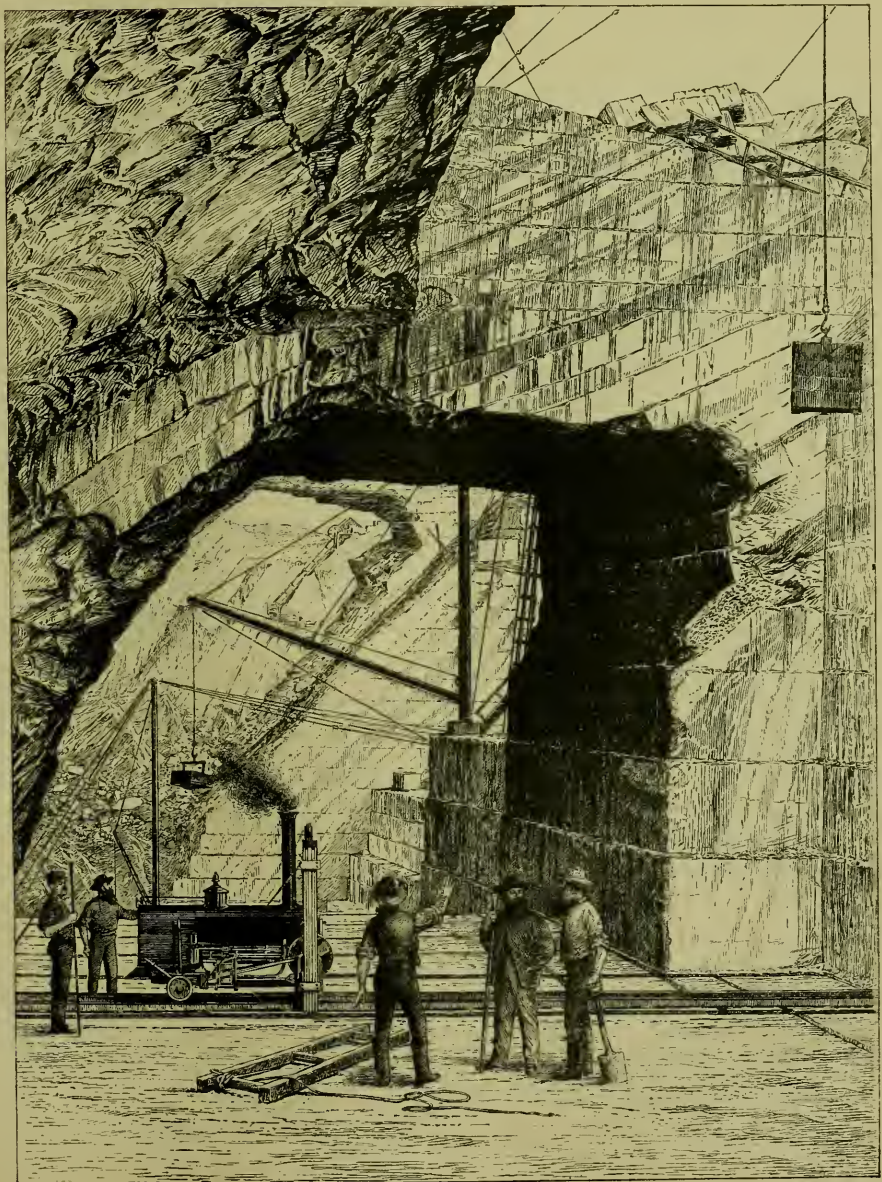
PLATE XXII.—Excavation in nearly horizontally stratified marble. The quarry floor is kept parallel with the stratification, and the channels are cut at right angles to the stratification with bars by hand or with the diamond channeling-machines. The roof is strong and capable of supporting itself over a wide span. However, the pillars left in these quarries are not sufficient to support the roof properly, and large masses of roof occasionally scale off and fall into the bottom of the quarries. It can hardly be hoped that no serious accident will ever result from these falls, though it is claimed that no person was ever injured by them.

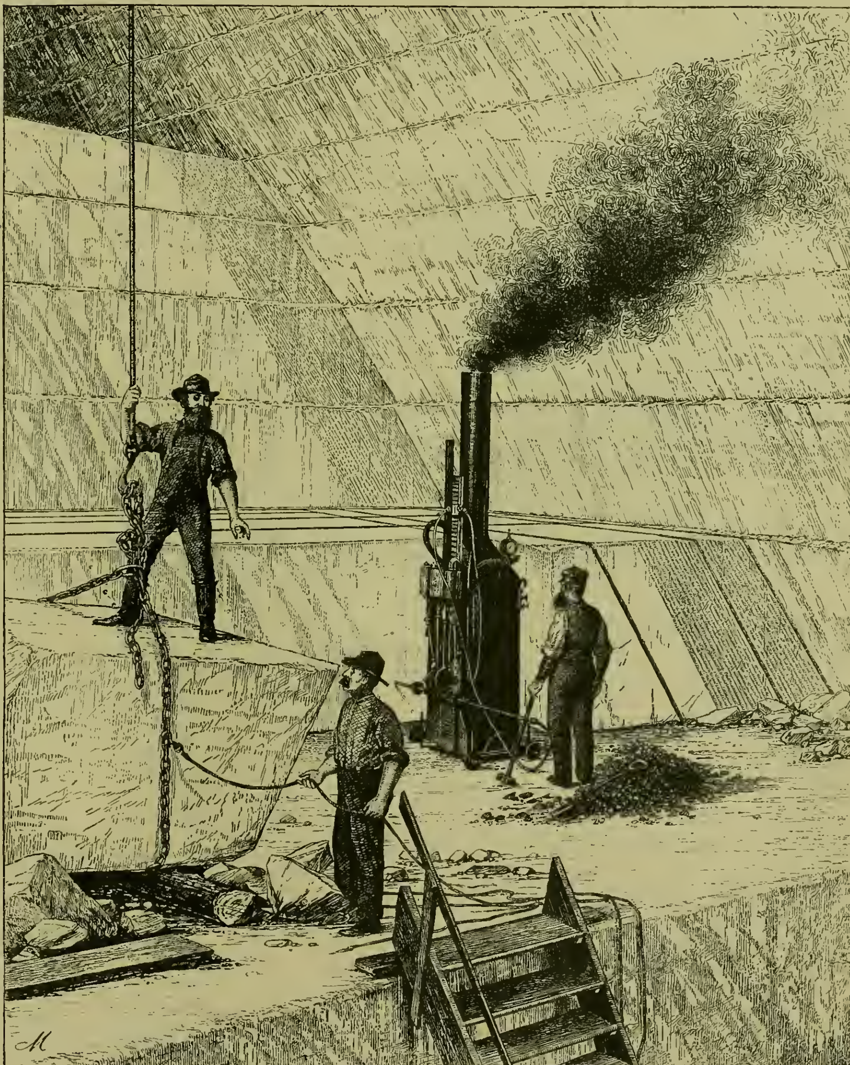
PLATE XXIII.—Illustration of the method of quarrying sandstone by channeling and wedging. The end of the quarry on the left of the picture is cut off by a channel about two feet in width, and the back of the quarry is cut off by a similar channel, so that a block may be detached by a row of wedges parallel to the first channel. Two men are driving a row of wedges, each man striking an alternate wedge as he moves forward. Two others, with picks, are cutting grooves for rows of wedges. The manner of splitting the blocks with the stratification is shown in the foreground to the right.

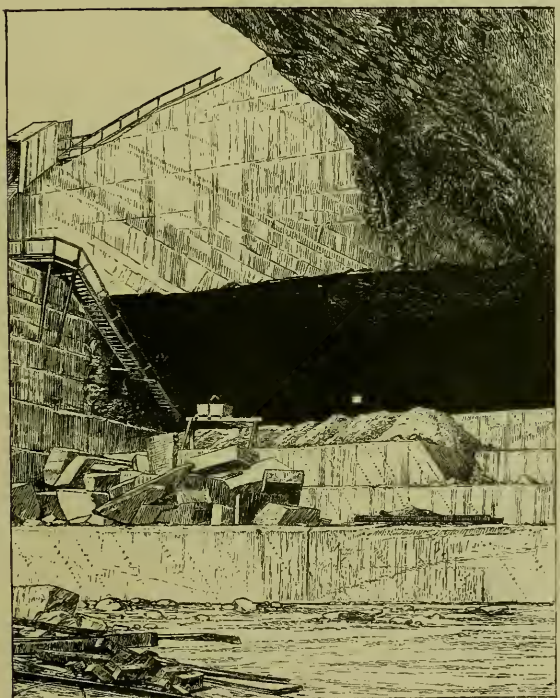
PLATE XXIV.—Greenstone or serpentine quarry. The rock is naturally much broken up by joints, and it is still more broken up by the powder with which it is quarried.

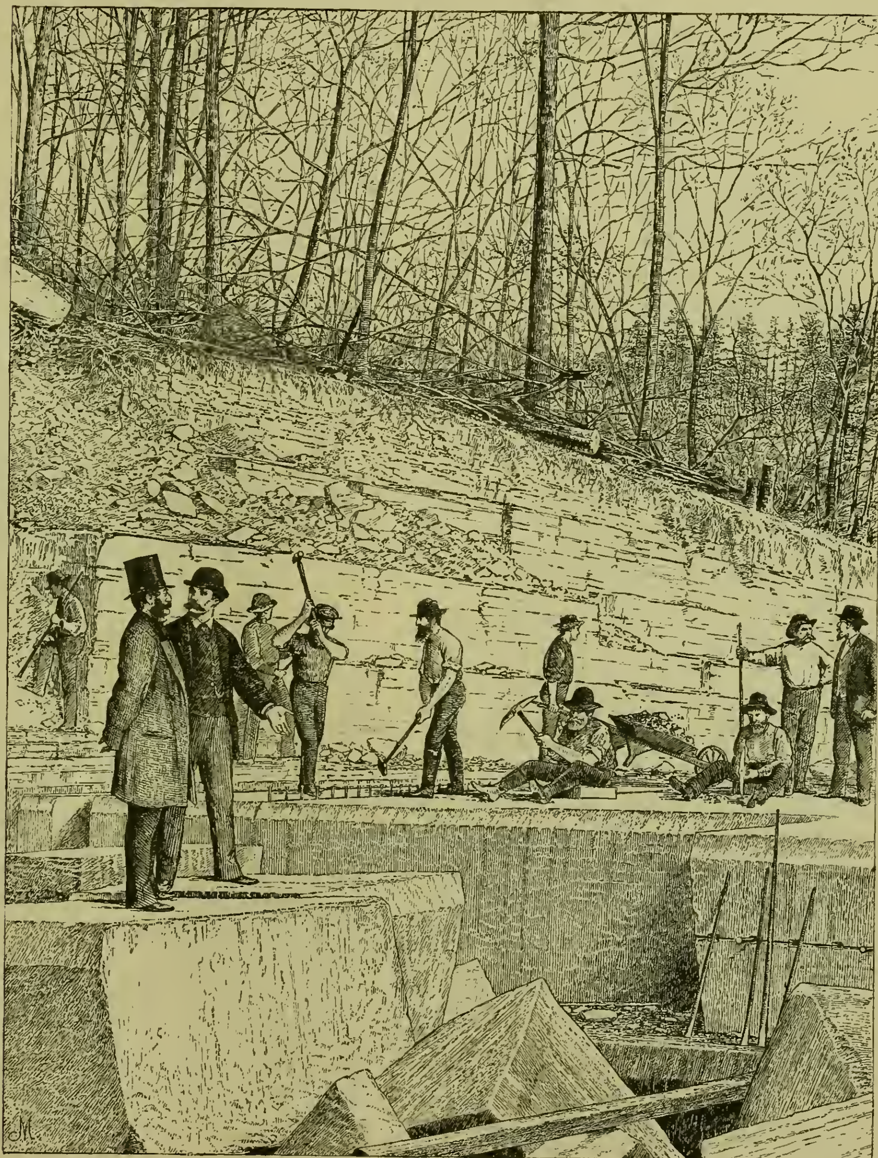
PLATE XXV.—Wardwell channeling-machine. For description, see page 35.

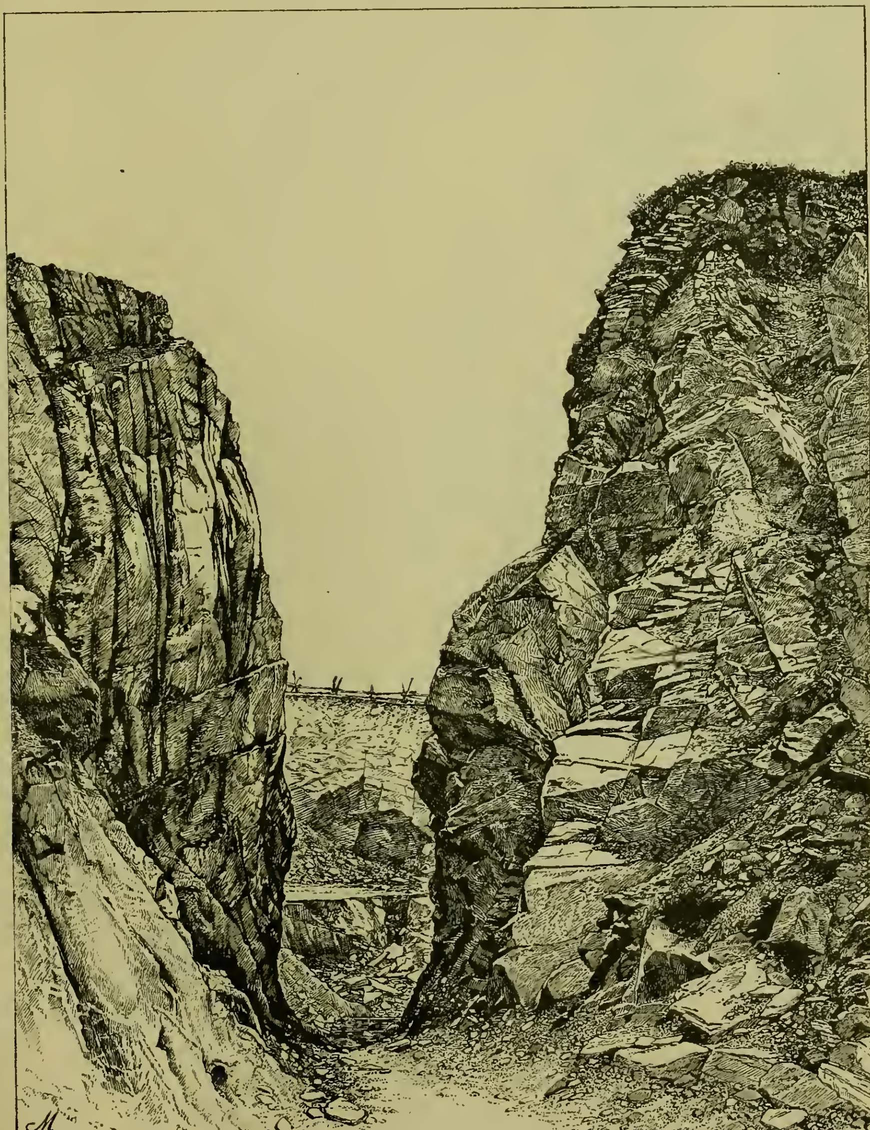
PLATE XXVI.—Two-spindle diamond channeling-machine. For description and use, see page 35.

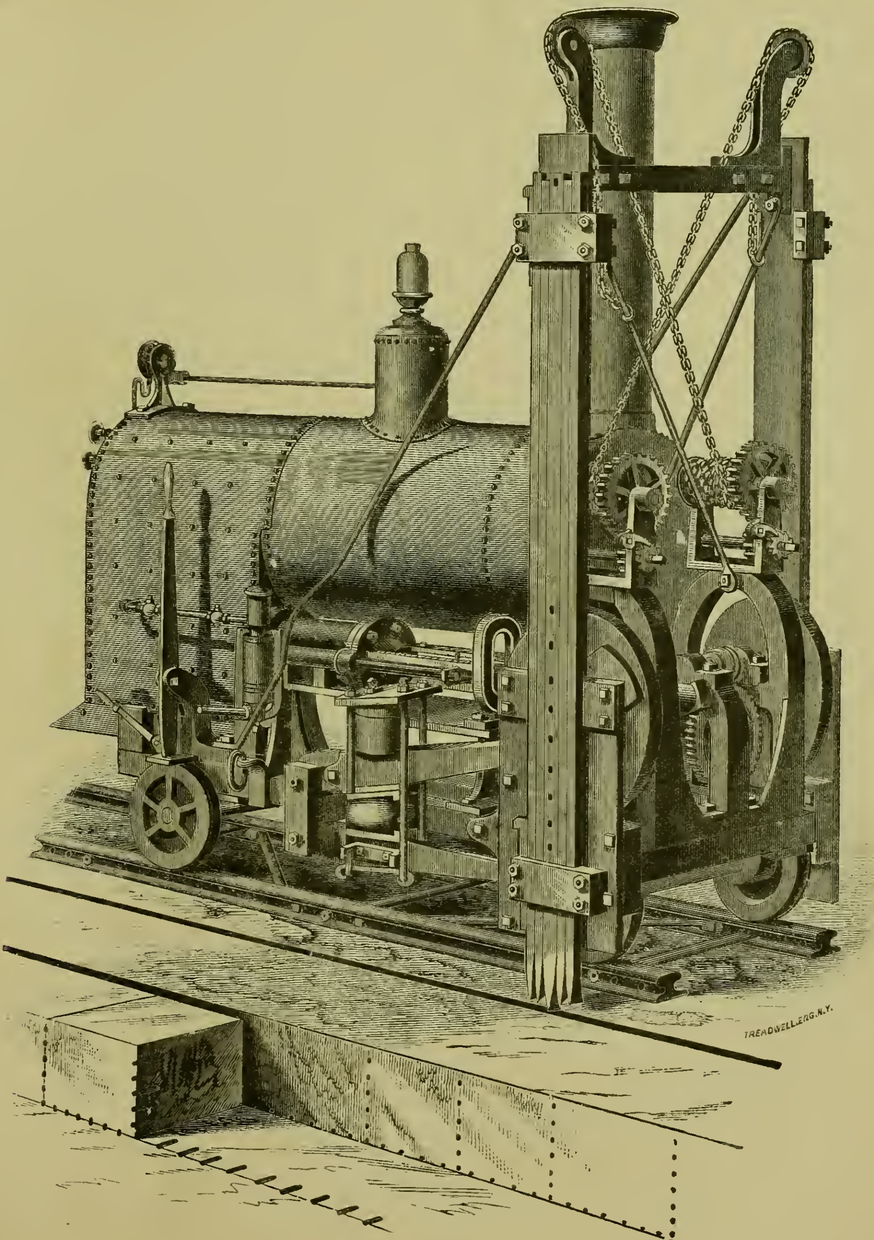








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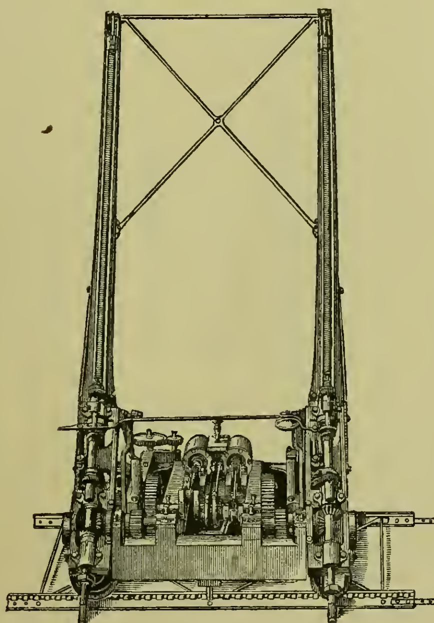

CHAPTER V.

STATISTICS OF BUILDING STONES.

TABLE I.—GENERAL STATISTICS OF THE QUARRYING INDUSTRIES OF THE UNITED STATES: 1880.

	States and Territories.	Number of quarries.	Capital invested.	Product in census year.	Value of product in census year.	NUMBER OF MACHINES EMPLOYED. For quarrying.	For hoisting.	For dressing.	Value of explosives used in census year.
			Dollars.	*Cubic feet.*	*Dollars.*				*Dollars.*
	Total for United States	1, 525	25, 414, 497	115, 380, 133	18, 356, 055	339	2, 290	1, 308	192, 175
	TOTALS BY KINDS OF ROCKS.								
1	Marble and limestone (*a*)	616	10, 565, 497	65, 523, 965	6, 856, 681	190	709	499	61, 408
2	Sandstone	502	6, 229, 600	24, 776, 930	4, 780, 391	40	634	95	27, 571
3	Crystalline siliceous rocks	313	5, 291, 250	20, 506, 568	5, 188, 998	64	763	322	70, 397
4	Slate	94	3, 328, 150	4, 572, 670	1, 529, 985	45	184	392	32, 799
	TOTALS BY STATES AND TERRITORIES.								
1	California	2	100, 000	413, 000	172, 450	....	6	14	1, 000
2	Colorado	6	13, 500	662, 790	50, 400	....	8	....	500
3	Connecticut	38	1, 730, 560	3, 527, 400	1, 087, 425	27	116	5	13, 590
4	Dakota	1	3, 500	38, 400	12, 000	....	1	....	324
5	Delaware	3	4, 800	45, 900	12, 600	....	3	....	....
6	Georgia	3	60, 600	288, 960	68, 980	2	2	....	615
7	Illinois	43	2, 120, 000	13, 321, 199	1, 342, 572	15	68	22	6, 805
8	Iowa	131	556, 775	10, 929, 783	670, 754	2	109	11	6, 859
9	Indiana	70	613, 560	8, 413, 827	633, 775	13	107	14	2, 300
10	Kansas	19	73, 700	1, 400, 346	142, 570	....	34	3	35
11	Kentucky	19	143, 250	1, 724, 675	92, 216	2	18	2	927
12	Maine	74	2, 285, 500	2, 465, 670	1, 259, 086	29	178	95	14, 744
13	Maryland	17	307, 935	1, 375, 917	346, 629	4	31	19	5, 725
14	Massachusetts	113	1, 616, 850	5, 468, 030	1, 711, 104	22	265	169	29, 355
15	Michigan	9	74, 700	648, 060	79, 165	....	13	....	1, 222
16	Minnesota	41	284, 225	3, 169, 113	255, 818	....	67	3	3, 812
17	Missouri	34	328, 550	4, 699, 600	613, 171	6	29	6	3, 050
18	Nebraska	1	5, 000	330, 000	15, 000	....	4	....	125
19	New Hampshire	39	128, 800	1, 920, 340	303, 066	1	109	14	4, 216
20	New Jersey	25	231, 900	3, 251, 621	514, 420	2	29	....	2, 596
21	New York	251	1, 080, 445	6, 057, 278	1, 261, 495	14	152	52	14, 819
22	Ohio	245	4, 166, 802	19, 673, 309	2, 541, 647	16	447	79	18, 763
23	Pennsylvania	164	3, 077, 885	15, 310, 184	1, 944, 208	56	173	213	33, 820
24	Rhode Island	17	476, 000	1, 352, 900	623, 000	6	43	22	2, 228
25	Tennessee	13	131, 700	792, 621	192, 695	14	30	4	605
26	Vermont	61	4, 732, 040	2, 468, 150	1, 752, 333	88	183	537	12, 300
27	Virginia	14	721, 250	1, 316, 556	410, 678	2	30	24	3, 911
28	Washington	2	2, 500	32, 500	3, 044	....	1	....	20
29	West Virginia	10	55, 350	294, 700	16, 689	3	13	....	696
30	Wisconsin	60	286, 820	3, 981, 304	227, 065	15	21	....	7, 213

a With "Marble and limestone" is included one quarry of serpentine rocks.

TABLE I.—GENERAL STATISTICS OF THE QUARRYING INDUSTRIES OF THE UNITED STATES: 1880.

NUMBER OF MONTHS IN OPERATION IN CENSUS YEAR.			NUMBER OF LABORERS EMPLOYED DURING CENSUS YEAR.					NUMBER OF ANIMALS EMPLOYED.			MEANS OF TRANSPORTATION.				
On full time.	On three-fourths time.	On one-half time.	Greatest number employed.	Males above 16 years of age.	Males below 16 years of age.	Employed in quarrying.	Employed in dressing.	Number of horses.	Number of mules.	Number of oxen.	Number of wagons.	Number of vessels.	Number of cars.	Number of locomotives.	
13,021	293	112	39,723	38,945	778	25,726	9,840	8,059	851	1,096	3,685	265	651	5	
5,001	87	53	15,646	15,363	283	11,269	2,756	4,439	586	163	1,571	111	363	2	1
4,166	22	16	9,567	9,428	139	6,623	1,219	2,091	140	277	1,023	73	72	2	2
2,832	126	38	11,477	11,340	137	6,139	4,501	1,258	105	652	981	81	144	1	3
1,022	58	...	3,033	2,814	219	1,695	1,364	271	20	4	110	...	72	...	4
23	...	...	195	194	1	50	100	8	...	16	3	...	...	...	1
60	...	...	134	134	...	129	...	17	5	...	9	...	...	...	2
341	36	2	1,902	1,883	19	1,369	466	112	54	266	455	46	15	...	3
6	...	3	35	35	...	26	...	18	...	...	9	...	...	...	4
30	...	...	30	30	...	...	14	7	...	...	2	...	...	...	5
36	...	...	146	143	3	84	50	6	44	...	13	...	...	...	6
314	4	...	2,315	2,287	28	1,987	298	380	39	...	177	41	51	...	7
914	34	23	2,091	2,075	16	1,819	198	824	343	...	160	8	40	...	8
579	5	...	1,788	1,701	87	1,121	142	545	...	...	153	...	46	...	9
158	...	13	434	422	12	273	104	86	16	14	31	...	...	...	10
160	2	1	806	791	15	486	140	199	...	...	57	1	...	...	11
606	31	17	4,011	3,936	75	1,793	2,058	241	...	218	181	29	85	...	12
153	22	...	701	682	19	480	211	34	12	12	37	2	5	2	13
1,055	48	13	2,951	2,907	44	1,795	957	371	3	166	214	14	29	...	14
73	...	...	200	190	10	187	13	56	...	...	15	2	2	...	15
228	12	15	1,175	1,173	2	865	253	333	4	2	151	...	...	...	16
316	6	4	783	764	19	437	122	71	96	...	69	...	6	...	17
8	...	...	55	55	...	40	15	22	...	...	...	...	...	...	18
325	16	4	595	595	...	323	190	204	...	84	114	3	7	...	19
265	...	...	812	812	...	615	130	85	6	37	68	5	...	...	20
2,186	6	3	3,302	3,220	82	2,426	656	774	23	24	429	12	22	...	21
2,083	11	5	4,902	4,856	46	2,943	329	1,853	49	60	516	29	35	2	22
1,458	43	...	4,284	4,078	206	2,904	1,212	819	57	...	451	26	270	...	23
166	...	...	962	953	9	342	418	134	...	52	75	2	6	1	24
124	...	...	443	440	3	377	30	18	65	...	26	2	...	...	25
627	5	...	2,762	2,694	68	1,487	1,230	281	...	131	130	38	5	...	26
144	8	6	919	908	11	554	365	44	29	...	34	...	...	...	27
17	...	...	16	16	...	10	6	...	...	...	...	...	...	...	28
85	...	...	154	154	...	75	42	28	...	...	11	3	20	...	29
481	4	3	820	817	3	729	91	489	6	14	95	2	7	...	30

TABLE II.—STATISTICS OF THE QUARRYING INDUSTRIES OF THE UNITED STATES, SHOWING NUMBER OF QUARRIES AND PRODUCTION, BY KINDS OF ROCK AND BY STATES AND TERRITORIES: 1880.

States and Territories.	Number of quarries.	Capital invested.	Product in census year.	Value of product in census year.
		Dollars.	*Cubic feet.*	*Dollars.*
Total United States	1,525	25,414,497	115,380,133	18,356,055
MARBLE AND LIMESTONE (a)	616	10,565,497	65,523,965	6,856,681
Illinois	38	2,101,200	13,013,139	1,320,742
Indiana	65	539,660	8,102,115	593,375
Iowa	128	552,775	10,772,283	666,554
Kansas	17	59,700	1,340,346	131,570
Kentucky	19	143,250	1,724,675	92,216
Maryland	3	142,435	70,617	65,929
Massachusetts	4	284,500	99,425	230,495
Michigan	4	61,050	97,800	26,085
Minnesota	33	159,575	2,816,298	201,593
Missouri	27	242,350	4,419,300	421,211
Nebraska	1	5,000	330,000	15,000
New York	55	508,620	2,836,025	431,439
Ohio	119	872,102	11,098,583	669,723
Pennsylvania (a)	24	592,160	3,339,722	240,934
Tennessee	13	131,700	792,621	192,695
Vermont	18	3,886,000	1,192,100	1,340,050
Virginia	2	35,000	20,000	27,750
Wisconsin	46	248,420	3,458,916	189,320
SANDSTONE	502	6,229,600	24,776,930	4,780,391
Colorado	3	2,000	108,750	9,000
Connecticut	6	1,167,500	988,200	680,200
Dakota	1	3,500	38,400	12,000
Illinois	5	18,800	308,060	21,830
Indiana	5	73,900	311,712	40,400
Iowa	3	4,000	157,500	4,200
Kansas	2	14,000	66,000	11,000
Massachusetts	15	95,800	729,980	144,294
Michigan	5	13,650	550,260	53,080
Minnesota	5	113,600	324,000	41,150
Missouri	5	51,200	194,000	81,960
New Jersey	20	210,100	2,384,791	400,420
New York	181	510,775	2,980,353	724,556
Ohio	126	3,294,700	8,574,726	1,871,924
Pennsylvania	95	560,825	6,229,110	627,943
Washington	1	1,500	14,000	2,000
West Virginia	10	55,350	294,700	16,689
Wisconsin	14	38,400	522,388	37,745
CRYSTALLINE SILICEOUS ROCKS	313	5,291,250	20,506,568	5,188,998
California	2	100,000	413,000	172,450
Colorado	3	11,500	554,040	41,400
Connecticut	32	563,060	2,539,200	407,225
Delaware	3	4,800	45,900	12,600
Georgia	2	60,000	278,960	64,480
Maine	68	1,625,500	2,203,670	1,175,286
Maryland	7	106,000	1,182,500	224,000
Massachusetts	92	1,217,150	4,623,125	1,329,315
Minnesota	3	11,050	28,815	13,075
Missouri	2	35,000	86,300	110,000

a With "Marble and limestone" is included one quarry of serpentine rocks.

TABLE II.—STATISTICS OF THE QUARRYING INDUSTRIES OF THE UNITED STATES—Cont'd.

States and Territories.	Number of quarries.	Capital invested.	Product in census year.	Value of product in census year.
CRYSTALLINE SILICEOUS ROCKS—Continued.		*Dollars.*	*Cubic feet.*	*Dollars.*
New Hampshire	39	128, 800	1, 920, 340	303, 066
New Jersey	2	10, 500	820, 000	99, 000
New York	3	16, 000	42, 400	10, 000
Pennsylvania	15	243, 500	3, 028, 222	211, 454
Rhode Island	17	476, 000	1, 352, 900	623, 000
Vermont	12	50, 140	187, 140	59, 675
Virginia	10	631, 250	1, 181, 556	331, 928
Washington	1	1, 000	18, 500	1, 044
			Squares.	
SLATE	94	3, 328, 150	457, 267	1, 529, 985
Georgia	1	600	1, 000	4, 500
Maine	6	660, 000	26, 200	83, 800
Maryland	7	59, 500	12, 280	56, 700
Massachusetts	2	19, 400	1, 550	7, 000
New Jersey	3	11, 300	4, 683	15, 000
New York	12	45, 050	19, 850	95, 500
Pennsylvania	30	1, 681, 400	271, 313	863, 877
Vermont	31	795, 900	108, 891	352, 608
Virginia	2	55, 000	11, 500	51, 000

TABLE III.—EXTENT TO WHICH BUILDING STONES AND SLATES ARE QUARRIED FOR APPLIANCES

LIMESTONE AND MARBLE.

	States and Territories.	Number of quarries.	Capital invested.	Total amount of excavation.	Product in census year.	Value of product in census year.	Number of machines employed: For quarrying.	For hoisting.	For dressing.	Value of explosives used in census year.	Number of months in operation in census year: On full time.	On three-quarter time.	On half time.
			Dollars.	*Cubic yards.*	*Cubic feet.*	*Dollars.*				*Dollars.*			
	The United States..	615	10, 540, 497	50, 529, 854	65, 373, 965	6, 846, 681	190	706	407	61, 358	4, 993	87	53
1	Illinois	38	2, 101, 200	10, 073, 350	13, 013, 139	1, 320, 742	15	63	21	6, 705	296	4	....
2	Indiana	65	539, 660	5, 619, 495	8, 102, 115	593, 375	13	90	14	1, 690	533	5	....
3	Iowa	128	552, 775	6, 491, 897	10, 772, 283	666, 554	2	108	11	6, 644	894	34	23
4	Kansas	17	50, 700	219, 390	1, 340, 346	131, 570	....	34	3	35	138	....	13
5	Kentucky	19	143, 250	934, 460	1, 724, 675	92, 216	2	18	2	927	160	2	1
6	Maryland	3	142, 435	121, 424	70, 617	65, 929	2	2	1	....	17	....	....
7	Massachusetts	4	284, 500	173, 000	99, 425	230, 495	10	3	....	35	39	4	....
8	Michigan	4	61, 050	501, 130	97, 800	26, 085	....	1	....	600	30	....	....
9	Minnesota	33	159, 575	1, 305, 149	2, 816, 298	201, 593	....	56	3	3, 522	173	8	15
10	Missouri	27	242, 350	822, 775	4, 419, 300	421, 211	....	8	....	2, 525	254	6	4
11	Nebraska	1	5, 000	200, 000	330, 000	15, 000	....	4	....	125	8	....	....
12	New York	55	508, 620	7, 958, 628	2, 836, 025	431, 439	11	103	20	7, 830	484	4	1
13	Ohio	119	872, 102	7, 681, 563	11, 098, 583	669, 723	10	62	....	12, 140	1, 020	3	1
14	Pennsylvania (*a*)	23	567, 160	4, 192, 000	3, 189, 722	230, 934	16	27	2	7, 215	232	9	....
15	Tennessee	13	131, 700	331, 255	702, 621	102, 695	14	30	4	605	124	....	....
16	Vermont	18	3, 886, 000	2, 438, 858	1, 102, 100	1, 340, 050	83	81	404	3, 971	170	2	....
17	Virginia	2	35, 000	1, 280	20, 000	27, 750	....	....	12	....	12	2	....
18	Wisconsin	46	248, 420	1, 464, 200	3, 458, 916	189, 320	12	16	....	6, 730	400	4	....

a The quarry of serpentine included in this group in Table II is here omitted.

SANDSTONE.

	States and Territories.	Number of quarries.	Capital invested.	Total amount of excavation.	Product in census year.	Value of product in census year.	For quarrying.	For hoisting.	For dressing.	Value of explosives used in census year.	On full time.	On three-quarter time.	On half time.
	The United States..	502	6, 229, 600	38, 185, 533	24, 776, 930	4, 780, 301	40	634	95	27, 571	4, 166	22	16
1	Colorado	3	2, 000	10, 000	108, 750	9, 000	....	4	....	200	24	....	....
2	Connecticut	6	1, 167, 500	4, 357, 000	988, 200	680, 200	18	26	....	4, 329	53	12	....
3	Dakota	1	3, 500	7, 260	38, 400	12, 000	....	1	....	324	6	....	3
4	Illinois	5	18, 800	19, 900	308, 060	21, 830	....	5	1	100	18	....	....
5	Indiana	5	73, 900	107, 730	311, 712	40, 400	....	17	....	610	46	....	....
6	Iowa	3	4, 000	137, 000	157, 500	4, 200	....	1	....	215	20	....	....
7	Kansas	2	14, 000	17, 000	66, 000	11, 000	....	....	....	....	20	....	....
8	Massachusetts	15	95, 800	860, 000	729, 980	144, 294	....	19	1	2, 026	144	2	6
9	Michigan	5	13, 650	240, 600	550, 260	53, 080	....	12	....	622	43	....	....
10	Minnesota	5	113, 600	79, 822	324, 000	41, 150	....	6	....	210	35	....	....
11	Missouri	5	51, 200	425, 185	194, 000	81, 960	4	15	5	35	41	....	....
12	New Jersey	20	210, 100	2, 384, 000	2, 384, 791	400, 420	2	23	....	1, 424	212	....	....
13	New York	181	510, 775	7, 727, 523	2, 980, 353	724, 556	....	28	....	4, 229	1, 537	....	....
14	Ohio	126	3, 294, 700	15, 219, 763	8, 574, 726	1, 871, 924	6	385	79	6, 623	1, 054	8	4
15	Pennsylvania	95	560, 825	5, 858, 650	6, 229, 110	627, 943	4	73	9	5, 425	735	....	....
16	Washington	1	1, 500	2, 000	14, 000	2, 000	....	1	....	20	12	....	....
17	West Virginia	10	55, 350	551, 500	294, 700	16, 689	3	13	....	696	85	....	....
18	Wisconsin	14	38, 400	180, 600	522, 388	37, 745	3	5	....	483	81	....	3

CRYSTALLINE SILICEOUS ROCKS.

	States and Territories.	Number of quarries.	Capital invested.	Total amount of excavation.	Product in census year.	Value of product in census year.	For quarrying.	For hoisting.	For dressing.	Value of explosives used in census year.	On full time.	On three-quarter time.	On half time.
	The United States..	313	5, 291, 250	27, 090, 841	20, 506, 568	5, 188, 998	64	763	322	70, 397	2, 832	126	38
1	California	2	100, 000	377, 000	413, 000	172, 450	....	6	14	1, 000	23	....	....
2	Colorado	3	11, 500	114, 000	554, 040	41, 400	....	4	....	300	36	....	....
3	Connecticut	32	563, 060	1, 832, 9[illegible]0	2, 539, 200	407, 225	9	90	5	9, 261	288	24	2
4	Delaware	3	4, 800	2, 100	45, 900	12, 600	....	3	....	....	30	....	....
5	Georgia	2	60, 000	5, 050, 000	278, 960	64, 480	2	2	....	515	24	....	....
6	Maine	68	1, 625, 500	1, 957, 453	2, 203, 670	1, 175, 286	20	166	74	9, 494	556	22	17
7	Maryland	7	106, 000	1, 460, 000	1, 182, 500	224, 000	2	20	....	3, 275	67	13	....
8	Massachusetts	92	1, 217, 150	5, 985, 105	4, 623, 125	1, 329, 315	11	242	168	26, 894	856	34	7
9	Minnesota	3	11, 050	14, 821	28, 815	13, 075	....	5	....	80	20	4	....
10	Missouri	2	35, 000	15, 500	86, 300	110, 000	2	6	1	490	21	....	....
11	New Hampshire	39	128, 800	4, 332, 566	1, 920, 340	303, 066	1	109	14	4, 216	325	16	4
12	New Jersey	2	10, 500	34, 700	820, 000	99, 000	....	2	....	1, 108	20	....	....
13	New York	3	16, 000	92, 822	42, 400	10, 000	3	5	....	220	27	....	2
14	Pennsylvania	15	243, 500	4, 008, 600	3, 028, 222	211, 454	5	15	....	8, 170	159	9	....
15	Rhode Island	17	476, 000	1, 024, 224	1, 352, 900	623, 000	6	43	22	2, 228	166	....	....
16	Vermont	12	50, 140	241, 700	187, 140	59, 675	1	17	16	215	99	....	....
17	Virginia	10	631, 250	546, 900	1, 181, 556	331, 928	2	28	8	2, 931	110	4	6
18	Washington	1	1, 000	1, 000	18, 500	1, 044	....	....	....	....	5	....	....

SLATE.

	States and Territories.	Number of quarries.	Capital invested.	Total amount of excavation.	Product in census year.	Value of product in census year.	For quarrying.	For hoisting.	For dressing.	Value of explosives used in census year.	On full time.	On three-quarter time.	On half time.
	The United States..	94	3, 328, 150	13, 740, 891	*a* 457, 267	1, 520, 985	45	184	302	32, 799	1, 022	58	....
1	Georgia	1	600	50, 000	1, 000	4, 500	....	....	....	100	12	....	....
2	Maine	6	660, 000	440, 900	26, 200	83, 800	9	12	21	5, 250	50	9	....
3	Maryland	7	50, 500	403, 310	12, 286	56, 706	....	9	18	2, 450	69	9	....
4	Massachusetts	2	19, 400	84, 000	1, 550	7, 000	1	1	....	400	16	8	....
5	New Jersey	3	11, 300	37, 344	4, 683	15, 000	....	4	....	64	33	....	....
6	New York	12	45, 050	1, 198, 100	19, 850	95, 500	....	16	32	2, 481	138	2	....
7	Pennsylvania	30	1, 681, 400	6, 383, 437	271, 318	863, 877	31	65	200	12, 960	324	25	....
8	Vermont	31	795, 900	4, 973, 800	108, 891	352, 608	4	85	117	8, 114	358	3	....
9	Virginia	2	55, 000	170, 000	11, 500	51, 000	....	2	4	980	22	2	....

a Squares.

PURPOSES OF CONSTRUCTION IN THE UNITED STATES, AND THE CAPITAL, LABOR, AND DEVOTED THERETO.

LIMESTONE AND MARBLE.

NUMBER OF LABORERS EMPLOYED DURING CENSUS YEAR.					NUMBER OF ANIMALS EMPLOYED.			MEANS OF TRANSPORTATION.				AVERAGE DAY'S WAGES.		
Greatest number employed.	Males above 16 years of age.	Males below 16 years of age.	Employed in quarrying.	Employed in dressing.	Number of horses.	Number of mules.	Number of oxen.	Number of wagons.	Number of vessels.	Number of cars.	Number of locomotives.	Skilled labor.	Unskilled labor.	
15, 632	15, 349	283	11, 259	2, 752	4, 427	586	163	1, 566	111	363	2	$2 24	$1 34	
2, 208	2, 181	27	1, 913	265	355	38		171	41	51		2 41	1 55	1
1, 636	1, 573	65	1, 054	132	504			137		46		2 32	1 30	2
2, 018	2, 002	16	1, 786	192	798	323		160	6	40		2 04	1 35	3
404	392	12	257	101	82	8	2	23				2 41	1 30	4
806	791	15	486	140	199			57	1			2 06	1 41	5
153	147	6	113	30	4	4		8		5	2	3 00	1 21	6
152	126	26	123	29	10		10	7				1 58	1 25	7
45	43	2	45		30			10	2				1 37	8
1, 035	1, 033	2	768	210	316	4		140				2 53	1 58	9
354	335	19	267	22	64	75		59				2 44	1 74	10
55	55		40	15	22							2 75	1 75	11
1, 291	1, 269	22	744	442	326	21	24	186	5	22		2 48	1 25	12
1, 781	1, 760	21	1, 150	98	1, 041	22	2	346	14	4		2 00	1 20	13
642	632	10	577	36	128	20		95		187		1 70	1 18	14
443	440	3	377	30	18	65		26	2			1 76	1 05	15
1, 896	1, 862	34	915	943	103		113	53	38	5		1 93	1 15	16
51	51		45	6								2 50	1 65	17
660	657	3	599	61	427	6	12	88	2	3		2 16	1 45	18

SANDSTONE.

9, 567	9, 428	139	6, 623	1, 219	2, 089	140	277	1, 023	73	72	2	$2 35	$1 46	
39	39		39		5	5		2				3 50	2 17	1
984	984		791	172	43	41	160	282	25			1 98	1 29	2
35	35		26		18			9				2 00	1 50	3
107	106	1	74	33	25	1		6				2 08	1 17	4
150	128	22	67	10	41			16				3 00	1 50	5
73	73		33	6	26	20			2			1 50	1 42	6
30	30		16	3	4	8	12	8				1 62	1 13	7
332	330	2	271	61	55		8	32				2 05	1 50	8
155	147	8	142	13	26			5		2		2 12	1 31	9
74	74		59	15	14			7				2 50	1 60	10
169	169		90	15	4	15		4				2 19	1 56	11
582	582		389	126	79	6	37	65	5			2 30	1 40	12
1, 830	1, 772	58	1, 540	176	426			235	7			1 54	1 13	13
3, 121	3, 096	25	1, 703	231	812	27	58	170	15	31	2	2 15	1 45	14
1, 560	1, 537	23	1, 082	280	423	17		164	16	15		2 18	1 42	15
12	12		6	6								4 25	1 75	16
154	154		75	42	28			11	3	20		2 71	1 40	17
160	160		130	30	62		2	7		4		2 62	1 52	18

CRYSTALLINE SILICEOUS ROCKS.

11, 477	11, 340	137	6, 139	4, 501	1, 258	105	652	981	81	144	1	$2 07	$1 36	
105	104	1	50	100	8		16	3				3 37	2 12	1
95	95		90		12			7				2 66	2 00	2
918	899	19	578	294	69	13	106	173	21	15		2 40	1 55	3
30	30			14	7			2				2 00	1 25	4
136	133	3	77	47	3	44		10				2 50	95	5
3, 800	3, 733	67	1, 712	1, 975	206		218	107	29	23		1 81	1 25	6
422	412	10	203	1[illegible]9	28	2	12	28	2			2 58	1 28	7
2, 445	2, 429	16	1, 383	863	306	3	148	175	14	29		2 06	1 49	8
66	66		38	28	3		2	4				2 53	1 62	9
260	260		80	85	3	6		6		6		2 68	1 33	10
595	595		323	190	204		84	114	3	7		2 15	1 35	11
188	188		184	4								1 50	1 50	12
38	38		28	9	3							3 00	1 58	13
437	437		406	16	157	14		150	10	58		1 82	1 21	14
962	953	9	342	418	134		52	75	2	6	1	1 78	1 24	15
111	110	1	104	1	86		14	38				2 15	1 19	16
775	764	11	447	328	29	23		29				2 22	97	17
4	4		4									2 25		18

SLATE.

3, 033	2, 814	219	1, 695	1, 364	271	20	4	110		72		$1 75	$1 17	
10	10		7	3	3			3				1 75	1 00	1
211	203	8	81	83	35			14		62		1 75	1 27	2
126	123	3	74	52	2	6		1				1 60	1 11	3
22	22		18	4								2 00	1 50	4
42	42		42		0			3				1 75	1 21	5
143	141	2	114	20	19	2		8				1 57	1 25	6
1, 631	1, 458	173	829	876	99	6		37		10		1 70	1 14	7
755	722	33	468	266	92		4	30				1 59	1 23	8
93	93		62	31	15	6		5				2 00	80	9

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

NOTE.—It will be noted that the numbers of quarries represented in this table do not in all cases agree with those given in the tables preceding. This is due to the fact that the data for this table were not obtained for all quarries from which statistics of business were received; and, on the other hand, it was judged advisable, for various reasons, to introduce certain quarries here, although their product during the census year did not reach a valuation of $1,000.

MAINE—CRYSTALLINE SILICEOUS ROCKS.

	Location of quarry.	County.	Name of the corporation, company, or individual.	SPECIFIC VARIETY OF STONE.	
				Popular name.	Scientific name.
1	Red Beach	Washington	Maine Red Granite Company	Granite	Biotite granite
2	2 miles east of Jonesboro'	do	Bodwell Granite Company	do	do
3	4 miles southwest of Indian River	do	H. B. Nash (Diamond Granite Quarry)	do	Diabase
4	6 miles southeast of Addison Point	do	Pleasant River Black Granite Company	do	Olivine diabase
5	West Sullivan	Hancock	J. H. Stimpson	do	Biotite granite
6	West Sullivan	Hancock	Crabtree & Harvey	Granite	Biotite granite
7	do	do	Joseph H. West	do	do
8	Franklin	do	Blaisdell Brothers	do	do
9	2 miles south of Mount Desert	do	Whiting & Allen	do	do
10	2½ miles south of Mount Desert	do	C. J. Hall	do	do
11	East Bluehill	Hancock	Collins Granite Company	Granite	Biotite granite
12	do	do	G. W. Collins & Co	do	do
13	do	do	Chase & Hall	do	do
14	Deer Isle	do	Paul Thurlow & Co	do	do
15	do	do	Owens & McGee	do	do
16	Deer Isle	Hancock	Goss & Goss	Granite	Biotite granite
17	Green's Landing	do	James & C. A. Bayard	do	do
18	Frankfort	Waldo	Mount Waldo Granite Works	do	
19	Prospect	do	Edward Avery	do	
20	Swanville	do	Oak Hill Granite Company	do	Biotite granite
21	Lincolnville	Waldo	Beach Grove Granite Company	Granite	Muscovite-biotite granite
22	3 miles north by west of Vinal Haven.	Knox	John S. Hopkins	do	Biotite granite
23	Vinal Haven	do	J. S. Black	do	do
24	do	do	Bodwell Granite Company	do	do
25	do	do	do	do	do
26	Vinal Haven	Knox	Bodwell Granite Company	Granite	Biotite granite (light); olivine diabase (dark).
27	Hurricane island	do	Davis Tilson	do	Biotite granite
28	Dix island	do	Dix Island Granite Company	do	do
29	South Thomaston	do	Ward & Woodward	do	do
30	do	do	Bodwell Granite Company	do	do
31	South Thomaston	Knox	Mirrick Sawyer	Granite	Biotite granite
32	do	do	M. T. Jamerson & Co	do	do
33	do	do	Nathan Stanton	do	do
34	4 miles east of Saint George	do	Atlantic Granite Company	do	do
35	3½ miles southeast of Saint George	do	Clark's Island Granite Company	do	do
36	Saint George	Knox	Wild Cat Granite Company	Granite	Biotite granite
37	do	do	Long Cove Granite Company	do	Hornblende-biotite granite (dark); biotite granite (light).
38	Waldoboro'	Lincoln	Day & Otis	do	Biotite granite
39	Jefferson	do	J. P. Glidden	do	Muscovite-biotite gneiss
40	Round Pond	do	Brown, McAllister & Co	do	Biotite granite
41	2½ miles east of Augusta	Kennebec	A. A. Young	Granite	Muscovite-biotite granite
42	2 miles west of Augusta	do	Kennebec Granite Company	do	do
43	Augusta	do	J. L. Dutton	do	do
44	do	do	Wall & Packard	do	do
45	2½ miles west of Hallowell	do	Hallowell Granite Company	do	do
46	Wayne	Kennebec	J. F. Gordon	Syenite	Biotite granite
47	2½ miles south of S. Norridgewock	Somerset	Lawton Brothers	Granite	
48	3 miles south of Norridgewock	do	Joseph Taylor	do	
49	3 miles northwest of Canaan	do	Sam. L. Fowler	do	Biotite granite
50	3 miles north of Canaan	do	Nathaniel Hall	do	do
51	North Jay	Franklin	A. W. Woodman	Granite	Muscovite-biotite granite
52	do	do	Maine Central Railroad Company	do	do
53	do	do	Emerson & Bryant	do	do
54	4 miles northeast of Chesterville	do	J. H. Plummer	do	Biotite granite
55	Bryant's Pond	Oxford	Grand Trunk Railway	do	do
56	3½ miles south of Turner	Androscoggin	C. H. Barrell	Granite	Biotite gneiss
57	2½ miles south of Brunswick	Cumberland	A. P. Woodside	do	Biotite granite
58	2½ miles south of Pownal	do	Charles H. Hodson	do	do
59	3½ miles south of Pownal	do	Thomas S. Reed	do	do
60	Biddeford	York	J. M. Andrews	do	do
61	Biddeford	York	C. H. Bragdon	Granite	Biotite granite
62	do	do	C. H. & A. Goodwin	do	do
63	do	do	Gooch & Haine	do	do
64	Kennebunkport	do	Smith & Walker	do	do
65	7 miles northwest of Kennebunkport.	do	George W. Ross	do	do
66	8 miles north of Kennebunkport	York	Francis Day	Granite	Biotite granite
67	9 miles north of Kennebunkport	do	Leavitt & Downes	do	do
68	4 miles southeast of South Berwick	do	Albert L. Goodwin	do	do

NOTE.—Thanks are due Mr J. P. Iddings, of the United States Geological Survey, for aid in determining certain of the crystalline siliceous rocks of doubtful nature.

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

MAINE—CRYSTALLINE SILICEOUS ROCKS.

Color.	STRUCTURE.			GEOLOGICAL AGE OF FORMATION.		Year in which opened.	
	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.		
Red	Coarse	Massive	Vertical, transverse, and horizontal.	Archæan		1875	1
do	do	do	Vertical and horizontal	do		1870	2
Black	Fine	do	Vertical and transverse	Devonian		1880	3
do	do	do	do	do		1878	4
Light gray	do	Indistinctly laminated	Horizontal and vertical	Archæan		1840	5
Light gray	Coarse	Massive	Inclined sheets	Archæan		1872	6
do	Fine	do	Irregular	do		1876	7
do	do	do	Vertical, transverse, and horizontal.	do		1879	8
Light pinkish gray	do	do	Horizontal sheets	do		1875	9
do	Coarse	do	Inclined sheets	do		1871	10
Light pinkish gray	Fine	Massive	Irregular	Archæan		1873	11
Light gray	Coarse	do	Inclined sheets	do		1879	12
do	do	do	do	do		1872	13
do	do	Indistinctly laminated	do	do		1877	14
do	do	do	do	do		1870	15
Light gray	Coarse	Indistinctly laminated	Inclined sheets	Archæan		1871	16
do	do	do	do	do		1878	17
Gray	Coarse, porphyritic	Massive	do	do		1853	18
do	Coarse	do	Horizontal sheets	do		1871	19
do	Fine	Indistinctly laminated	Horizontal and parallel, vertical.	do		1873	20
White, or very light gray	Fine	Massive	Vertical and horizontal	Archæan		1876	21
Dark gray	Coarse	Indistinctly laminated	Horizontal sheets	do		1872	22
Light gray	Fine	do	do	do		1879	23
do	Coarse	do	Vertical, transverse, and horizontal.	do		1857	24
do	do	do	do	do		1858	25
Light gray and black	Fine	Indistinctly laminated	Horizontal sheets	Archæan		1850	26
Dark gray	Coarse, porphyritic	do	Irregular	do		1870	27
do	Coarse	do	do	do		1851	28
do	Medium	do	do	do		1878	29
do	Coarse	do	Horizontal sheets	do		1860	30
Dark gray	Coarse	Indistinctly laminated	Horizontal sheets	Archæan		1859	31
do	Fine	do	Irregular	do		1878	32
do	do	do	do	do		1870	33
Gray	Fine, porphyritic	do	do	do		1879	34
Dark gray	Fine	do	Horizontal and parallel, vertical.	do		1871	35
Dark gray	Fine	Indistinctly laminated	Horizontal and parallel, vertical.	Archæan		1874	36
Dark gray and black	do	do	Vertical, transverse, and horizontal.	do		1874	37
Gray	do	do	Horizontal sheets	do		1830	38
Light gray	do	Laminated	Irregular	do		1876	39
Dark gray	do	Indistinctly laminated	Broken, irregular	do		1877	40
Gray	Fine	Massive	Horizontal sheets	Archæan		1873	41
do	do	do	do	do		1877	42
do	do	do	do	do		1856	43
do	do	do	do	do		1876	44
White, or very light gray	do	Indistinctly laminated	do	do		1800	45
Spotted, black, and white	Coarse	Massive	Irregular	Archæan		1860	46
Dark gray	Fine	do	Horizontal sheets	do		1866	47
do	do	Indistinctly laminated	Horizontal and parallel, vertical.	do		1850	48
do	Coarse	do	Horizontal sheets	do		1830	49
do	do	do	do	do		1860	50
Light gray	Fine	Massive	Horizontal sheets	Archæan		1872	51
do	do	do	do	do		1877	52
do	do	do	do	do		1876	53
do	do	Indistinctly laminated	Horizontal and parallel, vertical.	do		1845	54
Dark gray	do	do	Irregular	do		1864	55
Dark gray	Fine	Laminated	Horizontal and vertical	Archæan		1856	56
Light gray	Coarse	Massive	Horizontal sheets	do		1836	57
Gray	Fine	do	do	do		1860	58
do	do	do	do	do		1872	59
Light gray	Coarse, porphyritic	do	Irregular	do		1872	60
Gray	Coarse	Massive	Irregular	Archæan		1868	61
do	do	do	Horizontal sheets	do		1862	62
do	do	do	Irregular	do		1860	63
Light gray	do	do	Horizontal sheets	do		1876	64
Gray	do	do	Irregular	do		1868	65
Gray	Coarse	Massive	Irregular	Archæan		1860	66
do	do	do	do	do		1878	67
do	Fine	Indistinctly laminated	do	do		1878	68

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

MAINE—SLATE.

	Location of quarry.	County.	Name of the corporation, company, or individual.	SPECIFIC VARIETY OF STONE. Popular name.	Scientific name.
1	Brownville	Piscataquis	Adams H. Merrill	Slate	
2	2 miles northwest of Brownville	....do	Piscataquis Central Slate Company	....do	
3	Monson	....do	Monson Pond Slate Company	....do	
4	....do	....do	Dirigo Slate Company	....do	
5	....do	....do	Hebron Pond Slate Company	.. do	
6	3 miles north of Blanchard	Piscataquis	Blanchard Slate Mining Company	Slate	

MASSACHUSETTS—CRYSTALLINE SILICEOUS ROCKS.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Popular name.	Scientific name.
1	Gloucester	Essex	Stephen P. Andrews	Syenite	Hornblende-biotite granite
2	....do	... do	Cape Ann Granite Company	....do	Hornblende granite
3	... do	....do	Trumble Granite Company	....do	.. do
4	....do	....do	Solomon Trumble	....do	....do
5	....do	....do	John Butman	....do	.. do
6	Gloucester	Essex	Barker Brothers	Syenite	Hornblende granite
7	....do	....do	Vernon Brothers	....do	....do
8	Rockport	....do	Rockport Granite Company	....do	Hornblende-biotite granite
9	....do	....do	Pigeon Hill Granite Company	do	do
10	Lynn	... do	J. R. Jordan	Granite	Hornblende granite
11	Lynn	Essex	J. D. Wilson	Granite	Hornblende granite
12	Peabody	... do	Samuel Brown	Syenite	....do
13	....do	....do	Putnam & Linneham	...do	....do
14	....do	... do	Scott Brothers	....do	....do
15	....do	....do	H. A. Newhall	....do	.. do
16	Lynnfield	Essex	Thomas R. Newhall	Syenite	Hornblende granite
17	....do	....do	T. J. Newhall	Granite	...do
18	West Andover	....do	J. Maddox	Bastard granite	Muscovite gneiss
19	Lawrence	... do	Jesse Moulton	....do	....do
20	Lowell	Middlesex	S. L. Ward	Gneiss	Biotite gneiss (granitoid)
21	Medford	Middlesex	Town of Medford	Diabase	Diabase (micaceous)
22	....do	....do	Nicholas White	....do	....do
23	Ashland	.. do	Judson W. Cole	Granite	
24	Framingham	.. do	J. G. Cloyse	Porphyry	Biotite granite
25	Westford	....do	Andrew Fletcher	Granite	Muscovite gneiss (granitoid)
26	Westford	Middlesex	Prescott & Son	Granite	Muscovite gneiss (granitoid)
27	....do	... do	David Reed	....do	.. do
28	....do	... do	Swett & Smith	... do	Biotite-muscovite gneiss (granitoid)
29	....do	....do	Sol. Spaulding	... do	....do
30	....do	....do	Benjamin Palmer & Sons	....do	Muscovite gneiss (granitoid)
31	Westford	Middlesex	William Reed	Granite	Muscovite gneiss (granitoid)
32	....do	... do	Samuel Fletcher	....do	.. do
33	Ayer	... do	....do	....do	do
34	Fitchburg	Worcester	S. P. Litchfield	....do	Muscovite-biotite granite
35	....do	....do	Fred. Hale	....do	Biotite granite
36	Leominster	Worcester	S. L. Kittredge	Granite	Biotite granite
37	Clinton	... do	L. M. Allen	....do	... do
38	2 miles northeast of Worcester	....do	G. D. Webb	....do	Biotite-muscovite granite
39	1½ miles northeast of Worcester	....do	B. Converse	....do	Muscovite granite
40	1½ miles north of Milford	....do	Richard Carroll	....do	
41	Northbridge	Worcester	Diamond Hill Granite Company	Gneissoid granite	Biotite gneiss
42	... do	....do	Samuel Fowler, jr	....do	.. do
43	. do	....do	George M. Blanchard	....do	....do
44	Charlton	....do	Lamson & Woodbury	....do	Muscovite gneiss
45	....do	... do	Stone & Hiscox	....do	.. do
46	Northfield	Franklin	Bassett & Lyons	Gneissoid granite	Biotite gneiss
47	Deerfield	... do	Westcott & Ames	Mica-schist	Biotite schist
48	....do	... do	J. G. Noakes	....do	... do
49	Pittsfield	Berkshire	E. L. Humphrey	Limestone	Limestone
50	Becket	... do	McClellan & Goodwin	Gneiss	Muscovite-biotite gneiss
51	Becket	Berkshire	Chester Granite Company (York & Baldwin).	Granite and gneiss	Muscovite-biotite gneiss
52	Monson	Hampden	W. N. Flynt & Co	Gneiss	Biotite (dark) muscovite (light) gneiss (granitoid).
53	Brighton	Suffolk	S. W. Brown, jr	Blue-stone	Melaphyre
54	....do	... do	....do	....do	....do
55	Dedham	Norfolk	M. Bollard	Porphyry	Epidote granite
56	Dedham	Norfolk	John Delaney	Porphyry	Epidote granite
57	Sharon	....do	John Moyle	Granite	
58	Quincy	....do	James Marks	Blue syenite	Hornblende granite
59	... do	....do	John O'Neal	....do	....do
60	... do	....do	Kennedy & Mahan	do	....do
61	Quincy	Norfolk	Churchill & Hitchcock	Dark blue syenite	Hornblende granite
62	....do	....do	S. Dill	Blue syenite	....do
63	....do	....do	Lee E. Faxar	Pink syenite	....do
64	....do	....do	Barker & Sons	Pink and blue syenite.	....do
65	....do	....do	McDonnell & Bros	Blue syenite	... do

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

MAINE—SLATE.

Color.	Structure. Texture.	Structure. Stratification.	Structure. Jointing, bedding, or natural surface.	Geological age of formation. Period.	Geological age of formation. Epoch.	Year in which opened.	
Bluish black	Fine	Rhomboidal	Irregular	Lower Silurian		1846	1
do	do	Rectangular	do	do		1875	2
do	do	Rectangular and irregular	Smooth	do		1879	3
do	do	Rhomboidal	do	do		1872	4
do	do	do	do	do		1871	5
Bluish black	Fine	Irregular	Even	Lower Silurian		1880	6

MASSACHUSETTS—CRYSTALLINE SILICEOUS ROCKS.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Dark gray	Coarse	Massive	Irregular, broken	Archæan		1876	1
Light and dark gray	do	do	Few joints	do		1869	2
do	do	do	do	do		1870	3
do	do	do	do	do		1879	4
Dark gray	do	do	Irregular	do		1853	5
Dark gray	Coarse	Massive	Few joints	Archæan		1851	6
do	do	do	Irregular	do		1878	7
do	Medium	do	Horizontal and vertical	do		1830	8
do	do	do	do	do		1870	9
Dark greenish gray	Coarse	do	Horizontal, inclined, and vertical.	do		1850	10
Dark greenish gray	Coarse	Massive	Horizontal, inclined, and vertical.	Archæan		1860	11
Pinkish gray	do	do	Irregular	do		1841	12
Dark gray	do	do	Horizontal and irregular, vertical.	do		1872	13
do	do	do	do	do		1861	14
do	do	do	do	do		1871	15
Dark gray	Coarse	Massive	Few joints	Archæan		1870	16
do	do	do	Irregular	do		1861	17
do	Coarse, porphyritic	Laminated	Horizontal, vertical, and transverse.	do		1879	18
do	do	do	Horizontal and vertical	do		1847	19
do	Fine	do	Irregular	do		1876	20
Black	Coarse	Massive	Irregular	Lower Silurian		1872	21
do	do	do	do	do		1871	22
Gray	do	do	do	Archæan		1874	23
Pinkish gray	Coarse, porphyritic	do	do	do		1851	24
Light gray	Fine, porphyritic	Laminated	do	do		1880	25
Bluish gray	Fine	Laminated	Irregular	Archæan		1850	26
Pinkish gray	do	do	do	do		1854	27
Light gray	Fine, porphyritic	do	Horizontal and vertical	do		1845	28
do	do	do	do	do		1847	29
do	Fine	do	Irregular	do		1847	30
Dark gray	Fine	Laminated	Irregular	Archæan		1847	31
Pinkish gray	Fine, porphyritic	do	do	do		1847	32
Gray	Fine	Indistinctly laminated	do	do		1877	33
Light gray	do	do	do	do		1831	34
do	do	do	do	do		1876	35
Dark gray	Fine	Indistinctly laminated	Irregular	Archæan		1872	36
do	do	Massive	do	do		1875	37
Light gray	Medium	do	do	do		1830	38
do	do	do	Irregular, broken	do		1870	39
Reddish yellow	do	do	Horizontal, vertical, and transverse.	do		1869	40
Light gray	Medium	Indistinctly laminated	Irregular	Archæan		1855	41
do	do	do	Few joints	do		1869	42
do	do	do	Irregular	do		1865	43
do	do	do	Parallel, vertical, and inclined.	do		1864	44
do	do	do	do	do		1879	45
Light gray	Fine	Indistinctly laminated	Horizontal, inclined, and vertical.	Archæan		1875	46
Rusty brown	do	Laminated	Inclined, vertical, and transverse.	Upper Silurian		1880	47
do	do	do	do	do		1880	48
Light blue	Coarse	do	Vertical, transverse, and inclined.	Lower Silurian		1871	49
Light gray	Fine	do	Irregular, broken	Archæan		1880	50
Light gray	Fine	Laminated	Horizontal and vertical	Archæan		1878	51
Light and dark gray	do	do	Horizontal sheets	do		1839	52
Dark greenish blue	do	Indistinctly laminated	Irregular, broken	do		1878	53
do	do	do	do	do		1850	54
Red	Fine, porphyritic	Massive	Irregular	do		1870	55
Red	Fine, porphyritic	Massive	Irregular	Archæan		1868	56
Light blue	Coarse	do	do	do		1874	57
Blue	do	do	do	do		1831	58
do	do	do	do	do		1876	59
do	do	do	do	do		1878	60
Dark blue	Coarse	Massive	Irregular	Archæan		1840	61
Blue	do	do	do	do		1875	62
Pink	do	do	do	do		1862	63
Pink and blue	do	do	do	do		1834	64
Blue	do	do	Irregular and broken	do		1832	65

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

MASSACHUSETTS—CRYSTALLINE SILICEOUS ROCKS—Continued.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone.	
				Popular name.	Scientific name.
66	Quincy	Norfolk	E. De Gruney	Blue syenite	Hornblende granite
67	...do	...do	C. Dunn	Blue granite	...do
68	...do	...do	E. Baker	...do	...do
69	...do	...do	Lewis Dill	...do	...do
70	...do	...do	Wild & Field	...do	...do
71	Quincy	Norfolk	Hector Murry	Gray granite	Hornblende granite
72	...do	...do	McKinza & Patterson	Blue granite	...do
73	...do	...do	H. Farnum	Syenite	...do
74	...do	...do	William Moore	...do	...do
75	...do	...do	James Garrity	Blue syenite	...do
76	Quincy	Norfolk	C. Hardwicke & Co	Blue syenite	Hornblende granite
77	...do	...do	Frederick & Field	...do	...do
78	...do	...do	Wendell & Co	Granite	...do
79	...do	...do	William Tranior	Blue syenite	...do
80	...do	...do	Charles Johnson	...do	...do
81	Quincy	Norfolk	E. Roberts & Co	Blue syenite	Hornblende granite
82	West Quincy	...do	Elcock & Sons	Syenite	...do
83	...do	...do	James Berry	...do	...do
84	...do	...do	Walter Berry	...do	...do
85	...do	...do	F. J. Fuller & Co	...do	...do
86	West Quincy	Norfolk	O. T. Rogers & Co	Syenite	Hornblende granite
87	...do	...do	Granite Railroad Company	...do	...do
88	...do	...do	Charles Wilson	...do	Hornblende granite
89	Randolph	...do	S. B. Corliss	Granite	Biotite granite
90	Brockton	Plymouth	W. T. Cleveland	...do	...do
91	Fall River	Bristol	William Beatty	Granite	Biotite granite
92	...do	...do	Nathaniel Thurston	...do	...do
93	Freetown	...do	Fall River Granite Company	...do	...do

MASSACHUSETTS—MARBLE AND LIMESTONE.

1	Pittsfield	Berkshire	E. L. Humphrey	Granite	Magnesian limestone
2	Lee	...do	F. S. Gross	Marble	Dolomite
3	Alford	...do	Horace S. Fitch	...do	Limestone
4	Sheffield	...do	Briggs Company	...do	Magnesian limestone

MASSACHUSETTS—SANDSTONE.

1	Lowell	Middlesex	W. E. Livingstone	Mortar stone	
2	...do	...do	City of Lowell	...do	
3	Newton	...do	Patrick Grace	Pudding stone	
4	Brighton	Suffolk	J. Welch	...do	
5	Boston Highlands	...do	Owen Mawn	...do	
6	Boston Highlands	Suffolk	Michael Leonard	Pudding stone	
7	...do	Norfolk	T. McCarty	...do	
8	...do	...do	Hugh Anan	...do	
9	Deerfield	Franklin	James Smith	Sandstone	
10	...do	...do	Blake Brothers	...do	
11	Northampton	Hampshire	John Delaney	Sandstone	
12	Holyoke	Hampden	L. P. Bosworth	...do	
13	West Springfield	...do	Curtis D. Stoddard	...do	
14	Longmeadow	...do	S. J. Billings & Co	...do	
15	...do	...do	Norcross Bros. & Taylor	...do	

MASSACHUSETTS—SLATE.

1	Cambridge	Middlesex	City of Cambridge	Slate	
2	Lancaster	Worcester	Lancaster Slate Company	...do	

RHODE ISLAND—CRYSTALLINE SILICEOUS ROCKS.

1	Pascoag	Providence	Garvey Brothers	Gneissoid granite	Biotite gneiss
2	Woonsocket	...do	Fairmount Farm Company	Mica-schist	Biotite schist
3	Diamond Hill	...do	Diamond Hill Granite Company	Gneissoid granite	Hornblende gneiss
4	Smithfield (4 miles east of)	...do	Smithfield Granite Company	Granite	Biotite granite
5	Cranston	...do	Richard Fenner	Mica-schist	Mica-schist
6	West Greenwich	Kent	Horace Vaughn	Granite	Biotite granite
7	...do	...do	Joseph Tarbox	...do	...do
8	...do	...do	James Ray	...do	...do
9	Newport	Newport	J. S. Stacey	...do	...do
10	2 miles east of Westerly	Washington	Charles P. Chapman	...do	...do
11	2 miles east of Westerly	Washington	New England Granite Works	Granite	Biotite granite
12	...do	...do	Smith Granite Company	...do	...do
13	...do	...do	...do	...do	...do
14	...do	...do	Charles P. Chapman	...do	...do
15	...do	...do	John R. Macomber	...do	...do
16	2 miles east of Westerly	...do	R. L. Means	Granite	Biotite granite
17	Niantic	...do	A. G. Crumb & Co	...do	...do

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

MASSACHUSETTS—Crystalline Siliceous Rocks—Continued.

Color.	Structure.			Geological age of formation.		Year in which opened.	
	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.		
Blue	Coarse	Massive	Irregular and broken	Archæan		1879	66
do	do	do	Vertical and horizontal	do		1879	67
do	do	do	do	do		1879	68
do	do	do	do	do		1857	69
do	do	do	Irregular	do		1810	70
Gray	Coarse	Massive	Irregular	Archæan		1840	71
Blue	do	do	do	do		1818	72
do	do	do	do	do		1878	73
do	do	do	do	do		1874	74
Dark gray	do	do	do	do		1868	75
Dark gray	Coarse	Massive	Irregular	Archæan		1810	76
do	do	do	do	do		1839	77
Gray	do	do	do	do		1829	78
Blue	do	do	do	do		1850	79
do	Medium	do	do	do		1845	80
Blue	Medium	Massive	Irregular	Archæan		1838	81
do	Coarse	do	Irregular, broken	do		1870	82
do	do	do	do	do		1850	83
do	do	do	do	do		1827	84
do	Medium	do	Horizontal and vertical	do		1840	85
Blue	Medium	Massive	Horizontal and vertical	Archæan		1826	86
do	do	do	Vertical, horizontal, and inclined.	do		1826	87
Dark gray	Coarse	do	Irregular	do		1852	88
Red	Medium	do	do	do		1872	89
do	do	do	do	do		1879	90
Gray	Medium	Massive	Horizontal, vertical, and transverse.	Archæan		1840	91
do	do	do	do	do		1873	92
do	do	do	Horizontal and vertical	do		1874	93

MASSACHUSETTS—Marble and Limestone.

Gray	Coarse crystalline	Irregular	Uneven, thick	Lower Silurian		1871	1
White	Coarsely crystalline	Massive	do	do		1852	2
Bluish white	Crystalline	do	do	do		1843	3
White	do	do	do	do		1845	4

MASSACHUSETTS—Sandstone.

Green	Fine	Irregular	Uneven, thick	Archæan		1850	1
do	do	do	do	do		1856	2
Light blue	Coarse, conglomerate	Massive	Thick	Lower Silurian		1880	3
Blue	do	do	do	Archæan		1878	4
do	Coarse	do	do	Lower Silurian		1878	5
Blue	Coarse	Massive	Thick	Lower Silurian		1860	6
do	do	do	do	do		1840	7
do	do	do	do	do		1850	8
Red	do	do	Uneven, thick	Triassic		1880	9
do	do	do	do	do		1880	10
Dark brown	Coarse	Massive	Even, thick	Triassic		1840	11
Dark rusty brown	do	do	do	do		1874	12
Reddish brown	Inferior	Irregular	do	do		1850	13
Red	Fine, even	Massive	do	do		1867	14
do	do	do	do	do		1800	15

MASSACHUSETTS—Slate.

Dark blue	Very fine	Irregular	Even	Archæan		1841	1
Bluish black	Porous	Rectangular	Stratification lines distinct	do		1879	2

RHODE ISLAND—Crystalline Siliceous Rocks.

Pink, black, and white	Coarse	Massive	Parallel and vertical	Archæan		1873	1
Blue to green	Fine to coarse	Laminated	do	do		1859	2
Blue and bluish black	Medium	do	do	do		1840	3
Light pink	Coarse	Massive	do	do		1871	4
Bluish black	Variable	Laminated	Irregular	Carboniferous ?		1820	5
Red	Coarse	Massive	Parallel and vertical	Archæan		1865	6
do	do	do	do	do		1863	7
Black and white	do	do	do	do		1877	8
Red	Medium fine	do	Irregular	do		1855	9
Red and blue	Fine	Indistinctly laminated	Parallel and vertical	do		1862	10
Red, white, and blue	Fine	Indistinctly laminated	Parallel and vertical	Archæan		1850	11
White and blue	do	do	Irregular and vertical	do		1843	12
Red	Medium coarse	Massive	Few joints	do		1850	13
White and blue	Fine	do	Parallel and vertical	do		1874	14
Gray, red, and white	Medium coarse	do	Irregular	do		1860	15
White	Medium coarse	Massive	Few joints	Archæan		1879	16
do	Fine	do	Vertical	do		1859	17

Table IV.—TABLES INDICATING THE AMOUNT AND KINDS

NEW HAMPSHIRE—Crystalline Siliceous Rocks.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone. Popular name.	Specific variety of stone. Scientific name.
1	Plymouth	Grafton	Jarvis Sanborn	Granite	Biotite granite
2	Lebanon	do	Charles Freeman	Granitic gneiss	Biotite-epidote gneiss
3	do	do	P. H. Freets & Son	Granite	do
4	Hanover	do	David L. Tilton	do	Biotite granite
5	Rumney	do	George D. Keniston	do	Biotite-muscovite granite
6	Sunapee	Sullivan	Charles E. Boyce	Granite	Biotite-muscovite granite (light and dark).
7	West Concord	Merrimack	Putney & Nutting	do	Biotite-muscovite granite
8	do	do	Crowley & Quinn	do	do
9	do	do	George A. Bosworth	Concord granite	do
10	Concord	do	Donagan & Davis	Granite	do
11	Concord	Merrimack	Abijah Hollis	Granite	Biotite-muscovite granite
12	do	do	Harrison Granite Company	do	do
13	do	do	M. H. Johnson	do	do
14	do	do	Francis Hodgman	do	do
15	do	do	Fuller & Pressy	do	do
16	Concord	Merrimack	Granite Railway Company	Granite	Biotite-muscovite granite
17	Allenstown	do	Charles A. Bailey	do	do
18	Durham	Strafford	Joseph S. Abbott	Syenite	Biotite granite
19	Raymond	Rockingham	Aaron F. Keys	Granite	do
20	Peterborough	Hillsborough	Dennis O'Keefe	Gneiss	Muscovite-biotite gneiss
21	Milford	Hillsborough	Kittredge & Carlton	Granite	Biotite granite
22	do	do	Everett & Hutchingson	do	do
23	do	do	Thomas King	do	do
24	do	do	Nathan Merrill	do	do
25	do	do	George F. Parker	do	do
26	2 miles southwest of Milford	Hillsborough	L. M. Burns	Granite	Biotite granite
27	2 miles northwest of Milford	do	A. D. Bates	do	do
28	Mason	do	James Maxwell	do	do
29	do	do	William Braman	do	do
30	do	do	Alexander MacDonald	do	do
31	Nashua	Hillsborough	C. W. Stevens	Gneiss	Muscovite granite
32	Manchester	do	Amoskeag Manufacturing Company	Granite	Biotite granite
33	Fitzwilliam	Cheshire	D. H. Read	do	Muscovite-biotite granite
34	do	do	R. L. Angier & Co	do	Biotite granite
35	do	do	Melvin Wilson	do	Muscovite-biotite granite (light); biotite granite (dark).
36	Fitzwilliam	Cheshire	Ethan Blodgett	Granite	Biotite granite (dark)
37	do	do	John E. Fisher	do	Muscovite-biotite granite
38	do	do	Albert Hayden	Granitic gneiss	Muscovite-biotite gneiss
39	Marlborough	do	Albert G. Mann	Granite	Muscovite-biotite granite

VERMONT—Crystalline Siliceous Rocks.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Popular name.	Scientific name.
1	Brunswick	Essex	Saint Johnsbury Granite Company	Granite	Biotite granite
2	Morgan	Orleans	D. T. Turner & Son	do	do
3	Ryegate	Caledonia	R. F. Carter	do	Biotite-muscovite granite
4	do	do	R. W. Laird	do	do
5	2½ miles northeast of Woodbury	Washington	C. W. Cilley	do	Biotite granite
6	Woodbury	Washington	J. Ainsworth & Son	Granite	Biotite granite
7	do	do	Voodry & Towne	do	do
8	Barre	do	E. L. Smith	do	do
9	do	do	G. W. Mann	do	do
10	do	do	Wetmore & Morse	do	do
11	Bethel	Windsor	Edwin Kittredge	Granite	Muscovite biotite (dark); muscovite granite (light).
12	do	do	E. Sturtevant & Co	do	Muscovite granite

VERMONT—Marble and Limestone.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Popular name.	Scientific name.
1	Swanton	Franklin	G. & R. L. Barney	Lyonnaise marble	Magnesian limestone
2	Isle La Motte	Grand Isle	Ira & L P. Hall	Marble and limestone	do
3	do	do	Estate of Peter Fleury	do	do
4	do	do	Goodsell & Hursh	Limestone and marble.	do
5	do	do	H. C. Fisk & Son	do	do
6	Pittsford	Rutland	F. W. Smith & Co	Marble	Magnesian limestone
7	Rutland	do	Flint Brothers & Co	do	Magnesian limestone and calcareous dolomite.
8	do	do	Sutherland Falls Marble Company	do	Limestone
9	do	do	Columbian Marble Company	do	do
10	West Rutland	do	Rutland Marble Company	do	do
11	do	Rutland	Gilson & Woodfin	Marble	Limestone
12	do	do	Sheldons & Slason	do	do
13	do	do	Sherman & Gleason	do	do
14	South Wallingford	do	William W. Kelly	do	do
15	Dorset	Bennington	S. F. Prince & Co	do	do

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

NEW HAMPSHIRE—Crystalline Siliceous Rocks.

Color.	Structure. Texture.	Structure. Stratification.	Structure. Jointing, bedding, or natural surface.	Geological age of formation. Period.	Geological age of formation. Epoch.	Year in which opened.	
	Fine	Massive	Horizontal sheets	Archæan		1870	1
Light pink	Medium	Obscurely stratified	Horizontal and vertical	do		1865	2
Gray	Coarse	Indistinctly laminated	do	do		1844	3
do	do	Massive	Horizontal sheets	do		1870	4
do	Fine	do	do	do		1870	5
	Fine	Massive	Inclined sheets	Archæan		1846	6
Gray	do	do	Horizontal and vertical	do		1851	7
do	do	do	do	do		1866	8
do	do	do	Irregular	do		1870	9
	do	do	Horizontal and vertical	do		1866	10
	Fine	Massive	Horizontal and vertical	Archæan		1865	11
Gray	do	Indistinctly laminated	do	do		1875	12
	do	Massive	do	do		1879	13
Gray	do	Indistinctly laminated	Horizontal sheets	do		1874	14
do	do	Massive	Horizontal and vertical	do		1867	15
Gray	Fine	Massive	Horizontal sheets	Archæan		1862	16
do	Medium	do	Horizontal and vertical	do		1876	17
do	Coarse	do	Inclined sheets	do		1871	18
Light pink	Medium	Indistinctly laminated	do	do		1850	19
	Coarse	Laminated	do	do		1850	20
Gray	Medium	Indistinctly laminated	Irregular	Archæan		1877	21
do	Fine	do	do	do		1871	22
do	do	do	Vertical and transverse	do		1871	23
do	Coarse	Massive	do	do		1874	24
	Fine	Indistinctly laminated	Irregular	do		1870	25
	Coarse	Massive	Horizontal sheets	Archæan		1820	26
	Fine	Indistinctly laminated	Vertical and transverse	do		1865	27
	Medium	do	Solid	do		1875	28
Gray	do	do	Horizontal and vertical	do		1860	29
do	Fine	do	do	do		1869	30
	Coarse	Indistinctly laminated	Irregular	Archæan		1822	31
Pink	do	do	Horizontal and vertical	do		1873	32
Gray	Fine	Massive	Horizontal sheets	do		1864	33
Light and dark gray	do	do	Inclined sheets	do		1864	34
Gray	do	do	Horizontal sheets	do		1860	35
Gray	Fine	Massive	Irregular	Archæan		1868	36
do	Medium	do	Horizontal and vertical	do		1879	37
do	Fine	Indistinctly laminated	do	do		1870	38
do	do	Massive	Inclined sheets	do		1812	39

VERMONT—Crystalline Siliceous Rocks.

Dark gray	Fine	Massive	Rectangular	Archæan		1854	1
Light gray	do	Indistinctly laminated	Vertical and transverse	Upper Silurian		1870	2
Gray	Coarse	do	Vertical joints	do		1875	3
Light gray	Fine	Laminated	Horizontal and vertical joints.	do		1850	4
Light pinkish gray	Medium	Indistinctly laminated	Inclined sheets	do		1880	5
Light pinkish gray	Medium	Indistinctly laminated	Horizontal and vertical joints.	Upper Silurian		1876	6
Light gray	do	Massive	Parallel vertical joints	do		1879	7
do	Fine	do	Horizontal and vertical joints.	do		1835	8
Dark gray	do	do	Horizontal and parallel vertical joints.	do		1878	9
Light gray	Medium	do	Horizontal and vertical joints.	do		1840	10
Light gray	Fine	Massive	Inclined sheets	Upper Silurian		1868	11
do	Medium	do	Parallel vertical joints	do		1879	12

VERMONT—Marble and Limestone.

Red, variegated	Coarse and fine	Massive	Thick	Lower Silurian		1866	1
Black, gray, and variegated	Fine	do	Even, thick	do		1874	2
do	Coarse	do	Thick	do		1820	3
do	Coarse and fine	do	Even, thick	do		1874	4
do	do	do	do	do		1776	5
White to dark blue	Fine	Massive	Even, thick	Lower Silurian		1880	6
White with dark shades	do	do	Thick	do		1866	7
White with dark bands and streaks.	do	do	do	do		1836	8
White with dark shades	do	do	do	do		1867	9
White to dark blue	do	do	do	do		1845	10
White and blue	Fine	Massive	Thick	Lower Silurian		1845	11
do	do	do	do	do		1844	12
White and mottled	do	do	Obscure	do		1844	13
White	do	do	Even, thick	do		1867	14
White and mottled	do	do	do	do		1850	15

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

VERMONT—MARBLE AND LIMESTONE—Continued.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone. Popular name.	Scientific name.
16	Dorset	Bennington	Freedly & Son	Marble	Limestone
17	East Dorset	do	Hollister, Tyrell & Co. (New Dorset Marble Company).	do	
18	do	do	D. L. Kent & Co	do	Magnesian limestone

VERMONT—SLATE.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Popular name.	Scientific name.
1	Northfield	Washington	Adams Slate and Tile Company	Slate	
2	Castleton	Rutland	Richard Conway	do	
3	do	do	Clifford & Litchfield	do	
4	do	do	Lake Shore Slate Company	do	
5	do	do	Blue Slate Company	do	
6	Castleton	Rutland	Snowden Slate Company	Slate	
7	Fair Haven	do	Pierce Roberts	do	
8	do	do	Jones, Owens & Co	do	
9	do	do	Vermont Union Slate Company	do	
10	do	do	Fair Haven Marble and Marbleized Slate Company.	do	
11	Fair Haven	Rutland	Griffiths, Owen & Co. (north quarry)	Slate	
12	do	do	Griffiths, Owen & Co. (south quarry)	do	
13	Poultney	do	Eureka Slate Company	do	
14	do	do	Globe Slate Company	do	
15	do	do	Evergreen Slate Company	do	
16	Poultney	Rutland	Lloyd, Owens & Co	Slate	
17	do	do	R. E. Lloyd	do	
18	do	do	Griffith & Nathaniel	do	
19	do	do	Daniel Culver	do	
20	do	do	Williams Brothers & Co	do	
21	Poultney	Rutland	J. Evans & Co	Slate	
22	Pawlet	do	M. Welch	do	
23	do	do	H. J. Williams	do	
24	do	do	E. R. Norton	do	
25	do	do	J. S. Warren	do	
26	Pawlet	Rutland	W. J. Evans	Slate	
27	West Pawlet	do	H. W. Hughes	do	
28	do	do	Rising & Nelson	do	
29	do	do	Owen Evans & Son	do	
30	do	do	The Brownell Slate and Flagging Company	do	
31	West Pawlet	Rutland	H. Dillingham	Slate	

CONNECTICUT—CRYSTALLINE SILICEOUS ROCKS.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Popular name.	Scientific name.
1	East Killingly	Windham	Joseph Oatley	Gneiss	Hornblende-biotite gneiss
2	Sterling	do	Jeremiah W. Boswell	Granite	Biotite gneiss
3	do	do	Samuel Townsend	do	
4	do	do	Oneco Ledge Company	do	
5	Willimantic	do	Alanson Humphrey	Gneiss	Biotite gneiss
6	Bolton	Tolland	Bolton Quarry Company (S. Beldon & Son)	Mica-schist	Biotite gneiss
7	Glastonbury	Hartford	Chester Hentze	Gneiss	do
8	West Norfolk	Litchfield	Snow & Wooster	do	Biotite-muscovite granite
9	Thomaston	do	Plymouth Granite Company	Gneissoid granite	do
10	Roxbury	do	E. Mower	Granitic gneiss	do
11	Greenwich	Fairfield	John Voorhis	Gneiss	Hornblende-biotite gneiss
12	do	do	Sylvester D. Hill	do	do
13	do	do	William Ritch	do	do
14	do	do	Thomas Ritch	do	do
15	North Bridgeport	do	Wheeler Beers	do	do
16	Ansonia	New Haven	Spring & Wilcox	Gneiss	Muscovite-biotite gneiss
17	New Haven	do	Patrick Dowling	Trap	Diabase
18	do	do	Francis Donnelly	do	do
19	do	do	C. W. Blakeslee	do	do
20	Branford (south of)	do	C. D. Allen (2 quarries)	Granite	Biotite gneiss
21	Leetes island	New Haven	John Beattie	Granite	Biotite granite
22	Stony Creek	do	John Robbins	do	do
23	Haddam	Middlesex	Isaac Arnold	Gneiss	Hornblende-biotite gneiss
24	Middletown	do	Burr & Whitmore	do	do
25	Lyme	New London	C. J. McCurdy and E. E. Salisbury	Red porphyry granite	Biotite granite
26	Lyme (6 miles east of)	New London	Luce & Hoskins	Gray granite	Biotite gneiss
27	Waterford	do	J. B. Palmer & Co	Granite	Biotite granite
28	Niantic (2½ miles southeast of)	do	Warren Gates' Sons	do	do
29	Groton	do	Groton Granite Company	do	do
30	do	do	Charles F. Stoll	do	do
31	Groton	New London	Merritt, Gray & Company	Granite	Biotite granite
32	Mason's island	do	F. K. Ballou	do	do

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

VERMONT—MARBLE AND LIMESTONE—Continued.

Color.	Structure. Texture.	Stratification.	Jointing, bedding, or natural surface.	Geological age of formation. Period.	Epoch.	Year in which opened.	
White and mottled	Fine	Massive	Even, thick	Lower Silurian		1840	16
....do	....do	....do	....do	....do		1850	17
....do	....do	....do	....do	....do		1827	18

VERMONT—SLATE.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Blue-black	Fine	Rectangular	Even and smooth	Lower Silurian		1855	1
Purple	....do	Rhomboidal	....do	....do		1865	2
....do	....do	Rhomboidal and rectangular.	....do	....do		1854	3
Purple and green	....do	Rhomboidal	Regular	....do		1852	4
Blue and green	....do	Trapezoidal	....do	....do		1865	5
Purple	Fine	Rectangular	Regular	Lower Silurian		1864	6
Purple and green	....do	Rhomboidal	Even, smooth	....do		1879	7
Variegated	....do	....do	....do	....do		1879	8
Purple, green, and variegated.	....do	....do	....do	....do		1867	9
Variegated, various shades.	....do	Irregular	Even	....do		1852	10
Green and purple, variegated.	Fine	Rhomboidal	Even	Lower Silurian		1876	11
Purple, variegated	....do	....do	....do	....do		1876	12
Green	....do	Irregular	....do	....do		1852	13
Green, purple, and variegated.	....do	Rhomboidal and rectangular.	....do	....do		1868	14
Green	....do	Rhomboidal	Irregular	....do		1867	15
Green, purple, and variegated.	Fine	Rhomboidal	Even	Lower Silurian		1868	16
....do	....do	Irregular	....do	....do		1870	17
Green	....do	....do	....do	....do		1871	18
Sea-green	....do	Variable	....do	....do		1870	19
Green	....do	....do	....do	....do		1879	20
Green	Fine	Variable	Even	Lower Silurian		1874	21
Sea-green	....do	Rhomboidal	....do	....do		1870	22
....do	....do	....do	....do	....do		1878	23
Purple	....do	Variable	....do	....do		1878	24
Sea-green	....do	....do	....do	....do		1872	25
Sea-green	Fine	Variable	Even	Lower Silurian		1872	26
....do	....do	Rhomboidal	....do	....do		1873	27
....do	....do	Rectangular	....do	....do		1876	28
....do	....do	Irregular	....do	....do		1876	29
Sea-green and blue-black	....do	Joints parallel	Smooth and fine	....do		1872	30
Sea-green	Fine	Rectangular	Smooth	Lower Silurian		1878	31

CONNECTICUT—CRYSTALLINE SILICEOUS ROCKS.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Light gray	Coarse	Laminated	Irregular, vertical	Archæan		1842	1
Gray and light gray	....do	....do	....do	....do		1877	2
....do	....do	....do	....do	....do		1875	3
....do	....do	....do	....do	....do		1855	4
	Fine	....do	Irregular	....do		1877	5
	Fine	Laminated	Irregular; nearly vertical	Archæan		1805	6
Dark gray	Coarse	....do	Irregular sheet and vertical	....do		1850	7
Light gray	Fine	....do	....do	....do		1873	8
....do	....do	....do	Irregular, vertical, and inclined sheet.	....do		1855	9
....do	....do	....do	....do	....do		1873	10
Black	Coarse to fine	Laminated	Irregular sheet and vertical	Archæan		1835	11
....do	....do	....do	....do	....do		1830	12
....do	....do	....do	....do	....do		1850	13
....do	....do	....do	....do	....do		1850	14
Dark gray	Coarse	....do	....do	....do		1873	15
Bluish gray	Compact, granular	Laminated	Horizontal sheet and vertical.	Archæan		1848	16
Black	Fine	Massive	Irregular, vertical	Triassic		1870	17
....do	....do	....do	....do	....do		1871	18
....do	....do	....do	....do	....do		1863	19
Dark gray	Coarse	....do	Much broken	Archæan		1879	20
Gray to red	Coarse, porphyritic	Massive	Irregular sheet and vertical	Archæan		1870	21
....do	....do	....do	....do	....do		1878	22
Black	Fine	Laminated	....do	....do		1800	23
....do	Coarse	....do	Solid	....do		1830	24
Red	Coarse, porphyritic	Massive	Irregular sheet and vertical	....do		1876	25
Gray	Coarse, striated	Laminated	Irregular sheet and vertical	Archæan		1875	26
Light gray	Fine	Massive	....do	....do		1835	27
....do	....do	....do	....do	....do		1832	28
....do	....do	Indistinctly laminated	....do	....do		1857	29
....do	....do	....do	....do	....do		1869	30
Light gray	Fine	Indistinctly laminated	Irregular sheet and vertical	Archæan		1840	31
	Coarse to fine	Massive	Much broken	....do		1879	32

Table IV.—TABLES INDICATING THE AMOUNT AND KINDS

CONNECTICUT—Sandstone.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone. Popular name.	Scientific name.
1	Manchester	Hartford	Charles O. Wolcott	Sandstone	Sandstone
2	East Haven	New Haven	Francis Donelly	do	do
3	do	do	Robert Redfield	do	do
4	Portland	Middlesex	Brainerds & Co	do	do
5	do	do	Middlesex Quarry Company	do	do
6	Portland	Middlesex	Shaler & Hall Quarry Company	Sandstone	Sandstone

NEW YORK—Crystalline Siliceous Rocks.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Popular name.	Scientific name.
1	Hastings-upon-Hudson	Westchester	Munson & Co	Gneiss	Biotite gneiss
2	Cold Spring	Putnam	J. E. Bailey	Granite	Hornblende gneiss
3	Clayton	Jefferson	Robert Forsyth	do	Hornblende granite

NEW YORK—Marble and Limestone.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Popular name.	Scientific name.
1	Tuckahoe	Westchester	Tuckahoe Marble Company	Marble	Dolomite
2	do	do	John M. Masterton	do	do
3	Greenport	Columbia	F. W. Jones	Limestone	Limestone
4	Sandy Hill	Washington	Kingsbury Blue Stone Company	do	do
5	Saratoga	Saratoga	Prince Wing	do	Magnesian limestone
6	South Glens Falls	Saratoga	Thomas Reynolds & Co	Limestone	Magnesian limestone
7	Glens Falls	Warren	Glens Falls Company	do	do
8	Crown Point	Essex	Frank Clark	do	do
9	Willsborough	do	Lake Champlain Quarry Company	do	do
10	Plattsburgh	Clinton	Burlington Manufacturing Company	do	
11	Gouverneur	Saint Lawrence.	Gouverneur Marble and Whitney Granite Company.	Limestone	Magnesian limestone
12	Three Mile Bay	Jefferson	Oren Fish	do	do
13	Lowville	Lewis	L. H. Carter	do	Limestone
14	Talcottville	do	Melchor Auer	do	
15	Prescott	Oneida	Evan T. Thomas	do	Magnesian limestone
16	Prescott	Oneida	H. & L. N. Jones	Limestone	Magnesian limestone
17	Canajoharie	Montgomery	Charles Shaper	do	do
18	Tribes Hill	do	James Shanahan	do	do
19	do	do	Henry Hurst	do	do
20	do	do	James Shanahan & Co	do	do
21	Amsterdam	Montgomery	James Griswold	Limestone	Magnesian limestone
22	do	do	James Shanahan	do	do
23	do	do	D. C. & N Hewitt	do	do
24	Sharon Springs	Schoharie	Charles J. Smith	do	do
25	Cobleskill	do	Reilly & Scanlon	do	do
26	Howe's Cave	Schoharie	Howe's Cave Association	Limestone	Magnesian limestone
27	Springfield Centre	Otsego	McCabe Brothers	do	do
28	Onondaga	Onondaga	Hughes, Brother & Co	do	do
29	do	do	John Murray	do	do
30	do	do	Patrick McElroy	do	do
31	Fairmount	Onondaga	John Connors	Limestone	Magnesian limestone
32	do	do	M. Degnan	do	do
33	Manlius	do	O. P. Hughes	do	do
34	Auburn	Cayuga	Goodrich & Son	do	do
35	do	do	John Bennett	do	do
36	Auburn	Cayuga	Albert Garret	Limestone	Magnesian limestone
37	Union Springs	do	A. B. Niles	do	do
38	Waterloo	Seneca	Loren Thomas	do	do
39	do	do	John Emmett	do	do
40	Rochester	Monroe	J. B. Pike	do	Dolomite
41	Rochester	Monroe	J. B. Bennett	Limestone	Dolomite
42	do	do	H. S. Brown	do	do
43	Le Roy	Genesee	J. W. Woodruff	do	Magnesian limestone
44	do	do	Wm. S. Brown	do	do
45	Lockport	Niagara	R. & J. Carpenter	do	Calcareous dolomite
46	Williamsville	Erie	J. B. Young	Limestone	Limestone
47	do	do	Lautz & Co	do	do
48	do	do	W. Foglesange	do	do
49	do	do	J. Uebelhoer	do	Magnesian limestone
50	East Buffalo	do	W. W. Bailey	do	do
51	Buffalo	Erie	J. Uebelhoer	Limestone	Magnesian limestone
52	do	do	John Gehsl	do	do
53	do	do	Mrs. J. Gehres	do	do
54	do	do	John Ortner	do	do
55	do	do	A. Kaple	do	do

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

CONNECTICUT—Sandstone.

Color.	Structure. Texture.	Structure. Stratification.	Structure. Jointing, bedding, or natural surface.	Geological age of formation. Period.	Geological age of formation. Epoch.	Year in which opened.	
Red	Fine	Massive	Irregular	Triassic		1855	1
do	Coarse	do	do	do		1840	2
do	do	do	do	do		1874	3
Brown	Fine	do	do	do		1700	4
do	do	do	do	do		1826	5
Brown	Fine	Massive	Irregular	Triassic		1827	6

NEW YORK—Crystalline Siliceous Rocks.

Light gray	Coarse, porphyritic	Laminated	Few joints	Archæan		1861	1
Gray	Fine	do	Irregular	do		1877	2
Red	Coarse	Massive	Not jointed	do		1876	3

NEW YORK—Marble and Limestone.

White	Fine, crystalline	Massive	Even, thick	Archæan		1860	1
"Water blue"	Medium, crystalline	do	Uneven, thick	do		1825	2
Gray	Semi-crystalline, fossiliferous.	do	do	Upper Silurian		1850	3
Dark gray	Fine	do	Even, thick	Lower Silurian		1870	4
Blue-black	Fine, fossiliferous	Irregular	Even, medium thick	do		1860	5
Blue-black	Fine, fossiliferous	Massive	Even, thick	Lower Silurian		1850	6
do	do	do	do	do		1850	7
do	Fine	do	do	do		1876	8
do	Fine, fossiliferous	do	do	do		1835	9
Gray and red	do	do	do	do		1879	10
Gray	Fine, semi-crystalline	Massive	Uneven, thick	Archæan		1876	11
Dark drab	Fine, crystalline	Even, parallel	Even, thin to medium	Lower Silurian		1873	12
Drab	Fine, fossiliferous	Massive	Even, medium to thick	do		1838	13
Dark drab	Fine and coarse	Even, parallel	Even, thin to medium	do		1850	14
Gray	Fine, crystalline	Massive	Even, thick	do		1852	15
Gray	Fine, crystalline	Massive	Even, thick	Lower Silurian		1860	16
Dark drab	Fine and coarse	Indistinct	Even, thin to medium	do		1855	17
Blue-black	Medium, semi-crystalline	Massive	Even, medium	do		1830	18
do	do	do	Even, thick	do		1852	19
do	do	do	do	do		1864	20
Blue-black	Medium, semi-crystalline	Massive	Even, medium to thick	Lower Silurian		1873	21
do	do	do	do	do		1860	22
do	do	do	Even, thin, medium, and thick.	do		1865	23
do	Fine	Indistinct	Even, thin to thick	Upper Silurian		1850	24
Blue and gray	do	Massive	Thin to thick	Devonian		1850	25
Blue-black and gray	Fine	Indistinct	Uneven, thin to thick	Upper Silurian		1866	26
Blue-black	do	Massive	Medium to thick	Devonian		1869	27
Gray	Fine, semi-crystalline	Indistinct	Thick	do		1840	28
do	do	do	do	do		1840	29
do	do	do	do	do		1840	30
Gray	Fine, semi-crystalline	Indistinct	Uneven, medium	Devonian		1830	31
do	do	do	do	do		1830	32
do	do	do	do	do		1870	33
do	Fine, crystalline	Massive	Even, medium	do		1830	34
do	do	do	do	do		1860	35
Gray	Fine, crystalline	Massive	Even, medium	Devonian		1830	36
Blue-black	Fine	do	Even, medium to thick	do		1834	37
Dark gray	do	do	Even, thick	do		1830	38
do	do	do	do	do		1820	39
Dark drab	do	do	Irregular	do		1868	40
Dark drab	Fine	Massive	Irregular	Devonian		1872	41
Blue-black	do	do	Uneven, medium	Upper Silurian		1869	42
Dark gray	Fine, semi-crystalline	do	Even, medium	Devonian		1850	43
do	do	do	do	do		1874	44
Light gray	Medium, semi-crystalline	do	Thick	Upper Silurian		1836	45
Light gray	Medium, semi-crystalline	Massive	Uneven, medium	Devonian		1838	46
do	do	do	do	do		18[illegible]8	47
do	do	do	do	do		1850	48
do	do	do	Even, medium thick	do		1870	49
Gray	do	do	do	do		1835	50
Light gray	Medium, semi-crystalline	Massive	Even, medium thick	Devonian		1865	51
Gray	do	do	do	do		1859	52
Dark drab	do	do	Even, thick	do		1858	53
do	do	do	do	do		1868	54
do	Fine, semi-crystalline	do	do	do		1820	55

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

NEW YORK—SANDSTONE.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone.	
				Popular name.	Scientific name.
1	Potsdam	Saint Lawrence	Potsdam Sandstone Company	Sandstone	Sandstone
2	Hammond	do	James Finnegan	do	do
3	Fort Ann	Washington	Jenkins White	do	do
4	Schenectady	Schenectady	Upper Aqueduct Quarry Company	do	do
5	Eminence	Schoharie	Simmonds & Bogardus	Blue-stone	do
6	Hunter's Land	Schoharie	Middleburgh Bluestone Company	Blue-stone	Sandstone
7	Reidsville	Albany	William Stoneburne & Isaac Brate	do	do
8	do	do	Edward Udell	do	do
9	do	do	James B. Winne	do	do
10	Dormansville	do	Allen Kniffen	do	do
11	Leeds	Greene	Leeds Quarries	Blue-stone	Sandstone
12	Kiskatom	do	Jessup & McCarthy	do	do
13	do	do	Moon & Meyer	do	do
14	do	do	James Butler	do	do
15	do	do	Peter Jessup & Co	do	do
16	Kiskatom	Greene	McCabe & Co. and William Dorsey	Blue-stone	Sandstone
17	Palenville	do	Alfred Griffin	do	do
18	do	do	H. B. Walters	do	do
19	Quarryville	Ulster	Peter Daly & Co	do	do
20	do	do	S. O. Haggadon	do	do
21	Quarryville	Ulster	Asa Cook & Co	Blue-stone	Sandstone
22	do	do	Schoonmaker & Cook	do	do
23	do	do	D. Lyman	do	do
24	do	do	Mason & Mack	do	do
25	do	do	John Fawley	do	do
26	Quarryville	Ulster	Mower & Co	Blue-stone	Sandstone
27	do	do	A. Carwright	do	do
28	do	do	Thomas Fitzpatrick	do	do
29	do	do	Daniel Driscoe	do	do
30	do	do	Michael Maloy	do	do
31	Quarryville	Ulster	Patrick Merinor	Blue-stone	Sandstone
32	do	do	Daniel Driscoe & Co	do	do
33	do	do	Cunningham Brothers	do	do
34	do	do	Francis Stone	do	do
35	do	do	W. Teetsel & Co	do	do
36	Quarryville	Ulster	Adam Sax	Blue-stone	Sandstone
37	do	do	Corcoran & Kelley	do	do
38	do	do	Patrick Devery & Co	do	do
39	do	do	Michael Kelley	do	do
40	Saugerties	do	John Hackett	do	do
41	Saugerties	Ulster	Thomas Maher	Blue-stone	Sandstone
42	do	do	Thomas Rafferty	do	do
43	do	do	Pat Moore & Co	do	do
44	do	do	Berhaus & Brainard	do	do
45	do	do	Margaret Pierce	do	do
46	Saugerties	Ulster	John Dorgan	Blue-stone	Sandstone
47	do	do	John Lanagan	do	do
48	do	do	Thomas Malone	do	do
49	do	do	Scott Brothers	do	do
50	Kingston	do	William Hart	do	do
51	Kingston	Ulster	Phillip Stauble	Blue-stone	Sandstone
52	do	do	Jno. H. Carle & Co	do	do
53	do	do	Mean, Goldbaugh, Kull & Saan	do	do
54	do	do	R. Short & Co., H. Brink & Co., and others	do	do
55	do	do	Barney Burns	do	do
56	Kingston	Ulster	McDonald & Co., Riley & Co., and others	Blue-stone	Sandstone
57	do	do	Frank Young	do	do
58	do	do	Carle & Van Hautenburgh	do	do
59	do	do	Patrick Maguire	do	do
60	do	do	Burke & Co	do	do
61	Kingston	Ulster	Christopher Maguire	Blue-stone	Sandstone
62	do	do	Leahy & Co	do	do
63	do	do	David Henderson	do	do
64	do	do	Osterhout & Sheehan	do	do
65	do	do	Robert & Robert J. Charlton	do	do
66	Kingston	Ulster	William Charlton	Blue-stone	Sandstone
67	do	do	Michael Coogan	do	do
68	do	do	Welsh & Hays	do	do
69	do	do	David Murphy	do	do
70	do	do	James Leahy	do	do
71	Kingston	Ulster	B. Leahy	Blue-stone	Sandstone
72	do	do	James Ryan	do	do
73	do	do	Ryan & Co	do	do
74	do	do	McCrief Brothers	do	do
75	do	do	William Donaldson	do	do
76	Kingston	Ulster	Morrissey Brothers	Blue-stone	Sandstone
77	do	do	Patrick Conlon	do	do
78	do	do	James F. Burke	do	do
79	do	do	Michael Lamb	do	do
80	do	do	Michael H. Fisher	do	do
81	Kingston	Ulster	James Highland, P. Urel	Blue-stone	Sandstone
82	do	do	James Haggerty	do	do
83	West Hurley	do	Thomas Conlon	do	do
84	do	do	Thomas Graut	do	do
85	do	do	Patrick Bahan	do	do

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

NEW YORK—SANDSTONE.

Color.	STRUCTURE.			GEOLOGICAL AGE OF FORMATION.		Year in which opened.	
	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.		
Red	Coarse	Even, parallel	Even, thin to medium	Lower Silurian		1856	1
do	do	Indistinct	Even, thin to thick	do		1876	2
Light gray	Medium to fine	Massive	Uneven, medium	do		1840	3
Blue-black	Fine	do	Uneven, thick	do		1867	4
Dark gray	Fine and coarse	Even, parallel	Even, thin	Devonian		1879	5
Dark gray	Coarse	Even, parallel	Variable	Devonian		1865	6
do	do	do	Even, thin	do		1850	7
do	do	do	do	do		1860	8
do	do	do	do	do		1850	9
do	do	do	do	do		1870	10
Dark gray	Fine and coarse	Even, parallel	Even, thin	Devonian		1840	11
do	do	do	do	do		1873	12
do	Medium	do	Even, thin to medium	do		1860	13
do	do	do	do	do		1850	14
do	Fine	do	do	do		1860	15
Dark gray	Fine	Even, parallel	Even, thin to thick	Devonian		1873	16
do	do	Indistinct	Even, thin to medium	do		1855	17
do	do	do	do	do		1850	18
do	do	Even, parallel	Even, thin to thick	do		1860	19
do	do	do	do	do		1845	20
Dark gray	Fine	Indistinct	Even, thin to thick	Devonian		1850	21
do	do	Even, parallel	do	do		1850	22
do	do	do	do	do		1854	23
do	do	Indistinct	Even, thin to medium	do		1850	24
do	do	do	do	do		1860	25
Dark gray	Fine	Indistinct	Even, thin to thick	Devonian		1850	26
do	do	do	do	do		1845	27
do	do	do	do	do		1845	28
do	do	do	do	do		1845	29
do	do	do	do	do		1845	30
Dark gray	Fine	Indistinct	Even, thin to thick	Devonian		1840	31
do	do	do	do	do		1850	32
do	do	do	do	do		1840	33
do	do	do	do	do		1862	34
do	do	Even, parallel	do	do		1855	35
Dark gray	Fine	Even, parallel	Even, thin to thick	Devonian		1845	36
do	do	do	do	do		1845	37
do	do	do	Even, thin to medium	do		1850	38
do	Coarse	do	Even, thin to thick	do		1877	39
do	do	Indistinct	do	do		1850	40
Dark gray	Fine	Indistinct	Even, thin to thick	Devonian		1845	41
do	do	do	do	do		1850	42
do	do	do	do	do		1870	43
do	do	do	do	do		1860	44
do	do	do	do	do		1845	45
Dark gray	Fine	Indistinct	Even, thin to thick	Devonian		1850	46
do	do	do	do	do		1845	47
do	do	do	do	do		1850	48
do	do	do	do	do		1845	49
do	do	Even, parallel	do	do		1860	50
Dark gray	Fine	Even, parallel	Even, thin to thick	Devonian		1850	51
do	do	do	do	do		1845	52
do	do	Indistinct	do	do		1850	53
do	do	Even, parallel	do	do		1861	54
do	do	Indistinct	do	do		1850	55
Dark gray	Fine	Even, parallel	Even, thin to thick	Devonian		1865	56
do	do	do	do	do		1860	57
do	do	do	do	do		1842	58
do	do	do	do	do		1840	59
do	do	do	do	do		1858	60
Dark gray	Fine	Even, parallel	Even, thin to thick	Devonian		1845	61
do	do	do	do	do		1850	62
Gray	do	do	do	do		1860	63
Dark gray	do	do	Even, thin to medium	do		1864	64
do	do	do	Even, thin to thick	do		1850	65
Dark gray	Fine	Even, parallel	Even, thin to thick	Devonian		1850	66
do	do	do	do	do		1850	67
do	do	do	do	do		1850	68
do	do	do	do	do		1871	69
do	do	do	do	do		1871	70
Dark gray	Fine	Even, parallel	Even, thin to thick	Devonian		1850	71
do	do	do	do	do		1868	72
do	do	do	do	do		1871	73
do	do	do	Even, thin to medium	do		1850	74
do	do	do	Even, thin to thick	do		1869	75
Dark gray	Fine	Even, parallel	Even, thin to medium	Devonian		1870	76
do	do	do	do	do		1840	77
Bluish gray	do	do	do	do		1850	78
Dark gray	do	do	do	do		1847	79
do	do	do	do	do		1840	80
Dark gray	Fine	Even, parallel	Even, thin to medium	Devonian		1847	81
do	do	do	do	do		1850	82
do	do	do	do	do		1860	83
do	do	do	do	do		1850	84
do	do	do	do	do		1860	85

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

NEW YORK—SANDSTONE—Continued.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone.	
				Popular name.	Scientific name.
86	West Hurley	Ulster	John Dunn	Blue-stone	Sandstone
87	....do	... do	Thomas Pearl	....do	....do
88	....do	.. do	Dumond, Ferguson, France	... do	.. .do
89	....do	....do	Patrick O'Neil	... do	....do
90	....do	....do	William H. Shader	....do	....do
91	West Hurley	Ulster	Ira Ploss & Co	Blue-stone	Sandstone
92	....do	....do	Obediah Wolven	.. do	....do
93	....do	... do	L. Lawson	... do	....do
94	....do	....do	William F. Stewart	....do	... do
95	....do	....do	Rufus Smedes	.. do	....do
96	West Hurley	Ulster	Joseph Scully	Blue-stone	Sandstone
97	....do	....do	Michael Handreen, Michael Doyle	....do	... do
98	... do	....do	Purcell & Doolan, P. Finnigan	....do	... do
99	....do	....do	Patrick Keeney and others	....do	... do
100	....do	....do	Richard Dunn	... do	....do
101	West Saugerties	Ulster	Elias Snider	Blue-stone	Sandstone
102	....do	... do	Edward Bach	... do	... do
103	... do	....do	Wesley Lewis	... do	... do
104	High Woods	....do	W. Short & Co	... do	....do
105	....do	....do	Van Aken & Co	... do	....do
106	High Woods	Ulster	Nathan Van Aken	Blue-stone	Sandstone
107	....do	....do	James Van Aken	....do	... do
108	....do	....do	Carle & Co	....do	... do
109	....do	... do	Green & Co	....do	... do
110	Woodstock	....do	Philip H. Lapo	....do	....do
111	Woodstock	Ulster	Elting & Maxwell	Blue-stone	Sandstone
112	....do	....do	Lawson & Fitch	... do	... do
113	....do	... do	Noah Wolven	... do	... do
114	....do	....do	Michael Brophy	... do	....do
115	....do	....do	Thomas Mead, John Gable	....do	....do
116	Woodstock	Ulster	Thomas Hennessy	Blue-stone	Sandstone
117	... do	....do	Henry Russell & Co	....do	....do
118	Shandaken	....do	J. H. Risley	... do	... do
119	....do	....do	....do	Sandstone	... do
120	Phœnicia	....do	J. L. McGrath	Blue-stone	....do
121	Phœnicia	Ulster	Janneson Brothers	Blue-stone	Sandstone
122	....do	....do	George Wilson	... do	... do
123	....do	... do	Darius Rider	... do	....do
124	....do	....do	Delamater & Bouse	....do	....do
125	....do	....do	Merritt & Delamater	....do	....do
126	Phœnicia	Ulster	J. McGrath	Blue-stone	Sandstone
127	Boiceville	....do	James Schermerhorn	....do	... do
128	... do	....do	Lane & Co	....do	....do
129	... do	....do	Uriah A. Avery	....do	... do
130	Brodhead	... do	James H. Shaw	....do	... do
131	Brodhead	Ulster	Cornish & Rowe	Blue-stone	Sandstone
132	... do	... do	J. B. Hammond	... do	... do
133	... do	... do	P. W. Van Kleek	....do	....do
134	....do	....do	A. Bishop & Co	....do	....do
135	....do	... do	Hungerford & Boice	....do	....do
136	Ellenville	Ulster	Rochester and Wawarsing Quarries	Blue-stone	Sandstone
137	3 miles north of Poughkeepsie	....do	William Fuller	....do	... do
138	Nyack	Rockland	Nelson Puff	Brownstone	....do
139	Pond Eddy	Sullivan	Whalen, Martin & Van Aken	Blue-stone	....do
140	3 miles west of West Brookville	....do	West Brookville Quarries	....do	....do
141	Rockland	Delaware	Patrick Fenden and others	Blue-stone	Sandstone
142	Trout Brook	....do	John Rhodes	... do	....do
143	....do	....do	Patrick Riley	....do	....do
144	.. do	....do	George Whitehead	....do	....do
145	Margarettville	....do	Grant Brothers	... do	... do
146	Roxbury	Delaware	B. B. Boughton	Blue-stone	Sandstone
147	... do	....do	Robinson & Soop	... do	....do
148	Grand Gorge	....do	Samuel Draffen and Andrew Elflcin	... do	....do
149	Cooperstown	Otsego	John Wood	Sandstone	....do
150	Oneonta	....do	D. Orr	Blue-stone	....do
151	Guilford	Chenango	Mrs. W. W. Davis	Blue-stone	Sandstone
152	Smithville Flats	....do	John Miller	do	....do
153	3 miles from New Hartford	Oneida	Mallory & Griffith	Sandstone	... do
154	Camden	do	Nathan Beebe	....do	... do
155	Atwater	Cayuga	J. G. Baeger	Blue-stone	....do
156	Ithaca	Tompkins	McCluoe's Quarry	Blue-stone	Sandstone
157	Trumansburg	....do	Dumont & Cusic	Flag-stone	....do
158	Covert	Seneca	T. H. King	....do	Sandstone (calcareous)
159	... do	... do	C. O. Ogden	....do	... do
160	Watkins Glen	Schuyler	Northern Central Railway Company	Sandstone	Sandstone
161	Corning	Steuben	John Kelley	Sandstone	Sandstone (calcareous)
162	....do	....do	George Barnard	... do	....do
163	... do	....do	L. Field	....do	... do
164	Canisteo	... do	James Mullen	....do	....do
165	Brockport	Monroe	Hugh Quinn	....do	Sandstone
166	Brockport	Monroe	George Coon	Sandstone	Sandstone
167	Hulburton	Orleans	O'Brien & O'Reilly	... do	....do
168	....do	....do	A. J. Squires	....do	....do
169	Albion	....do	Gilbert Brady	....do	....do
170	....do	....do	Albion and Medina Sandstone Company	....do	....do

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

NEW YORK—SANDSTONE—Continued.

Color.	Structure. Texture.	Stratification.	Jointing, bedding, or natural surface.	Geological age of formation. Period.	Epoch.	Year in which opened.	
Dark gray	Fine	Even, parallel	Even, thin to medium	Devonian		1874	86
do	Coarse	do	do	do		1877	87
do	Fine	do	do	do		1865	88
do	do	do	Even, thin to thick	do		1864	89
do	do	do	Even, thin to medium	do		1860	90
Dark gray	Fine	Even, parallel	Even, thin to medium	Devonian		1860	91
do	do	do	do	do		1879	92
do	do	do	do	do		1845	93
do	do	do	do	do		1878	94
do	do	do	Medium to thick	do		1855	95
Dark gray	Fine	Even, parallel	Even, thin to medium	Devonian		1840	96
do	do	do	do	do		1860	97
do	do	do	do	do		1875	98
do	do	do	do	do		1860	99
do	do	do	do	do		1856	100
Dark gray	Fine	Indistinct	Even, thin to medium	Devonian		1850	101
do	do	do	do	do		1857	102
do	do	do	Even, thick	do		1850	103
do	do	do	Even, thin to thick	do		1860	104
do	do	do	do	do		1860	105
Dark gray	Fine	Indistinct	Even, thin to thick	Devonian		1860	106
do	do	do	do	do		1871	107
do	Coarse	do	do	do		1860	108
do	do	do	do	do		1860	109
do	Fine	do	Uneven, thin to thick	do		1875	110
Dark gray	Fine	Indistinct	Even, thick	Devonian		1869	111
do	do	do	do	do		1850	112
do	Coarse	do	do	do		1860	113
do	Fine	do	Even, thin to medium	do		1878	114
do	Coarse	do	Even, medium to thick	do		1850	115
Dark gray	Coarse	Indistinct	Even, medium to thick	Devonian		1850	116
do	do	do	do	do		1850	117
do	do	Even, parallel	Even, thin to medium	do		1872	118
do	do	do	do	do		1874	119
do	do	do	do	do		1871	120
Dark gray	Coarse	Massive	Even, thin to medium	Devonian		1876	121
do	do	do	do	do		1873	122
do	Fine	do	do	do		1875	123
do	do	do	do	do		1878	124
Reddish brown	do	do	Even, medium to thick	do		1879	125
Dark drab	Fine	Massive	Medium to thick	Devonian		1869	126
Dark gray	do	do	Even, thick	do		1877	127
do	do	do	do	do		1877	128
do	do	do	do	do		1877	129
do	do	do	do	do		1870	130
Blue-black	Coarse	Indistinct	Even, thick	Devonian		1878	131
Dark gray	Fine	do	do	do		1871	132
do	do	do	do	do		1871	133
do	do	do	do	do		1877	134
do	do	Massive	do	do		1877	135
Dark gray	Coarse	Even, parallel	Thin to medium	Devonian		1871	136
do	do	Variable	Even, thick	Lower Silurian		1870	137
Red	Fine	Massive	Even, medium to thick	Triassic		....	138
Gray	do	Even, parallel	Even, thin to medium	Devonian		1870	139
Dark gray	Coarse	do	Even, thin to thick	do		1850	140
Gray	Coarse	Even, parallel	Even, thin to thick	Devonian		1880	141
Dark gray	do	Indistinct	do	do		1880	142
do	do	do	do	do		1879	143
do	do	do	do	do		1879	144
do	Fine	do	Even, thin to medium	do	Catskill	1879	145
Grayish brown	Coarse	Indistinct	Even, thin to medium	Devonian	Catskill	1860	146
do	do	do	do	do	do	1871	147
Gray	Medium	do	do	do	do	1871	148
Dark gray	Fine	do	Even, thick	do	Hamilton	1862	149
do	do	do	Even, thin to medium	do	Chemung	1870	150
Dark gray	Fine	Massive	Even, thin to medium	Devonian	Chemung	1850	151
do	do	Indistinct	Even, medium to thick	do	do	1871	152
Light gray	Coarse	Massive	Uneven, medium to thick	Upper Silurian	Oneida	1860	153
do	do	Indistinct	Even, thin to medium	do	Medina	1863	154
Dark gray	Fine	Even, parallel	do	Devonian	Portage	1873	155
Dark gray	Fine	Even, parallel	Even, thin to medium	Devonian	Portage	1820	156
do	do	Massive	do	do	Chemung	1864	157
do	do	Even, parallel	Even, medium	do	do	1850	158
do	do	do	do	do	do	1849	159
do	do	Massive	Even, medium to thick	do	do	1878	160
Dark drab	Fine	Massive	Uneven, medium to thick	Devonian	Chemung	1871	161
do	do	do	do	do	do	1871	162
do	do	do	do	do	do	1830	163
Light blue	do	do	Even, medium	do	do	1871	164
Light gray	do	do	Uneven, thin to medium	Upper Silurian	Medina	1870	165
Light gray	Fine	Massive	Uneven, thin to medium	Upper Silurian	Medina	1876	166
Red	do	Indistinct	Uneven, thick	do	do	1873	167
do	Coarse	do	do	do	do	1869	168
do	Fine	do	Even, medium	do	do	1860	169
Light gray	do	Massive	Even, thick	do	do	1860	170

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

NEW YORK—SANDSTONE—Continued.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone.	
				Popular name.	Scientific name.
171	Medina	Orleans	Kearney, Barrett & Co	Sandstone	Sandstone
172	....do	....do	Isaac Holloway	....do	....do
173	....do	....do	Patrick Horan	....do	....do
174	....do	....do	A. J. McCormick	....do	....do
175	Lockport	Niagara	Charles Whitmore	....do	....do
176	Warsaw	Wyoming	Morris & Son	Flag-stone	Sandstone (calcareous)
177	....do	....do	Philander Twesdell	....do	....do
178	Castile	....do	George Sutherland	Sandstone	Sandstone
179	Belfast	Allegany	John Lang	....do	....do
180	Jamestown	Chautauqua	John McVeigh	....do	....do
181	Jamestown	Chautauqua	J. O'Brien	Sandstone	....do

NEW YORK—SLATE.

1	Hampton	Washington	New England Slate Company	Slate	
2	....do	....do	Boston and New York Slate Company	....do	
3	....do	....do	David Williams & Brothers	....do	
4	....do	....do	Lyman J. Warren	....do	
5	....do	....do	....do	....do	
6	Middle Granville	Washington	Penrhyn Slate Company	Slate	
7	....do	....do	Albany Slate Company	....do	
8	....do	....do	Middle Granville Slate Company	....do	
9	Granville	....do	Empire Slate Company	....do	
10	....do	....do	Mettowee Red Slate Company	....do	
11	Granville	Washington	North Bend Slate Company	Slate	
12	Salem	....do	Salem Slate Company	....do	

NEW JERSEY—CRYSTALLINE SILICEOUS ROCKS.

1	Bergen Hill	Hudson	Bergen Hill	Trap-rock	Diabase
2	Dover	Morris	Delaware, Lackawanna and Western Railroad Company.	Gneiss	Gneiss

NEW JERSEY—SANDSTONE.

1	Flagstone Hill, Wantage township.	Sussex	Asa & George Carr	Graywacke	
2	Southern outskirts of Paterson	Passaic	William P. Hartley	Sandstone	
3	Belleville. Avondale post-office	Essex	A. Philip & Son	....do	
4	....do	....do	William A. Joyce	....do	
5	....do	....do	J. B. L Robinson	....do	
6	Pleasant Valley, West Orange	Essex	F. W. Shrump	Sandstone	
7	Orange Mountain	....do	James Bell & Co	....do	
8	Newark	....do	Newark Quarry Company	....do	
9	....do	....do	Kocher Bros	....do	
10	....do	....do	Philip Hochule	....do	
11	Martinville	Somerset	William E. Bartle & Bro	Sandstone	
12	Milford, Belvidere, and Delaware Railroad.	Hunterdon	Smith Clark	....do	
13	1 mile northwest of Prallsville	....do	Pennsylvania Railroad Company	....do	
14	Stockton	....do	James Lilley	....do	
15	....do	....do	Peter Best	....do	
16	Princeton	Mercer	Thomas Jewell	Sandstone	
17	Greensburg	....do	L. Clark & Bro	....do	
18	....do	....do	Chas. Keeler & Son	....do	
19	....do	....do	Greensburg Granite and Freestone Company.	....do	
20	Egg Harbor City	Atlantic	Wolfsieffer Bros	....do	

NEW JERSEY—SLATE.

1	Princeton	Mercer	Stephen Margerum	Sandstone (slate)	
2	La Fayette	Sussex	Williams & Titus	Slate	
3	....do	....do	Thos. Jones	....do	

PENNSYLVANIA—CRYSTALLINE SILICEOUS ROCKS.

1	Twenty-third ward, Philadelphia	Philadelphia	Barbour & Ireland and S. France	Gneiss	Biotite granite
2	....do	....do	House of Correction, Employment, and Reformation.	Syenite	
3	Twenty-first ward, Philadelphia	....do	McKinney's	Gneiss	Hornblende gneiss
4	Twenty-second ward, Philadelphia	....do	John Nolan	....do	Muscovite gneiss
5	....do	....do	Nester & Shelmine	....do	Hornblende gneiss
6	Jenkintown	Montgomery	James Conn	Gneiss	Hornblende gneiss
7	Jenkintown and Mill Creek	....do	Eldridge & Stewart (2 quarries)	....do	....do
8	Chester	Delaware	A. O. & J. O. Deshong, jr	....do	Biotite-muscovite gneiss
9	....do	....do	George G. Leiper	....do	....do
10	....do	....do	H. L. Powell	....do	....do

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

NEW YORK—Sandstone—Continued.

Color	Structure.			Geological age of formation.		Year in which opened.	
	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.		
Pinkish gray	Fine	Massive	Even, thick	Upper Silurian	Medina	1840	171
Light gray	do	do	Even, medium	do	do	1851	172
Red	do	Indistinct	do	do	do	1845	173
Red and gray	do	do	do	do	do	1872	174
Light gray	do	Massive	do	do	do	1825	175
Gray	Fine	Massive	Even, medium	Devonian	Portage	1876	176
do	do	do	do	do	do	1873	177
do	do	do	Even, medium to thick	do	do	1873	178
Dark drab	do	do	Even, thick	do	Chemung	1876	179
Gray	do	do	Even, medium	do	do	1840	180
Gray	Fine	Massive	Even, medium	Devonian	Chemung	1840	181

NEW YORK—Slate.

Purple	Fine	Rhomboidal	Even	Lower Silurian	Cambrian	1850	1
Red	do	do	do	do	do	1860	2
Green and purple	do	do	do	do	do	1868	3
do	do	Rhomboidal, irregular	do	do	do	1876	4
Red	do	do	do	do	do	1880	5
Purple and green, variegated.	Fine	Prismatic, quadrangular	Even	Lower Silurian	Cambrian	1850	6
do	do	do	do	do	Potsdam	1869	7
do	do	do	do	do	do	1853	8
Variegated and purple	do	Rhomboidal	Uneven	do	Cambrian	1853	9
Red	do	do	Even	do	Potsdam	1877	10
Red	Fine	Rhomboidal	Even	Lower Silurian	Potsdam	1872	11
Purple variegated, green	do	do	do	do	Cambrian	1868	12

NEW JERSEY—Crystalline Siliceous Rocks.

Dark gray	Variable	Massive	Irregular	Triassic			1
Gray	Medium		Thick	Archæan		1869	2

NEW JERSEY—Sandstone.

Gray	Fine	Variable	Even, thin to thick	Lower Silurian		1859	1
Grayish brown	Medium	Massive	Thin to thick	Triassic		1848	2
do	do	Indistinct	Thick	do		1775	3
do	do	do	do	do		1854	4
do	do	do	do	do		1800	5
Grayish brown	Fine	Variable	Thick	Triassic		1871	6
do	Coarse	Massive	do	do		1880	7
do	Medium	Indistinct	do	do		1812	8
do	do	do	do	do		1872	9
do	do	Irregular	do	do		1858	10
Dark gray	Fine	Massive	Thick	Triassic		1837	11
do	do	Even, parallel	Thin	do		1859	12
Grayish brown	Coarse, conglomerate	Massive	Thick	do		1850	13
do	Coarse	do	do	do		1876	14
do	do	do	do	do		1876	15
Gray	Medium	Irregular	Thick	Triassic		1800	16
Grayish brown	do	Massive	do	do		1843	17
do	Coarse	do	do	do		1833	18
do	Medium		do	do		1843	19
Brown	Coarse, conglomerate	Irregular	do	Cretaceous		1873	20

NEW JERSEY—Slate.

	Fine			Triassic		1843	1
Blue-black	do			Lower Silurian	Hudson River slate	1844	2
do	do			do			3

PENNSYLVANIA—Crystalline Siliceous Rocks.

Dark gray	Fine	Indistinct	Horizontal sheet and vertical.	Archæan		1850	1
Gray	Coarse and fine	Laminated	do	do		1874	2
Dark gray	Fine	do	do	do		1837	3
Gray	Coarse	do	Irregular	do		1730	4
Dark gray	Fine	do	Horizontal and vertical	do		1860	5
Gray	Coarse and fine	Laminated	Irregular	Archæan		1858	6
do	do	do	do	do		1800, 1878	7
do	Fine	do	do	do		1800	8
do	Medium	do	Horizontal and vertical	do		1750	9
do	do	do	Irregular	do		1800	10

Table IV.—Tables indicating the amount and kinds

PENNSYLVANIA—Crystalline Siliceous Rocks—Continued.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone. Popular name.	Scientific name.
11	2½ miles east by northeast from Chester.	Delaware	Joseph H. Ward	Gneiss	Biotite gneiss
12	2½ miles north from Chester	do	Leiper & Lewis	do	Muscovite-biotite gneiss
13	Colline station or Falmouth post-office.	Lancaster	John Keller	Granite	Diabase
14	Etters	York	Northern Central Railway Company	Conewago granite	do
15	2½ miles south of Gettysburg	Adams	D. F. Pittenturf	Granite	do

PENNSYLVANIA—Marble and Limestone.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Popular name.	Scientific name.
1	Easton	Northampton	George & Isaac A. Smith	Limestone	Dolomite
2	William Penn	Montgomery	E. C. Potts	Marble and limestone	Limestone
3	East Conshohocken	do	East Conshohocken Stone Company	Limestone	Magnesian limestone
4	West Conshohocken	do	Conshohocken Stone Quarry Company	do	do
5	Bridgeport	do	Henderson Marble Company	Marble	Limestone
6	King of Prussia station	Montgomery	I. I. Derr	Marble	Limestone
7	Henderson station	do	Daniel O. Hituer, sr	do	do
8	Downingtown	Chester	Matthew Berry	Limestone	Calcareous dolomite
9	Tuckerton	Berks	Philadelphia and Reading Railroad Co	do	do
10	Reading	do	W. M. Staufman	do	do
11	Reading	Berks	Jno. H. Sternburg	Limestone	Calcareous dolomite
12	Aurille station	Lebanon	John W. Beaver	do	Limestone
13	Harrisburg (4½ miles southeast of)	Dauphin	Cumber & Zimmerman	do	Magnesian limestone
14	Leaman Place	Lancaster	H. H. Witmer (James Young, lessee)	do	Calcareous dolomite
15	Lancaster	do	John W. Mentzer	do	Dolomite
16	Lancaster	Lancaster	William Westman	Limestone	Dolomite
17	York	York	C. F. Winter	do	Calcareous dolomite
18	Harrisburg	Cumberland	McCormick & Co	do	Dolomite
19	do	do	L. Greek	do	do
20	Shiremanstown (3 miles south of)	do	Moser & Sidle	do	Calcareous-dolomitic limestone
21	Carlisle	Cumberland	W. F. Noble	Limestone	Calcareous dolomite
22	Chambersburg	Franklin	Henry Lippy	do	do
23	Connellsville (3 miles southeast of)	Fayette	A. R. Banning	Blue-stone	Limestone

PENNSYLVANIA—Sandstone.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Popular name.	Scientific name.
1	Lumberville	Bucks	Thomas H. Kemble	Sandstone	
2	Yardleyville	do	S. B. & E. W. Twining	do	
3	Newtown	do	Buckman & Farley	do	
4	Norristown	Montgomery	Louis Flum	do	
5	Bridgeport	do	J. J. Davis	do	
6	Mohn's Store	Berks	Eppler & Risehville	Sandstone	
7	Hummelstown (3 miles south of)	Dauphin	Hummelstown Brown Stone Company	do	
8	Columbia	Lancaster	Henry E. Wolfe	do	Argillaceous schist
9	Bethlehem	Lehigh	Brinker & Wagner		
10	Weissport	Carbon	Henry Mertz	Sandstone	Sandstone (bituminous)
11	Pond Eddy	Pike	C. W. Maxwell & Co	Blue-stone	
12	Scranton (3 miles north of)	Lackawanna	Jeremiah Williams	Sandstone	
13	do	do	do	do	
14	Laurel Run (Plains)	Luzerne	Philip Banker	do	
15	Shickshinny	do	Delaware, Lackawanna, and Western R. R.	do	
16	Shickshinny	Luzerne	George Nicely	Sandstone	
17	Danville	Montour	C. C. Ranch, agent	do	
18	Meshoppen	Wyoming	Brownscombe & King	do	
19	do	do	do	Flag-stone	
20	Black Walnut	do	Wyoming Stone Company	Sandstone	
21	Skinner's Eddy	Wyoming	A. R. Fordyce & Co	Sandstone	
22	do	do	Brink & Knapp	do	
23	Nicholson	do	Moses Shields & Son	do	
24	Brandt	Susquehanna	Harmony Brick Company	Flag-stone	
25	do	do	Joseph Botts	do	
26	Brandt	Susquehanna	McCoy & Co	Flag-stone	
27	Mainsburg	Tioga	Mainsburg Flagging Company	Sandstone	
28	Antrim	do	Patrick Bradley	do	
29	Farrandsville	Clinton	H. F. Hawk & Co	do	
30	do	do	Jno. McNally	do	
31	McVeytown	Mifflin	Joseph Watson	Sandstone	
32	Jack's Narrows	Huntingdon	Frank Hefright	do	
33	Altoona	Blair	William Myers	do	
34	Altoona (5 miles from)	do	Booth & Mackey	do	
35	Somerset	Somerset	John McAdams	Flag-stone	
36	Johnstown	Cambria	Cambria Iron Company	Mahoning sandstone	
37	do	do	Gore & Levergood	Sandstone	
38	Fuller	Jefferson	Allegheny Valley Railroad Company	do	
39	Freeport	Armstrong	David Taylor	do	
40	Lucesco	Westmoreland	John A. Huffman	do	
41	Derry	Westmoreland	Loyalhanna Coal and Coke Company	Sandstone	
42	do	do	John C. Campbell	do	
43	Greensburg	do	S. Zimmermann	do	
44	Webster	do	William Nelson	Flag-stone	
45	Scottdale	do	Samuel Dunmire	do	

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

PENNSYLVANIA—Crystalline Siliceous Rocks—Continued.

Color.	Structure. Texture.	Stratification.	Jointing, bedding, or natural surface.	Geological age of formation. Period.	Epoch.	Year in which opened.	
Gray	Fine	Laminated	Horizontal sheet	Archæan		1800	11
do	Coarse	do	Few joints	do		1770	12
Dark gray	Fine	Massive	Irregular	Triassic		1868	13
Gray	Coarse	do	do	do		1861	14
do	do	do	Bowlders	Archæan		1840	15

PENNSYLVANIA—Marble and Limestone.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Blue	Fine	Massive	Even, medium to thick	Lower Silurian		1870	1
Light blue	Coarse, fine, crystalline	Irregular	do	do		1756	2
Gray	Medium, crystalline	do	Uneven, thin to thick	do		1849	3
do	do	do	Uneven, medium to thick	do		1840	4
Light blue	Fine, crystalline	do	Even, medium to thick	do		1800	5
Blue	Fine, crystalline	Irregular	Uneven, thick	Lower Silurian		1825	6
do	do	do	Uneven, medium to thick	do		1808	7
do	Fine	do	Even, thick	do		1831	8
Gray	do	Massive	do	do		1840	9
Blue	do	Indistinct	Even, thin to thick	do		1830	10
Blue	Fine	Indistinct	Even, thin to thick	Lower Silurian		1881	11
Blue-black	Fine, crystalline	Irregular	Even, medium to thick	do		1866	12
Blue	Fine	do	Even, thin to thick	do		1836	13
Dark gray	do	Indistinct	Even, medium to thick	do		1869	14
Blue-black	do	do	Even, thin to thick	do		1840	15
Blue-black	Fine	Indistinct	Even, thin to thick	Lower Silurian		1840	16
Black	Fine, porphyritic	Massive	Even, medium to thick	do		1840	17
Dark drab	Fine	Even, parallel	Uneven, medium to thick	do		1860	18
do	do	do	do	do		1879	19
Blue	do	do	Even, thin to thick	do		1850	20
Blue-black	Fine	Indistinct	Even, thin to thick	Lower Silurian		1878	21
do	do	Massive	do	do		1812	22
Drab	Fine, crystalline, and compact.	Even, parallel	Even, thick	Sub-Carboniferous	Umbral	1875	23

PENNSYLVANIA—Sandstone.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Brown	Medium	Indistinct	Even, thick	Triassic		1874	1
do	Coarse	do	do	do		1840	2
do	do	Even	do	do		1856	3
do	do	Indistinct	Even, medium to thick	do		1878	4
do	do	do	Even, thick	do		1868	5
Brown	Medium	Massive	Even, thick	Triassic		1780	6
do	do	do	do	do		1867	7
	Fine			Lower Silurian		1843	8
Gray	do	Massive	Even, thick	do		1850	9
Dark gray	do	Even, parallel	Even, thin	Devonian		1878	10
Dark gray	Fine	Massive	Even, thin to medium	Devonian		1865	11
do	Medium	do	Even, thin to thick	Sub-Carboniferous		1864	12
Buff	do	Indistinct	Even, thin to medium	Devonian		1860	13
Red	do	Even, parallel	do	do		1850	14
Dark gray	do	do	Even, thick	Carboniferous		1840	15
Gray	Coarse	Even, parallel	Even, medium to thick	Carboniferous		1835	16
Dark gray	Fine	Massive	do	Upper Silurian		1830	17
do	do	do	Even, parallel, thick	Devonian		1867	18
do	do	do	Even, thin to medium	do		1876	19
do	do	do	Even, thin to thick	do		1860	20
Dark gray	Fine	Massive	Even, thin to thick	Devonian		1870	21
do	do	do	do	do		1860	22
do	do	do	do	do		1870	23
do	do	do	Even, thin to medium	do		1878	24
do	do	do	do	do		1878	25
Dark gray	Fine	Massive	Even, thin to medium	Devonian		1878	26
do	do	Variable	Even, thin	do		1871	27
Light gray	Coarse	Massive	Even, thick	Carboniferous		1872	28
Buff	Medium	do	Even, thin to thick	Devonian		1836	29
Dark gray and brown	Fine	Indistinct	Even, medium	do		1830	30
Gray	Coarse	Even, parallel	Even, thin to thick	Devonian		1830	31
Light gray	Medium	Irregular	Bowlders	Upper Silurian		1868	32
Gray	do	Even, parallel	Even, thin to thick	Sub-Carboniferous		1880	33
do	do	Irregular	Bowlders	Devonian		1810	34
do	do	do	Even and thin	Carboniferous		1830	35
Dark gray	Medium	Massive	Even, medium	Carboniferous		1865	36
Gray	Coarse	Indistinct	Uneven, medium to thick	do		1867	37
do	do	Massive	Even and thick	do		1872	38
Gray and light brown	do	Irregular	Uneven, medium	do		1865	39
Gray	do	do	Even, thick	do		1870	40
Gray	Medium	Massive	Even, thin to thick	Carboniferous		1850	41
Reddish gray	Coarse	Indistinct	Bowlders	do		1840	42
Gray	Medium	Irregular	Uneven, thin to medium	do		1861	43
do	Fine	Even, parallel	Even, thin to medium	do		1850	44
Brown	Medium	Irregular	Even, thin	do		1876	45

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

PENNSYLVANIA—SANDSTONE—Continued.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone. Popular name.	Scientific name.
46	Connellsville	Fayette	Christian Shibley	Sandstone	Sandstone
47	Uniontown (3 miles southeast of)	do	James Fraser	do	do
48	Uniontown (4 miles southeast of)	do	D. Shipley	do	do
49	Waynesburgh	Greene	Simeon Rinehart	do	do
50	West Union	do	John Lapham	do	do
51	Washington (5 miles west of)	Washington	D. Haggerty	Sandstone	Sandstone
52	Washington (3 miles east of)	do	Hallam Bros	do	do
53	Washington	do	John Brady	do	do
54	Canonsburg	do	John Cook	Freestone	do
55	Monongahela city	do	William Nelson	Sandstone	do
56	Sewickley	Allegheny	United States Government	Sandstone	Sandstone
57	Walker's Mills	do	Pittsburgh, Cincinnati, and Saint Louis R. R. Co.	do	do
58	do	do	Isaac Walker	do	do
59	Mansfield Valley	do	M. B. Brown	do	do
60	Pittsburgh	do	Thos. Rourke	do	do
61	Pittsburgh	Allegheny	Jesse P. Scharf	Sandstone	Sandstone
62	do	do	Evan Jones	do	do
63	do	do	Seely Bros	do	do
64	do	do	George Wright	do	do
65	do	do	Alf. Harrison	do	do
66	Allegheny	Allegheny	Henry James	Sandstone	Sandstone
67	do	do	Ritchie & Sauerbrier	do	do
68	do	do	John Schetzel	do	do
69	do	do	John Huckenstein	do	do
70	do	do	Charles King	do	do
71	Allegheny	Allegheny	Fred. Altevater	Sandstone	Sandstone
72	Baden	Beaver	I. G. Gallagher	do	do
73	Baker's Landing	do	Reed & Ewing	do	do
74	Beaver Falls	do	Jos. Hartman	do	do
75	Homewood	do	A. I. Jolly	do	do
76	Wampum	Lawrence	Jacob Friday	Sandstone	Sandstone
77	Sharon	Mercer	Jno. T. Anderson	do	do
78	do	do	Clemens Herrmann	do	do
79	Greenville	do	P. Leech	do	do
80	Shenango	do	Craigs, Pinkerton & Co	do	do
81	Greenville	Mercer	Amy & Kappenberger	Sandstone	Sandstone
82	do	do	Amy & Brown	do	do
83	do	do	Charles Fry	do	do
84	Stoneboro'	do	L. W. Odell	do	do
85	Franklin	Venango	Joseph Bell & Son	do	do
86	Franklin	Venango	W. Brodhead	Sandstone	Sandstone
87	Oil City	do	David Ready	do	do
88	Garland	Warren	Linn & Leary	do	do
89	do	do	Pennsylvania Railroad Company	do	do
90	Titusville	Crawford	Denis Brenan	do	do
91	Meadville	Crawford	B. McNeil	Sandstone	Sandstone
92	do	do	Frank Hock	do	do
93	Corry	Erie	J. M. Colegrove	do	do
94	Leboeuf	do	Frank Senger	do	do
95	Erie (4 miles east of)	do	James Leask	do	do

PENNSYLVANIA—SLATE.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Popular name.	Scientific name.
1	East Bangor	Northampton	Bray & Short	Slate	
2	do	do	Star Slate Company	do	
3	Bangor	do	Bangor Slate Company	do	
4	do	do	Bangor Union Slate Company	do	
5	do	do	North Bangor Manufacturing Company	do	
6	Pen Argyl	Northampton	John Jackson & Co	Slate	
7	do	do	H. Jory & Co	do	
8	do	do	West Bangor Slate Company	do	
9	do	do	Stephen Jackson & Co	do	
10	Chapman's station	do	Chapman and New York Slate Company	do	
11	6 miles northwest of Catasauqua; 9 miles from Allentown.	Lehigh	North Peach Bottom Slate Company	Slate	
12	5½ miles east of Slatington	do	R. Henry & Co	do	
13	1½ miles east of Slatington	do	John Paulus & Co	do	
14	1 mile east of Slatington	do	Caskie & Emack	do	
15	Slatington	do	James Hess & Co	do	
16	Slatington	Lehigh	W. H. Seibert	Slate	
17	do	do	David Williams	do	
18	½ mile west of Slatington	do	Columbia Slate Company	do	
19	do	do	Kuntz & Jacobs	do	
20	West of Slatington	do	The Industrial Slate Company	do	
21	West of Slatington	Lehigh	Krum & Maser	Slate	
22	Slatington	do	Joel Neff	do	
23	Slatedale	do	Locker Slate Company	do	
24	Lynnsport	do	Laurel Hill Slate Company	do	
25	1 mile west of Stinesville	do	Keever & Lutz	do	
26	1½ miles west of Stinesville	Lehigh	Greesimer & Bro	Slate	
27	Bangor	York	Peach Bottom Slate Manufacturing Co	do	
28	West Bangor	do	Jones & McLaughlin	do	
29	do	do	Robert L. Jones & Co	do	
30	½ mile from West Bangor	do	William C. Parry & Co	do	

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

PENNSYLVANIA—SANDSTONE—Continued.

Color.	Structure. Texture.	Stratification.	Jointing, bedding, or natural surface.	Geological age of formation. Period.	Epoch.	Year in which opened.	
Gray	Coarse	Indistinct	Even, thin to thick	Carboniferous		1867	46
...do	...do	Irregular	Bowlders	...do		1810	47
Light gray	Medium	...do	Even, thin	Sub-Carboniferous		1876	48
Gray	Coarse	Massive	Even, thick	Carboniferous		1850	49
...do	...do	...do	...do	...do		1880	50
Gray	Coarse	Irregular	Solid	Carboniferous		1860	51
...do	...do	...do	Even, medium to thick	...do		1880	52
...do	...do	...do	...do	...do		1816	53
...do	Medium	Even, parallel	Even, thin to medium	...do		1847	54
...do	Coarse	Massive	Even, thick	...do		1830	55
Gray	Medium	Massive	Even, thick	Carboniferous		1830	56
...do	...do	Irregular	Even, medium to thick	...do		1864	57
...do	...do	...do	...do	...do		1818	58
...do	...do	...do	Uneven, medium to thick	...do		1850	59
...do	...do	...do	Even, thin to thick	...do		1845	60
Gray	Medium	Irregular	Even, thin to thick	Carboniferous		1845	61
...do	...do	...do	...do	...do		1845	62
...do	...do	...do	...do	...do		1840	63
...do	...do	...do	...do	...do		1864	64
...do	...do	...do	...do	...do		1845	65
Gray	Medium	Irregular	Even, thin to thick	Carboniferous			66
...do	...do	...do	...do	...do		1860	67
...do	...do	...do	...do	...do		1845	68
...do	...do	...do	...do	...do		1840	69
...do	...do	...do	...do	...do		1840	70
Gray	Medium	Irregular	Even, thin to thick	Carboniferous		1870	71
...do	Coarse	Massive	Even, thick	...do		1840	72
...do	...do	...do	...do	...do		1830	73
...do	...do	Irregular	Even, thin to thick	...do		1872	74
Gray and brown	...do	...do	Uneven, thick	...do		1880	75
Gray	Coarse	Massive	Even, thick	Carboniferous		1860	76
...do	...do	...do	Medium to thick	...do		1872	77
...do	...do	...do	Even, medium to thick	...do		1878	78
...do	Fine	Even, parallel	Even, thin	...do		1868	79
...do	...do	...do	...do	...do		1876	80
Gray	Fine	Even, parallel	Even, thin	Carboniferous		1871	81
...do	...do	...do	...do	...do		1864	82
...do	...do	...do	...do	...do		1876	83
Gray and light brown	Coarse	Massive	Irregular, medium to thick	...do		1865	84
Gray	Fine	Even, parallel	Even, thin to medium	Sub-Carboniferous		1865	85
Gray	Fine	Even, parallel	Even, thin to medium	Sub-Carboniferous		1820	86
...do	Coarse	Massive	Even, thick	Carboniferous		1869	87
...do	...do	...do	...do	...do		1872	88
...do	...do	...do	...do	...do		1865	89
...do	...do	...do	...do	Sub-Carboniferous		1863	90
Gray	Coarse	Massive	Even, thick	Carboniferous		1879	91
...do	...do	...do	...do	...do		1835	92
...do	Fine	Variable	Uneven, medium	Sub-Carboniferous		1868	93
...do	...do	Even, parallel	Even, medium	Devonian		1840	94
...do	...do	Indistinct	...do	...do		1835	95

PENNSYLVANIA—SLATE.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Dark blue	Fine	Irregular	Smooth, even	Lower Silurian		1863	1
...do	...do	...do	Smooth	...do		1867	2
...do	...do	...do	...do	...do		1865	3
...do	Compact	...do	Even	...do		1872	4
...do	...do	...do	...do	...do		1872	5
Dark blue	Compact	Irregular	Smooth	Lower Silurian		1875	6
...do	...do	...do	...do	...do		1853	7
...do	Fine	...do	...do	...do		1872	8
...do	...do	...do	Smooth, even	...do		1875	9
Blue-black	...do	Variable		...do		1875	10
Blue-black	Fine	Rhomboidal	Even	Lower Silurian		1845	11
Blue	...do	Irregular	...do	...do		1846	12
Dark blue	...do	Rectangular		...do		1877	13
Black	...do	...do		...do		1857	14
Dark blue	...do	...do		...do		1848	15
Dark blue and black	Fine	Irregular	Smooth, even	Lower Silurian		1865	16
Black	...do	...do		...do		1864	17
Dark blue	...do	Rhomboidal		...do		1865	18
...do	...do	...do		...do		1853	19
...do	Hard	Rectangular		...do		1866	20
Dark blue	Fine	Rectangular		Lower Silurian		1848	21
...do	...do	Irregular	Smooth	...do		1849	22
...do	...do	...do		...do		1860	23
Blue	...do	...do		...do		1877	24
Dark blue	...do	...do	Even	...do		1878	25
Dark blue	Tough	Rectangular	Smooth	Lower Silurian		1867	26
Blue-black	Fine	Irregular		Archæan (?)		1846	27
Dark blue	...do	...do	Even, smooth	...do		1881	28
Blue-black	...do	...do	...do	...do		1852	29
Dark blue	...do	...do	...do	...do		1835	30

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

DELAWARE—CRYSTALLINE SILICEOUS ROCKS.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone.	
				Popular name.	Scientific name.
1	Near Wilmington	New Castle	Philip P. Tyre	Granite	
2	....do	....do	Hughes & Walker	....do	
3	... do	....do	James McKendrick	....do	

MARYLAND—CRYSTALLINE SILICEOUS ROCKS.

1	Near Port Deposit	Cecil	John Keaveny	Granite	Biotite gneiss
2	....do	....do	McClenahan & Brother	....do	....do
3	Half mile from Baltimore	Baltimore	John Harris	Gneiss	....do
4	Granite	....do	Gill & McMahon	Granite	Biotite granite
5	Near Woodstock	....do	William F. Weller	....do	....do
6	Near Woodstock	Baltimore	J. J. Evans	Granite	Biotite granite
7	Opposite Ellicott City	....do	Charles J. Werner	....do	Biotite gneiss

MARYLAND—MARBLE AND LIMESTONE.

1	Cockeysville	Baltimore	Beaver Dam Marble Company	Marble	
2	Hagerstown	Washington	T. G. Jones	Limestone	Magnesian limestone
3	....do	....do	Swartz Quarry	....do	....do

MARYLAND—SLATE.

1	Near Pennsylvania state line—West Bangor, Pennsylvania.	Harford	W. E. Williams & Co	Slate	
2	....do	....do	Thomas W. Jones & Co	....do	
3	do	....do	John W. Jones & Co	....do	
4	....do	....do	Harford Peach Bottom Slate Manufacturing Company.	....do	
5	....do	.. do	W. C. Roberts & Co	....do	
6	Near Pennsylvania state line—Delta, Pennsylvania.	Harford	John A. Barnett & Co	Slate	
7	....do	....do	Harford Peach Bottom Slate Company	... do	

VIRGINIA—CRYSTALLINE SILICEOUS ROCKS.

1	Near Catlett station	Fauquier	Chase Andrews	Diabase	Diabase
2	1½ miles from Fredericksburg	Spotsylvania	E. J. Loyburn	Granite	Biotite-muscovite granite
3	Tuckahoe district	Henrico	J. B. Mitchell & Co	....do	Biotite granite
4	Near Richmond	... do	Richmond Granite Company	....do	....do
5	Granite post-office	Chesterfield	Old Dominion Granite Company	....do	....do
6	Manchester	Chesterfield	Westham Granite Company	Granite	Biotite granite
7	Near Lynchburg	Amherst and Campbell.	Casey & O'Connel	Gneiss and mica-schist.	Biotite gneiss
8	....do	Campbell	S. Patterson & Son	Gneiss	....do
9	Namozine district	Dinwiddie	Smith & Southall	Granite	Biotite granite
10	.. do	....do	Gill & Hubbard	....do	....do

VIRGINIA—MARBLE AND LIMESTONE.

1	2 miles northeast of Staunton	Augusta	Red Bud Slate Company	Slate	
2	Craigsville	....do	Coral Marble Company	Marble	Magnesian limestone and limestone

VIRGINIA—SLATE.

1	New Canton	Buckingham	J. R. Williams & Co	Slate	
2	Orebanks	....do	Edwards & Roberts	....do	

WEST VIRGINIA—SANDSTONE.

1	Wheeling	Ohio	Adolph Yhaka	Sandstone	Sandstone
2	....do	....do	Henry Gunther	....do	....do
3	....do	....do	Schüler & Lotz	....do	....do
4	....do	....do	Andrew Long	....do	....do
5	Rowlesburg	Preston	Sullivan & Peat	....do	....do
6	Grafton	Taylor	Baltimore and Ohio Railroad Company	Sandstone	Sandstone
7	Parkersburg	Wood	B. F. Bacon	....do	....do
8	....do	....do	Nugent Keenan	....do	....do
9	....do	....do	Patrick Hopkins	....do	....do
10	Near Charleston	Kanawha	Joel T. Quarrier and others	....do	....do

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

DELAWARE—Crystalline Siliceous Rocks.

Color.	Structure.			Geological age of formation.		Year in which opened.	
	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.		
Black	Medium	Laminated	Irregular	Archæan		1872	1
...do	...do	...do	...do	...do		1876	2
...do	...do	...do	...do	...do		1873	3

MARYLAND—Crystalline Siliceous Rocks.

Dark gray	Coarse	Wavy	Vertical	Archæan		1840	1
...do	...do	...do	Inclined sheets	...do		1825	2
Dark greenish gray	Fine	Even, parallel	Irregular	...do		1830	3
Gray	Coarse	Indistinctly laminated	Horizontal sheets	...do		1830	4
...do	Fine	...do	Irregular	...do		1879	5
Gray	Coarse	Massive	Inclined sheets	Archæan		1836	6
Dark gray	...do	Wavy	Horizontal and vertical	...do		1872	7

MARYLAND—Marble and Limestone.

White	Fine and coarse crystalline.	Massive	Uneven, thick	Lower Silurian	Auroral	1840	1
Dark blue	Fine	Irregular	...do	...do	...do	......	2
Blue	...do	...do	...do	...do	...do	......	3

MARYLAND—Slate.

Bluish black	Fine	Rhomboidal	Silky fracture	Archæan		1849	1
...do	...do	...do	...do	...do		1870	2
...do	...do	...do	...do	...do		1870	3
...do	Fine and clear	...do	Even and smooth	...do		1867	4
...do	...do	...do	...do	...do		1866	5
Bluish black	Fine and clear	Rhomboidal	Medium smooth	Archæan		1870	6
Dark blue	...do	Irregular	Even	...do		1872	7

VIRGINIA—Crystalline Siliceous Rocks.

Dark gray	Fine	Massive	Broken, irregular	Mesozoic (Trias)		1880	1
Light gray	Medium	Indistinctly laminated	Vertical and horizontal	Archæan		1880	2
Gray	...do	Massive	...do	...do		1880	3
...do	...do	...do	Irregular	...do		1835	4
...do	...do	...do	Inclined sheets	...do		1850	5
Light gray	Fine	Massive	Horizontal sheets	Archæan		1837	6
Blue	...do	Laminated	Irregular	...do		1867	7
...do	...do	Massive	Inclined sheets	...do		1858	8
Greenish gray	Medium	Indistinctly laminated	Few joints	...do		1840	9
...do	...do	...do	Solid	...do		1879	10

VIRGINIA—Marble and Limestone.

Drab	Fine	Even, parallel	Vertical and transverse	Lower Silurian		1879	1
Pinkish gray	Fine semi-crystalline, fossiliferous.	Indistinct	Uneven, thick	Upper Silurian		1879	2

VIRGINIA—Slate.

Bluish black	Fine	Rectangular	Even, smooth	Archæan		1840	1
...do	...do	...do	...do	...do		1859	2

WEST VIRGINIA—Sandstone.

Light gray	Coarse	Irregular	Even, thick	Carboniferous	Upper Coal Measures.	1856	1
...do	...do	...do	...do	...do	...do	1860	2
...do	...do	...do	...do	...do	...do	1852	3
...do	...do	...do	...do	...do	...do	1852	4
Dark gray	Fine, compact	Even, parallel	...do	Devonian	Catskill?	1877	5
Reddish gray	Coarse	Massive	Even, thick	Carboniferous	Barren Measures	1870	6
Gray	Medium	Even, parallel	...do	...do	Upper Coal Measures.	1877	7
...do	...do	...do	...do	...do	...do	1859	8
...do	...do	...do	...do	...do	...do	1859	9
...do	Coarse	...do	Uneven, thick	...do	Barren Measures	1780	10

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

GEORGIA—CRYSTALLINE SILICEOUS ROCKS.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone.	
				Popular name.	Scientific name.
1	Atlanta	Fulton	Patrick Lynch	Granite	Hornblende-biotite gneiss
2	16 miles from Atlanta	De Kalb	Callahan & Welsh	do	Muscovite granite

GEORGIA—SLATE.

1	Rock Mart	Polk	G. W. Jones & Co	Slate	

TENNESSEE—MARBLE AND LIMESTONE.

1	Near Rogersville	Hawkins	Chesnut & Chesnut (Crescent quarry)	Marble	Limestone
2	4½ miles from Rogersville	do	John Hasson	do	do
3	Mooresburg	do	E. D. Dougherty	do	do
4	7 miles from Whitesburg	do	Joseph Stamps (Star quarry)	do	do
5	4 miles from Knoxville	Knox	Knoxville Marble Company	do	do
6	2 miles from Knoxville	Knox	Frierson & Morgan	Marble	Limestone
7	½ mile from Knoxville	do	John M. Ross	do	do
8	5½ miles southwest of Knoxville	do	Tennessee River Marble Company	do	do
9	9 miles from Cleveland	Bradley	Patrick & Smith	do	Magnesian limestone and limestone
10	2 miles from Chattanooga	Hamilton	Dominick Selare	Limestone	Magnesian limestone
11	Near Nashville	Davidson	Williams & Jones	Limestone	Siliceous dolomite and limestone
12	do	do	Callahan & Welsh	do	
13	Near Clarksville	Montgomery	John Conroy	do	

KENTUCKY—MARBLE AND LIMESTONE.

1	Newport	Campbell	Fitzsimmons & Sons	Limestone	Limestone
2	do	do	H. & F. Boehme	do	do
3	West of Covington	Kenton	J. G. Fadders	do	do
4	do	do	W. Clark	do	do
5	do	do	J. W. Rich	do	do
6	South of Covington	Kenton	Thomas Woods	Limestone	Limestone
7	On Ohio river	Pendleton	David Irwin	do	do
8	1 mile east of Louisville	Jefferson	Michael Gleason	do	Magnesian limestone
9	Louisville	do	City of Louisville	do	do
10	do	do	Dennis Maloney	do	do
11	Louisville	Jefferson	A. Steugh	Limestone	Magnesian limestone
12	do	do	Joseph Nevin	do	do
13	do	do	George Faust	do	do
14	do	do	John Jamison	do	do
15	do	do	A. Holocher	do	do
16	Leaches	Bullitt	Louisville & Nashville Railroad Company	Limestone	Magnesian limestone
17	Lexington	Fayette	City of Lexington	do	Limestone
18	Near Bowling Green	Warren	Belknap, Dunnsville Stone Company	do	Bitominous limestone
19	2½ miles east of Princeton	Caldwell	Princeton Stone and Marble Company	do	do

OHIO—SANDSTONE.

1	3 miles north of Wakeman	Erie	Nicholl & Miller	Sandstone	Sandstone
2	Berlin Heights	do	G. A. Baillie	do	do
3	Brownhelm	Lorain	Worthington & Sons	do	do
4	Amherst	do	do	do	do
5	do	do	L. Haldeman & Sons	do	do
6	Amherst	Lorain	Amherst Stone Company	Sandstone	Sandstone
7	do	do	Wilson & Hughes	do	do
8	do	do	W. H. Bryant	do	do
9	do	do	James Nicholl	do	do
10	do	do	Clough Stone Company	do	do
11	Grafton	Lorain	W. E. Miller	Sandstone	Sandstone
12	Elyria	do	Mussey & Co	do	do
13	do	do	John Weller	do	do
14	3½ miles north of Elyria	do	John Eschtruth	do	do
15	Ridgeville	do	H. L. Beebe	do	do
16	West View	Cuyahoga	Columbia Stone Company	Sandstone	Sandstone
17	Olmsted Falls	do	L. Barnum	do	do
18	Berea	do	McDermott & Berea Stone Company	do	do
19	3 miles east of Berea	do	Barnard Rafferty	do	do
20	Brooklyn	do	Jacob Hoehn	do	do

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

GEORGIA—Crystalline Siliceous Rocks.

Color.	Structure.			Geological age of formation.		Year in which opened.	
	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.		
Blue	Fine	Massive	Irregular	Archæan		1854	1
Light gray	....do	....do	Horizontal and inclined sheets.	....do		1865	2

GEORGIA—Slate.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Blue	Fine	Irregular	Even	Archæan		1859	1

TENNESSEE—Marble and Limestone.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Variegated	Fine, semi-crystalline	Massive	Thick	Lower Silurian		1880	1
....do	Fine, compact, semi-crystalline, fossiliferous.	....do	....do	....do		1872	2
....do	Fine, semi-crystalline, fossiliferous.	....do	....do	....do		1854	3
....do	....do	....do	....do	....do		1873	4
Pinkish gray	Medium, semi-crystalline	....do	Medium to thick	....do		1869	5
Pinkish gray	Medium, semi-crystalline	Massive	Even, thick	Lower Silurian		1879	6
Pink	....do	....do	Thick	....do		1879	7
Pinkish gray	Medium, semi-crystalline, fossiliferous.	....do	....do	....do		1880	8
....do	Medium, semi-crystalline	....do	....do	....do		1879	9
Blue-black	Fine, compact	....do	Medium to thick	....do		1855	10
Gray	Fine, compact	Massive	Medium to thick	Lower Silurian		1877	11
....do	....do	....do	Thick	....do		1840	12
....do	....do	....do	Medium to thick	Sub-Carboniferous		1869	13

KENTUCKY—Marble and Limestone.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Blue	Semi-crystalline, fossiliferous.	Massive	Even, thin to medium	Lower Silurian (Cincinnati).		1867	1
....do	....do	....do	....do	....do		1870	2
....do	....do	....do	....do	....do		1870	3
....do	....do	....do	....do	....do		1878	4
....do	....do	....do	....do	....do		1880	5
Blue	Semi-crystalline, fossiliferous.	Massive	Even, thin to medium	Lower Silurian (Cincinnati).		1876	6
....do	....do	....do	....do	....do		1871	7
Drab	Semi-crystalline	....do	Even, medium	Sub-Carboniferous		1858	8
....do	....do	....do	....do	....do		1870	9
....do	....do	....do	Even, thick	....do		1879	10
Drab	Semi-crystalline	Massive	Even, thick	Sub-Carboniferous		1877	11
....do	....do	....do	Medium to thick	....do		1850	12
....do	....do	....do	....do	....do		1870	13
....do	....do	....do	Even, medium to thick	....do		1855	14
....do	....do	....do	....do	....do		1865	15
Drab	Medium, fine	Massive	Even, thick	Sub-Carboniferous		1864	16
Gray	Semi-crystalline, fossiliferous.	....do	Even, thin to medium	Lower Silurian		1850	17
....do	Granular, fossiliferous	....do	Even, medium to thick	Sub-Carboniferous		1872	18
....do	Oolitic and compact	....do	Even, thick	....do		1878	19

OHIO—Sandstone.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Gray	Medium	Variable	Even, thickness varies	Sub-Carboniferous	Berea grit	1876	1
....do	....do	....do	....do	....do	....do	1870	2
....do	....do	....do	....do	....do	....do	1848	3
....do	....do	....do	....do	....do	....do	1856	4
....do	....do	....do	....do	....do	....do	1870	5
Gray	Medium	Variable	Even, thickness varies	Sub-Carboniferous	Berea grit	1872	6
....do	....do	....do	....do	....do	....do	1855	7
....do	....do	....do	....do	....do	....do	1874	8
....do	....do	....do	....do	....do	....do	1845	9
....do	....do	....do	....do	....do	....do	1852	10
Gray	Medium	Variable	Even, thickness varies	Sub-Carboniferous	Berea grit	1860	11
....do	....do	....do	....do	....do	....do	1871	12
....do	....do	....do	....do	....do	....do	1865	13
....do	....do	....do	....do	....do	....do	1873	14
....do	....do	....do	....do	....do	....do	1875	15
Gray	Medium	Variable	Even, thickness varies	Sub-Carboniferous	Berea grit	1867	16
....do	....do	....do	....do	....do	....do	1855	17
....do	Fine	....do	....do	....do	....do	1840	18
....do	Medium	....do	Uneven, thickness varies	....do	....do	1876	19
....do	....do	Coarse	Even, thickness medium	....do	....do	1840	20

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

OHIO—SANDSTONE—Continued.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone.	
				Popular name.	Scientific name.
21	Brooklyn	Cuyahoga	Anthony James' estate	Sandstone	Sandstone
22	East Cleveland	...do	James Haycox	...do	...do
23	...do	...do	C. E. Reader	...do	...do
24	...do	...do	W. G. Neff	...do	...do
25	...do	...do	H. P. Gale	...do	...do
26	Bedford	Cuyahoga	Bedford Stone Company	Sandstone	Sandstone
27	Independence	...do	J. R. Hurst	...do	...do
28	...do	...do	T. D. Smith	...do	...do
29	...do	...do	Wilson & Hughes	...do	...do
30	Newburgh	...do	Edwards Brothers	...do	...do
31	Newburgh	Cuyahoga	W. H. Caine	Blue-stone	Sandstone
32	...do	...do	Richard Braund	...do	...do
33	...do	...do	T. C. Garfield	...do	...do
34	Euclid	...do	Maxwell & Malone	...do	...do
35	...do	...do	John Wagner	...do	...do
36	Euclid	Cuyahoga	Forest City Stone Company	Blue-stone	Sandstone
37	...do	...do	McFarland Brothers	...do	...do
38	...do	...do	Slosson, Meeker & Co	...do	...do
39	Windsor	Ashtabula	Robert Stewart	Sandstone	...do
40	Mesopotamia	Trumbull	Mesopotamia Freestone Company	Freestone	...do
41	3 miles northeast of Warren	Trumbull	Austin Flagstone Company	Flag-stone	Sandstone
42	Near Warren	...do	Braceville Ridge Quarries	Sandstone	...do
43	Windham	Portage	Case & King	...do	...do
44	Twinsburg	Summit	Gardner Parmelee	...do	...do
45	...do	...do	Newton Herrick	...do	...do
46	Akron	Summit	Joseph Hugill	Sandstone	Sandstone
47	...do	...do	Wilhelm & Schroeder	...do	...do
48	Northampton township	...do	Hovey & Brown	Blue-stone	...do
49	Peninsula	...do	Ferdinand Schomacher	Sandstone	...do
50	Greenfield	Huron	George Graham	Flag-stone	...do
51	3 miles east of Norwalk	Huron	William Perrin	Sandstone	Sandstone
52	3 miles south of Norwalk	...do	Charles Grannell	...do	...do
53	Monclova	Lucas	Samuel Wagner	...do	...do
54	Leesville	Crawford	Leesville Stone Company	...do	...do
55	...do	...do	Morrow & Miller	...do	...do
56	Plymouth	Richland	S. W. Tuttle	Sandstone	Sandstone
57	...do	...do	William J. Bevier	...do	...do
58	Mansfield	...do	Christian Voetsch	...do	...do
59	...do	...do	Tobias Cline	...do	...do
60	Weller township	...do	Hughes & Cotter	...do	...do
61	Weller township	Richland	S. Shively	Sandstone	Sandstone
62	Bellville	...do	D. W. Zent	...do	...do
63	Wooster	Wayne	Coe Brothers	...do	...do
64	Warwick	...do	Walnut Grove Stone Company	...do	...do
65	West of Massillon	Stark	Warthorst & Co	...do	...do
66	Northwest of Massillon	Stark	Suter & Everhard	Sandstone	Sandstone
67	5 miles north of Massillon	...do	John Paul	...do	...do
68	3 miles north of Massillon	...do	John Vogt	...do	...do
69	Youngstown	Mahoning	Kirk Quarry, John Holden	...do	...do
70	2½ miles northwest of Youngstown	...do	Brier Hill Stone Company	...do	...do
71	2½ miles southwest of Youngstown	Mahoning	Thomas Connell	Sandstone	Sandstone
72	Near Austintown	...do	Austintown Quarries	...do	...do
73	New Lisbon	Columbiana	J. H. O'Mara	...do	...do
74	2 miles north of Carrollton	Carroll	Dr. N. M. Smith	...do	...do
75	5 miles north of Canal Dover	Tuscarawas	Tuscarawas Valley Coal and Iron Company	...do	...do
76	3 miles east of New Philadelphia	Tuscarawas	Alfred Mathias	Sandstone	Sandstone
77	3½ miles southwest of Millersburg	Holmes	W. H. Ling	...do	...do
78	Northeast of Mount Vernon	Knox	Bartlett Brothers	...do	...do
79	10 miles east of Mount Vernon	...do	Isaac Crichfield	...do	...do
80	Washington township	Morrow	Green & Coyle	...do	...do
81	North Bloomfield	Morrow	John Flowers	Sandstone	Sandstone
82	Iberia	...do	Wilson & Sharrock	...do	...do
83	...do	...do	Crane Brothers	...do	...do
84	2 miles south of Iberia	...do	William Goorley	...do	...do
85	Mount Gilead	...do	B. S. Russell	...do	...do
86	4 miles east of Cardington	Morrow	Robert Edgell	Sandstone	Sandstone
87	...do	...do	W. Brooke	...do	...do
88	Sunbury	Delaware	H. Flockner	...do	...do
89	...do	...do	C. B. Gaylord	...do	...do
90	10 miles east of Columbus	Franklin	William A. Forrester	...do	...do

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

OHIO—SANDSTONE—Continued.

Color.	Structure.			Geological age of formation.		Year in which opened.	
	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.		
Gray	Medium	Coarse	Even, thickness medium	Sub-Carboniferous	Berea grit	1845	21
do	do	do	do	do	do	1864	22
do	do	do	do	do	do	1879	23
do	do	do	do	do	do	1850	24
do	do	do	do	do	do	1864	25
Gray	Medium	Coarse	Irregular	Sub-Carboniferous	Berea grit	1880	26
do	do	do	do	do	do	1855	27
do	do	do	do	do	do	1872	28
do	do	do	do	do	do	1848	29
do	do	do	Uneven, thickness medium	do	do	1820	30
Gray	Fine	Massive	Even, thickness medium	Sub-Carboniferous	Bedford shale	1862	31
do	do	do	do	do	do	1872	32
do	do	do	do	do	do	1869	33
do	do	do	do	do	do	1873	34
do	do	do	do	do	do	1875	35
Gray	Fine	Massive	Even, thickness medium	Sub-Carboniferous	Bedford shale	1868	36
do	do	do	do	do	do	1875	37
do	do	do	do	do	do	1871	38
do	do	Variable	Even, thickness varies	do	Berea grit	1875	39
do	Medium	do	do	do	do	1874	40
Dark gray	Fine	Fine	Even, thin	Sub-Carboniferous	Cuyahoga shale	1872	41
Gray	Coarse	Coarse	Irregular, thick	Carboniferous	Base of Lower Coal Measures.	1820	42
Light gray	do	Massive	do	do	do	1873	43
Gray	do	do	Even, thick	do	do	1860	44
do	do	do	do	do	do	1866	45
Gray	Coarse	Coarse	Uneven, thick	Carboniferous	Base of Lower Coal Measures.	1872	46
do	do	do	do	do	do	1866	47
do	Fine	Massive	Even, variable, thick	Sub-Carboniferous	Berea grit	1875	48
do	Medium	Coarse and massive	Even, thick	do	do	1875	49
do	Fine	Fine and irregular	Rough, thin	do	do	1840	50
Gray	Medium	Variable	Even, variable, thick	Sub-Carboniferous	Berea grit	1835	51
do	do	do	Even, thin to medium	do	do	1840	52
Dark gray	Coarse	Massive	Even, medium thick	Devonian	Lower Corniferous	1870	53
do	Fine	Fine and massive	Even, variable, thick	Sub-Carboniferous	Berea grit	1840	54
do	do	do	do	do	do	1847	55
Gray	Fine	Massive	Uneven, medium thick	Sub-Carboniferous	Berea grit	1872	56
do	do	Coarse	Even, medium thick	do	do	1872	57
Gray and brown	Coarse	Massive	do	do	Waverly conglomerate.	1820	58
Gray	do	do	do	do	do	1857	59
do	do	do	Even, thick	do	do	1877	60
Gray	Coarse	Massive	Even, thick	Sub-Carboniferous	Waverly conglomerate.	1875	61
Gray and brown	do	Coarse	Even, variable, thick	do	do	1840	62
Gray	do	Massive	do	do	do	1869	63
do	do	do	Even, thick	Carboniferous	Base of Lower Coal Measures.	1860	64
Gray and pink	do	do	Uneven, thick	do	Lower Coal Measures.	1835	65
Gray and pink	Coarse	Massive	Uneven, thick	Carboniferous	Lower Coal Measures.	1880	66
do	Medium	do	do	do	do	1870	67
do	Coarse	do	do	do	do	1869	68
Gray	Medium	do	Even, thick	do	Base of Lower Coal Measures.	1873	69
do	do	Coarse and irregular	do	do	Lower Coal Measures.	1865	70
Gray	Medium	Coarse and irregular	Even, thick	Carboniferous	Lower Coal Measures.	1868	71
Light brown	Coarse	Coarse and massive	Uneven, variable, thick	do	do	1820	72
Gray	do	Irregular	Thick	do	do	1830	73
do	do	Massive	Uneven, thick	do	do	1840	74
do	do	do	do	do	do	1870	75
Gray	Coarse	Massive	Uneven, thick	Carboniferous	Lower Coal Measures.	1840	76
do	do	do	do	do	do	1820	77
do	do	Coarse and massive	Even, thick	do	Base of Lower Coal Measures.	1810	78
do	do	Coarse	Even, variable	Sub-Carboniferous	Waverly conglomerate.	1872	79
do	Fine	Fine and massive	Uneven, medium	do	Berea grit	1860	80
Gray	Fine	Fine and massive	Uneven, medium	Sub-Carboniferous	Berea grit	1875	81
Dark gray	do	Not distinct	Thin and smooth	do	do	1870	82
do	do	do	do	do	do	1880	83
Gray	do	Fine and massive	Uneven, thin to medium	do	do	1850	84
do	do	do	do	do	do	1847	85
Gray	Fine	Fine and massive	Uneven, thin to medium	Sub-Carboniferous	Berea grit	1869	86
do	do	do	do	do	do	1850	87
do	do	do	Even, thin to medium	do	do	1850	88
do	do	do	do	do	do	1855	89
do	do	Massive	Even, medium	do	do	1840	90

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

OHIO—SANDSTONE—Continued.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone.	
				Popular name.	Scientific name.
91	Newark	Licking	James Coyle	Freestone	Sandstone
92	8 miles east of Newark	....do	Charles Daugherty	Sandstone	....do
93	....do	.. do	O. Z. Hillery	....do	....do
94	2 miles southwest of Coshocton	Coshocton	Moses Cheney	....do	....do
95	Roscoe	....do	Robert Dickinson	....do	....do
96	Zanesville	Muskingum	T. B. Townsend	Sandstone	Sandstone
97	Cumberland	Guernsey and Noble.	....do	....do	....do
98	2½ miles northwest of Cambridge	Guernsey	Samuel Barr	....do	....do
99	2 miles southeast of Tippecanoe	Harrison	Robert Hosie	....do	....do
100	West side of Steubenville	Jefferson	Floto & Brothers	....do	....do
101	West side of Steubenville	Jefferson	Archer & Boal	Sandstone	Sandstone
102	West side of Martin's Ferry	Belmont	Charles Seabreght	....do	....do
103	2 miles west of Bellaire	... do	John R. Robinson	....do	....do
104	West side of Bellaire	... do	W. J. McClain	....do	....do
105	Lewis' Mills	....do	Joseph Hutchinson	....do	....do
106	Barnesville	Belmont	Baltimore and Ohio Railroad Company	Sandstone	Sandstone
107	Marietta	Washington	T. B. Townsend	....do	....do
108	2 miles southwest of Marietta	....do	C. Finch	....do	....do
109	6 miles southwest of Marietta	....do	Marietta Stone Company	....do	....do
110	....do	....do	Constitution Stone Company	....do	....do
111	7 miles southwest of Marietta	Washington	P. L. Cole	Sandstone	Sandstone
112	8 miles southwest of Marietta	... do	D. Briggs	....do	....do
113	8½ miles southwest of Marietta	....do	D. B. Calder	....do	....do
114	2½ miles west of Constitution	do	Constitution Stone Company	....do	....do
115	Lithopolis	Fairfield	Joseph Leydecker	Freestone	....do
116	Lancaster	Fairfield	Charles Bowmaster	Sandstone	Sandstone
117	Lancaster (east)	....do	Sharp & Crook	....do	....do
118	Lancaster (south)	....do	....do	....do	....do
119	Logan	Hocking	Weitzell Brothers	....do	....do
120	Piketon	Pike	Hays & Green	....do	....do
121	Piketon	Pike	Waverly Brown Stone Quarries	Freestone	Sandstone
122	2 miles west of Portsmouth	Scioto	Reitz & Co	....do	....do
123	12 miles from Portsmouth	....do	J. M. Inskeep	....do	....do
124	Freestone P. O. (Buena Vista)	....do	Buena Vista Freestone Company	....do	....do
125	Freestone	Scioto & Adams	John M. Mueller	....do	....do
126	Rockville	Scioto & Adams	W. J. Stewart	Freestone	Sandstone

OHIO—LIMESTONE.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Popular name.	Scientific name.
1	Point Marblehead	Ottawa	Fred. Roesling	Limestone	Bituminous dolomite
2	....do	....do	Clemons & Sons	....do	....do
3	.. do	....do	Johnson & Clemons	....do	....do
4	.. do	....do	W. A. Clemons	....do	....do
5	....do	....do	Ohlemacher Bros	....do	....do
6	Point Marblehead	Ottawa	John H. Hudson	Limestone	Bituminous dolomite
7	....do	... do	John H. James	....do	....do
8	Johnson's island	....do	L. B. Johnson & Co	....do	
9	White House	Lucas	Pray & Hall	....do	Magnesian limestone
10	5 miles from Weston	Wood	L. S. Pugh	....do	Dolomite
11	1 mile west of Fremont	Sandusky	Quilter Brothers	Limestone	Bituminous dolomite
12	Kelley's island	Erie	N. Kelley & Co	....do	Dolomite
13	Sandusky	....do	Ira T. Davis	....do	....do
14	... do	... do	David McGoray	....do	....do
15	....do	....do	Watson Hubbard	....do	... do
16	Sandusky	Erie	Charles Schoepfle	Limestone	Dolomite
17	... do	....do	Ambrose Lieb	....do	Bituminous dolomite
18	... do	....do	Michael Callan	....do	Dolomite
19	do	....do	Michael O'Donnell	....do	... do
20	Bloomville	Seneca	Fred. Seavert	....do	Magnesian limestone
21	Bloomville	Seneca	A. Reichert	Limestone	Magnesian limestone
22	....do	....do	E. H. France	....do	....do
23	Tiffin	....do	J. L. King	....do	Bituminous dolomite
24	....do	....do	H. W. Creeger	....do	....do
25	....do	....do	Thill & Graesner	....do	....do
26	Holmes township	Crawford	L. B. Gearhart	Limestone	Dolomite
27	Findlay	Hancock	Altman & Pressnell	....do	Bituminous magnesian limestone
28	....do	....do	L. J. Turley	....do	....do
29	1 mile east of Findlay	....do	I. Hershey	....do	....do
30	7 miles southeast of Ottawa	Putnam	John Hager	....do	Bituminous dolomite

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

OHIO—Sandstone—Continued.

Color.	Structure.			Geological age of formation.		Year in which opened.	
	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.		
Gray	Fine	Fine, not distinct	Even, thick	Sub-Carboniferous	Cuyahoga shale	1830	91
...do	Coarse	Coarse and massive	...do	...do	Waverly conglomerate.	1834	92
...do	...do	...do	...do	...do	...do	1834	93
Gray and light red	...do	...do	One 30-foot stratum	Carboniferous	Lower Coal Measures.	1880	94
...do	...do	...do	Even	...do	...do	1830	95
Gray	Coarse	Massive	One 40-foot stratum	Carboniferous	Lower Coal Measures.	1868	96
...do	Medium	Fine, not distinct	One 10-foot stratum	...do	Lower Barren Measures.	1855	97
Gray	Coarse	Massive	One 12-foot stratum	...do	...do	1850	98
...do	...do	Coarse and regular	Even, thick	...do	...do	[a]1881	99
...do	...do	Coarse and massive	...do	...do	Upper Coal Measures.	1870	100
Gray	Coarse	Coarse and massive	Even, thick	Carboniferous	Upper Coal Measures.	1872	101
...do	...do	Coarse and regular	One 30-foot stratum	...do	...do	1879	102
...do	...do	Massive	Even, thick	...do	...do	1875	103
...do	Medium	Fine and variable	Even, medium	...do	...do	1865	104
...do	Coarse	Variable and massive	Broken and irregular	...do	...do	1850	105
Gray	Coarse	Coarse and massive	One thick stratum	Carboniferous	Lower Barren Measures.	1867	106
...do	...do	...do	Uneven, thick	...do	Upper Coal Measures.	1880	107
...do	Variable	Coarse and variable	One 25-foot stratum	...do	...do	1830	108
...do	...do	...do	...do	...do	...do	1830	109
...do	...do	...do	...do	...do	...do	1830	110
Gray	Variable	Coarse and variable	One 25-foot stratum	Carboniferous	Upper Coal Measures.	1830	111
...do	...do	...do	...do	...do	...do	1830	112
...do	...do	...do	...do	...do	...do	1830	113
...do	...do	...do	...do	...do	do	1830	114
...do	Fine	Massive	Even and thin to medium	Sub-Carboniferous	Cuyahoga shale	1830	115
Gray and red	Coarse	Massive	One 30-foot stratum	Sub-Carboniferous	Waverly conglomerate.	1865	116
Gray and brown	Coarse and fine	Coarse and massive	Even, thick	...do	...do	1878	117
...do	...do	...do	...do	...do	...do	1835	118
Gray	Coarse and conglomerate	Coarse	...do	...do	...do	1879	119
...do	Fine	Variable	Even, thin to medium	...do	Berea grit	1830	120
Brown	Fine	Massive	Even, thick	Sub-Carboniferous	Cuyahoga shale	1870	121
Gray and brown	...do	...do	Even, medium thick	...do	...do	1865	122
Gray	...do	...do	Even, thin to medium	...do	...do	1874	123
...do	...do	...do	Even, medium thick	...do	...do	1840	124
Dark gray	...do	...do	...do	...do	...do	1849	125
Dark gray	Fine	Massive	Even, medium thick	Sub-Carboniferous	Cuyahoga shale	1814	126

[a] This quarry, though opened in 1881, was considered of sufficient importance to have a place in the tables.

OHIO—Limestone.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Gray	Semi-crystalline fossiliferous.	Massive	Even, medium to thick	Devonian	Corniferous	1830	1
...do	...do	...do	...do	...do	...do	1830	2
...do	...do	...do	...do	...do	...do	1830	3
...do	...do	...do	...do	...do	...do	1830	4
...do	Semi-crystalline	...do	...do	...do	...do	1854	5
Gray	Fossiliferous	Massive	Even, medium to thick	Devonian	Corniferous	1840	6
...do	...do	...do	...do	...do	...do	1874	7
...do	...do	...do	...do	...do	...do	1850	8
...do	Fine, compact, and vesicular.	Even and massive	Even and uneven, medium thick.	...do	...do	1860	9
...do	Compact and vesicular	Massive	Uneven, thin to medium	...do	...do	1850	10
Gray	Vesicular	Parallel, wavy	Even, medium thick	Upper Silurian	Helderberg (water-lime).	1868	11
...do	Semi-crystalline, fossiliferous.	Massive	...do	Devonian	Corniferous	1857	12
Bluish gray	...do	...do	...do	...do	...do	1837	13
...do	...do	...do	...do	...do	...do	1837	14
...do	...do	...do	...do	...do	...do	1837	15
Bluish gray	Semi-crystalline, fossiliferous.	Massive	Even, medium thick	Devonian	Corniferous	1874	16
...do	...do	...do	...do	...do	...do	1873	17
...do	...do	...do	...do	...do	...do	1873	18
...do	...do	...do	...do	...do	...do	1873	19
Drab	...do	...do	...do	...do	...do	1877	20
Drab	Semi-crystalline, fossiliferous.	Massive	Even, medium thick	Devonian	Corniferous	1850	21
...do	...do	...do	...do	...do	...do	1880	22
...do	Vesicular	Wavy and massive	...do	Upper Silurian	Helderberg (water-lime).	1878	23
...do	...do	...do	...do	...do	...do	1868	24
...do	...do	...do	...do	...do	...do	1862	25
Gray and bluish gray	Compact	Massive	Uneven, thin to medium	Devonian	Corniferous	1866	26
Drab	Porous and vesicular	Irregular	...do	Upper Silurian	Niagara	1875	27
...do	...do	...do	...do	...do	...do	1876	28
...do	...do	...do	...do	...do	...do	1874	29
Dark drab	Compact and vesicular, porphyritic.	Even, irregular, and massive.	Even, thin to medium	...do	Helderberg (water-lime).	1845	30

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

OHIO—LIMESTONE—Continued.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone.	
				Popular name.	Scientific name.
31	2 miles north of Columbus Grove	Putnam	J. Postlewait	Limestone	Bituminous dolomite
32	3 miles northeast of Van Wert	Van Wert	Miss Z. Palmer	do	Dolomite
33	4 miles east of Delphos	Allen	A. J. Patton	do	Bituminous dolomite
34	Lima	do	William Pugh	do	do
35	4 miles north of Lima	do	Mrs. B. A. Armentrout	do	do
36	5½ miles northeast of Lima	Allen	Jacob Custer	Limestone	Bituminous dolomite
37	Bluffton	do	John T. Bates	do	do
38	do	do	Ritzler & Greenwald	do	do
39	6 miles northeast of Marion	Marion	F. Hinamon	do	Dolomite
40	1 mile north of Marion	do	Marion Stone Company	do	do
41	1 mile north of Marion	Marion	T. R. Roberts & Co	Limestone	Dolomite
42	Marion	do	Haberman & Riley	do	do
43	do	do	Beattie & Sherbonda	do	do
44	do	do	Peters & Lawrence	do	do
45	Delaware	Delaware	R. J. Akers	do	
46	½ mile east of Bell Centre	Logan	W. L. Sickles	Limestone	Bituminous dolomite
47	1 mile northwest of Bellefontaine	do	J. H. Eaton	do	Dolomite
48	½ mile northwest of Bellefontaine	do	Angel, Miller & Co	do	do
49	1 mile east of Sidney	Shelby	A. Hall & Son	do	Arenaceous magnesian limestone
50	¾ mile west of Ludlow	Miami	G. Rumburg	do	Magnesian limestone
51	1 mile south of Covington	Miami	I. P. Watts & Co	Limestone	Arenaceous magnesian limestone
52	Covington	do	Conrad Shefbuch	do	do
53	do	do	N. W. Furnas	do	do
54	do	do	Lewis Face	do	do
55	do	do	Butt & Battorff	do	do
56	Covington	Miami	J. W. Ruhl	Limestone	Arenaceous magnesian limestone
57	do	do	Covington Stone Company	do	do
58	1½ miles south of Piqua	do	D. C. Stattler & Co	do	Magnesian limestone
59	2½ miles south of Piqua	do	H. G. Deweese	do	do
60	At Piqua	do	H. Clark & Son	do	do
61	At Piqua	Miami	Mitchell & Mitchell	Limestone	Magnesian limestone
62	do	do	J. Hamilton	do	do
63	4½ miles north of Urbana	Champaign	D. W. Happersett	do	Bituminous dolomite
64	2 miles west of Springfield	Clarke	W. S. Thompson	do	Dolomite
65	do	do	A. Rebert	do	do
66	2 miles west of Springfield	Clarke	A. L. Eppley	Limestone	Dolomite
67	4 miles west of Springfield	do	Mrs. E. Moores	do	Arenaceous dolomite
68	do	do	A. Holcomb	do	do
69	2 miles west of Springfield	do	Robert Moores	do	do
70	1½ miles west of Springfield	do	James Mowatt	do	do
71	1 mile west of Springfield	Clarke	George Sintz	Limestone	Arenaceous dolomite
72	North edge of Springfield	do	Petticrew & Bro	do	do
73	do	do	George H. Frey	do	do
74	3 miles west of Columbus	Franklin	Wilcox Bros	do	Limestone
75	4 miles northwest of Columbus	do	M. M. Williams	do	do
76	4 miles northwest of Columbus	Franklin	M. D. Slyh	Limestone	Limestone
77	do	do	Peter Burns	do	do
78	3 miles west of Columbus	do	Andrew McNinck	do	do
79	do	do	Lilley & Poston	do	do
80	4 miles west of Columbus	do	T. J. Price & Co	do	do
81	4 miles northwest of Columbus	Franklin	Smith & Price	Limestone	Limestone
82	Newtonville	Muskingum	T. B. Townsend	do	do
83	½ mile southwest of Zanesville	do	Philip Moran	do	do
84	Rockville	Fayette	I. N. Bonum	do	Bituminous dolomite
85	Yellow Springs	Greene	W. Sroufe	do	Argillaceous dolomite
86	4½ miles east of Xenia	Greene	Roots & Bickotte	Limestone	Magnesian limestone
87	4 miles southeast of Xenia	do	W. McDonald	do	do
88	6 miles east of Dayton	do	John Archer	do	do
89	8 miles east of Dayton	do	H. Huston	do	do
90	1½ miles southeast of Dayton	Montgomery	Huffman Stone Company	do	do
91	1½ miles southeast of Dayton	Montgomery	D. Renner	Limestone	Magnesian limestone
92	do	do	C. Fanver	do	do
93	do	do	M. Bosler	do	do
94	1½ miles southeast of Dayton	do	S. Fanver	do	do
95	7½ miles north of Dayton	do	J. S. Booker	do	do
96	1 mile east of Lewisburg	Preble	C. Dishler	Limestone	Arenaceous dolomite
97	1 mile northwest of Euphemia	do	I. J. Weaver	do	Dolomite
98	do	do	R. Swisher	do	do
99	do	do	Bowman & Thompson	do	do
100	New Paris	do	T. J. Smith	do	Arenaceous magnesian limestone
101	New Paris	Preble	Sam. Smith & Co	Limestone	Arenaceous magnesian limestone
102	3 miles northeast of Eaton	do	Young & Christman	do	Dolomite
103	5½ miles northeast of Eaton	do	John O. Deem	do	do
104	At Hamilton	Butler	Kilfoyle & Joyce	do	Limestone
105	3 miles northeast of Hamilton	do	R. Andrews	do	do

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

OHIO—LIMESTONE—Continued.

Color.	STRUCTURE.			GEOLOGICAL AGE OF FORMATION.		Year in which opened.	
	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.		
Dark drab	Compact and vesicular	Even and parallel	Even, medium thick	Upper Silurian	Helderberg (water-lime).	1854	31
Light gray	Semi-crystalline, vesicular	Even, parallel, and massive.	Uneven, medium thick	do	do	1876	32
Drab	Vesicular	Even, wavy, and irregular.	Uneven, thin	do	do	1878	33
do	do	Irregular	Uneven, thin and broken	do	do	1868	34
Drab and blue-black	Compact and vesicular	Massive, irregular, and even.	Even, thin to medium	do	do	1840	35
Drab	Compact and vesicular	Massive, irregular, and even.	Even, thin to medium	Upper Silurian	Helderberg (water-lime).	1877	36
Dark drab	Compact and porphyritic	Wavy and irregular	Even and thin	do	do	1880	37
do	do	do	do	do	do	1878	38
Bluish gray	Fine and compact	Massive	Even, thin to medium	Devonian	Corniferous	1840	39
Gray and bluish gray	do	do	Even, medium thick	do	do	1878	40
Gray and bluish gray	Fine and compact	Massive	Even, medium thick	Devonian	Corniferous	1877	41
do	do	do	do	do	do	1845	42
do	do	do	do	do	do	1878	43
do	do	do	do	do	do	1825	44
do	Compact	do	do	do	do	1860	45
Drab	Vesicular	Wavy and irregular	Even and thin	Upper Silurian	Helderberg (water-lime).	1855	46
Gray	Porous	Massive	Even, medium thick	Devonian	Corniferous	1877	47
do	do	do	do	do	do	1830	48
Drab	Vesicular	Wavy and irregular	Even, medium thick	Upper Silurian	Niagara (Guelf)	1869	49
do	do	Irregular	do	do	do	1851	50
Drab	Vesicular	Irregular	Even, medium thick	Upper Silurian	Niagara (Guelf)	1830	51
do	do	do	do	do	do	1870	52
do	do	do	do	do	do	1856	53
do	do	do	do	do	do	1865	54
do	do	do	do	do	do	1856	55
Drab	Vesicular	Irregular	Even, medium thick	Upper Silurian	Niagara (Guelf)	1868	56
do	do	do	do	do	do	1874	57
do	Semi-crystalline	Wavy and irregular	do	do	do	1858	58
do	do	do	do	do	do	1874	59
do	do	do	do	ke	do	1868	60
Drab	Semi-crystalline	Wavy and irregular	Even, medium thick	Upper Silurian	Niagara (Guelf)	1851	61
do	do	do	do	do	do	1851	62
Light drab	Vesicular	Irregular	Even and uneven, medium thick.	do	Helderberg (water-lime).	1802	63
Drab	do	Wavy and irregular	Even, medium thick	do	Niagara	1849	64
do	do	do	do	do	do	1876	65
Drab	Vesicular	Wavy and irregular	Even, medium thick	Upper Silurian	Niagara	1873	66
do	do	do	do	do	do	1862	67
Light drab	do	Irregular	do	do	do	1865	68
do	do	do	do	do	do	1860	69
do	do	do	do	do	do	1850	70
Light drab	Vesicular	Irregular	Even, medium thick	Upper Silurian	Niagara	1870	71
Drab	do	Wavy and irregular	do	do	do	1868	72
do	do	do	do	do	do	1840	73
Gray	Semi-crystalline, fossiliferous.	Irregular	Even, thick, and medium	Devonian	Corniferous	1881	74
do	do	do	do	do	do	1860	75
Gray	Semi-crystalline, fossiliferous.	Irregular	Even, thick, and medium	Devonian	Corniferous	1840	76
do	do	do	do	do	do	1860	77
do	do	do	do	do	do	1870	78
do	do	do	do	do	do	1880	79
do	do	do	do	do	do	1858	80
Gray	Semi-crystalline, fossiliferous.	Irregular	Even, thick, and medium	Devonian	Corniferous	1872	81
Drab	Fine, semi-crystalline	Massive	Even, thin to medium	Sub-Carboniferous	Maxville limestone.	1874	82
Blue-black	Compact and fossiliferous	do	One 3-foot stratum	Carboniferous	Lower Coal Measures.	1875	83
Drab	Vesicular	Irregular	Even and thin	Upper Silurian	Helderberg (water-lime).	1866	84
Drab and light drab	do	do	Even, variable, thick	do	Niagara	1864	85
Drab	Semi-crystalline	Irregular	Even, medium thick	Upper Silurian	Niagara	1840	86
do	do	do	do	do	do	1825	87
do	do	do	do	do	do	1870	88
do	do	do	do	do	do	1875	89
do	do	do	do	do	do	1861	90
Drab	Semi-crystalline	Irregular	Even, medium thick	Upper Silurian	Niagara	1845	91
do	do	do	do	do	do	1851	92
do	do	do	do	do	do	1873	93
do	do	do	do	do	do	1866	94
do	do	do	do	do	do	1871	95
Drab	Compact and vesicular	Irregular	Even, thin to medium	Upper Silurian	Niagara	1830	96
do	do	do	do	do	do	1869	97
do	do	do	Even, medium thick	do	do	1860	98
do	do	do	do	do	do	1840	99
do	Porphyritic	Wavy and irregular	Even, thin to medium	do	do	1840	100
Drab	Porphyritic	Wavy and irregular	Even, medium thick	Upper Silurian	Niagara	1840	101
do	Semi-crystalline	do	do	do	do	1830	102
do	do	do	do	do	do	1835	103
Blue	Semi-crystalline, highly fossiliferous.	Irregular	do	Lower Silurian	Cincinnati	1865	104
do	do	do	do	do	do	1874	105

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

OHIO—LIMESTONE—Continued.

	Location of quarry.	County.	Name of the corporation, company, or individual.	SPECIFIC VARIETY OF STONE.	
				Popular name.	Scientific name.
106	5 miles east of Hamilton	Butler	J. Rupp	Limestone	Limestone
107	1½ miles southwest of Lumberton	Clinton	W. F. Oglesbee	do	Magnesian limestone
108	Greenfield	Ross	G. I. Rucker & Son	do	Bituminous dolomite
109	do	Highland	do	do	do
110	do	do	McAltin & Co	do	do
111	2 miles south of Lexington	Highland	Mrs. L. Dunn	Limestone	Bituminous dolomite
112	do	do	A. Carriff	do	do
113	Point Pleasant	Clermont	J. Delaney	do	Limestone
114	Cincinnati	Hamilton	F. Teating	do	do
115	do	do	L. Grover	do	do
116	Cincinnati	Hamilton	J. Delaney	Limestone	Limestone
117	do	do	L. Lutterbey	do	do
118	do	do	J. Cinck	do	do
119	do	do	E. Howe	do	do

INDIANA—MARBLE AND LIMESTONE.

1	Decatur	Adams	B. P. Rice	Limestone	Dolomite
2	Bluffton	Wells	Kapp & Gardner	do	do
3	Wabash	Wabash	Bridges & Scott	do	Limestone
4	do	do	Hubbard & Smith	do	do
5	do	do	Philip Hipskin	do	do
6	Wabash	Wabash	William J. Ford	Limestone	Limestone
7	do	do	Moellering & Paul	do	Dolomite
8	do	do	Lillie & Shoemaker	do	Limestone
9	Logansport	Cass	Lux & Lux	do	Limestone and dolomite
10	do	do	J. E. Barnes	do	
11	Logansport	Cass	August Gleitz	Limestone	
12	3½ miles southwest of Kokomo	Howard	J. V. Smith	do	Magnesian limestone
13	Kokomo	do	George W. Defenbaugh	do	Limestone
14	Marion	Grant	D. R. McKinney	do	Magnesian limestone
15	do	do	Silvester Fankboner	do	do
16	Marion	Grant	John Murphy	Limestone	Magnesian limestone
17	Montpelier	Blackford	William Twibell	do	Dolomite
18	Eaton	Delaware	George W. Carter	do	do
19	do	do	Bosman Brothers	do	do
20	Yorktown	do	L. D. Koontz	do	do
21	Anderson	Madison	William Crim	Limestone	Magnesian limestone
22	do	do	J. W. Sansberry	do	do
23	Greencastle	Putnam	Patrick Ash	do	Limestone
24	2 miles southwest of Greencastle	do	William Steegs	do	do
25	do	do	A. J. Crawford	do	do
26	2 miles southwest of Greencastle	Putnam	Vandalia Railroad Company	Limestone	Limestone
27	Oakalla	do	Moss & Hillis	do	do
28	do	do	Torr & Brother	do	do
29	Putnamville	do	James Lee	do	Siliceous limestone
30	Longwood	Fayette	Wilson Ball	do	Ferruginous dolomite
31	Longwood	Fayette	R. H. Moffitt	Limestone	Ferruginous dolomite
32	2¾ miles northwest of Laurel, Franklin county.	do	H. Reese	do	Dolomite
33	2¼ miles west of Laurel	Franklin	M. E. Secrest	do	do
34	2½ miles west of Laurel	do	John McGlin	do	do
35	3 miles southwest of Laurel	do	A. Cloud	do	do
36	3 miles south of Laurel	Franklin	J. A. Thomas	Limestone	Dolomite
37	New Point	Decatur	W. W. Hollensbe	do	do
38	5 miles southwest of Greensburg	do	Greensburg Limestone Company	do	do
39	Saint Paul	do	W. W. Lowe	do	do
40	do	do	J. L. Scanlan	do	do
41	2 miles west of Saint Paul	Shelby	G. W. McNeely	Limestone	Dolomite
42	Ellettsville	Monroe	John Matthews & Sons	do	Bituminous limestone
43	do	do	Perry Brothers	do	do
44	Stinesville	do	W. H. McHenry	do	do
45	do	do	McHenry & Brother	do	do
46	Stinesville	Monroe	Davis & Cassner	Limestone	Bituminous limestone
47	Spencer	Owen	B. Schweitzer	do	Limestone
48	3½ miles northeast of Spencer	do	Simpson & Archer	do	Bituminous limestone
49	do	do	E. R. Bladen	do	do
50	do	do	Howard & Denig	do	do
51	5 miles west of Bedford	Lawrence	N. C. Hinsdale & Co	Limestone	Limestone
52	4½ miles west of Bedford	do	Voris, Rodgers & Co	do	do
53	Bedford	do	Chicago-Bedford Stone Company	do	do
54	do	do	Fillion & Smith	do	do
55	Lawrenceport	do	A. F. Berry	do	do
56	Fort Ritner	Jackson	E. B. Dixon	Limestone	Bituminous limestone
57	3½ miles north of North Vernon	Jennings	Hicks & Holmes	do	Limestone
58	North Vernon	do	P. Conklin & Co	do	do
59	3 miles south of North Vernon	do	H. C. Herrman	do	do
60	Oakdale	do	Hicks & Holmes	do	Magnesian limestone

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

OHIO—LIMESTONE—Continued.

Color.	Structure.			Geological age of formation.		Year in which opened.	
	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.		
Blue	Semi-crystalline, highly fossiliferous.	Irregular	Even, medium thick	Lower Silurian	Cincinnati	1850	106
Drab	Semi-crystalline	Wavy	do	Upper Silurian	Niagara	1860	107
do	Compact and vesicular	Even and massive	Very even, thin to medium	do	Helderberg (water-lime).	1850	108
do	do	do	do	do	do	1850	109
do	do	do	do	do	do	1840	110
Drab	Vesicular	Even and parallel	Even, medium thick	Upper Silurian	Niagara	1870	111
do	do	do	do	do	do	1825	112
Blue	Semi-crystalline, fossiliferous.	Irregular	Even, thin to medium	Lower Silurian	Cincinnati	1873	113
do	do	do	do	do	do	1850	114
do	do	do	do	do	do	1860	115
Blue	Semi-crystalline, fossiliferous.	Irregular	Even, thin to medium	Lower Silurian	Cincinnati	1867	116
do	do	do	do	do	do	1861	117
do	do	do	do	do	do	1861	118
do	do	do	do	do	do	1868	119

INDIANA—MARBLE AND LIMESTONE.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Drab	Compact and vesicular	Even and parallel	Thin to medium	Upper Silurian		1876	1
do	Finely vesicular	Massive	Even, medium thick	do		1867	2
do	Semi-crystalline	Wavy and irregular	Even and thin	do		1866	3
do	do	do	do	do		1876	4
do	do	do	do	do		1878	5
Drab	Semi-crystalline	Wavy and irregular	Even and thin	Upper Silurian		1873	6
do	Vesicular	Irregular	Even, medium thick	do		1866	7
do	do	do	Uneven and thin	do		1873	8
do	Semi-crystalline	Massive	Uneven, medium thick	do		1872	9
Gray	Fine and compact	Even and massive	Even, medium thick	do		1840	10
Gray	Fine and compact	Even and massive	Even, medium thick	Upper Silurian		1840	11
Drab	do	do	do	do		1876	12
do	Fine and compact (conchoidal fracture).	Even and indistinct	Even and thin	Devonian		1850	13
do	Semi-crystalline	Variable	do	Upper Silurian		1864	14
do	do	do	do	do		1864	15
Drab	Fine and compact	Variable	Even, thin to medium	Upper Silurian		1867	16
do	Semi-crystalline	Irregular	do	do		1870	17
do	Semi-crystalline, vesicular	do	Even and thin	do		1855	18
do	do	do	do	do		1855	19
do	Vesicular	Variable	do	do		1835	20
Gray	Fine and compact	Even	Even, thin to medium	Upper Silurian		1840	21
do	do	do	do	do		1840	22
Drab	Semi-crystalline	Massive	Even, medium thick	Sub-Carboniferous		1869	23
do	do	do	do	do		1860	24
do	do	do	do	do		1870	25
Drab	Semi crystalline	Massive	Even, medium thick	Sub-Carboniferous		1858	26
do	do	do	do	do		1873	27
do	do	do	do	do		1876	28
do	do	do	Even and thick	do		1865	29
Drab and buff	Vesicular	Wavy and massive	Even, medium thick	Upper Silurian		1862	30
Drab and buff	Vesicular	Wavy and massive	Even, medium thick	Upper Silurian		1879	31
Drab	Semi-crystalline	do	do	do		1877	32
do	do	do	do	do		1876	33
do	do	do	do	do		1870	34
do	do	do	do	do		1850	35
Drab	Semi-crystalline	Wavy and massive	Even, medium thick	Upper Silurian		1878	36
do	do	Massive	Even, thin to medium	do		1875	37
do	do	do	do	do		1850	38
do	do	do	Even, medium thick	do		1854	39
do	do	do	do	do		1859	40
Drab	Semi-crystalline	Massive	Even, medium thick	Upper Silurian		1859	41
Gray and drab	Granular (oolitic)	do	Even and thick	Sub-Carboniferous		1862	42
do	do	do	do	do		1866	43
Gray	do	do	do	do		1878	44
do	do	do	do	do		1879	45
Gray	Granular (oolitic)	Massive	Even and thick	Sub-Carboniferous		1875	46
Drab	Fine and compact (conchoidal fracture).	do	Even, medium thick	do		1869	47
Gray	Granular (oolitic)	do	Even and thick	do		1870	48
do	do	do	do	do		1879	49
do	do	do	do	do		1878	50
Gray	Granular (oolitic)	Massive	Even and thick	Sub-Carboniferous		1879	51
do	do	do	do	do		1879	52
do	do	do	do	do		1876	53
do	do	do	do	do		1867	54
do	do	do	do	do		1879	55
Gray	Granular (oolitic)	Even and parallel	Even and thick	Sub-Carboniferous		1860	56
Drab	Semi-crystalline	Massive	Even, medium thick	Upper Silurian		1875	57
do	do	Irregular	do	do		1873	58
do	do	do	do	do		1850	59
do	do	Massive	do	do		1876	60

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

INDIANA—MARBLE AND LIMESTONE—Continued.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone.	
				Popular name.	Scientific name.
61	Osgood	Ripley	Peter Wagner	Limestone	Magnesian limestone
62	....do	....do	Ashman & Glasgow	....do	....do
63	Salem	Washington	Emanuel Zink	....do	Limestone
64	3 miles west of New Albany	Floyd	Christian Haller	....do	....do
65	....do	....do	N. Bittinger	....do	....do

INDIANA—SANDSTONE.

1	Williamsport	Warren	B. F. Gregory estate	Sandstone	Sandstone
2	Attica	....do	S. Bernhart	....do	....do
3	French Lick	Orange	W. F. Osborne	....do	....do
4	....do	....do	T. N. Braxtan	....do	....do
5	3½ miles east of Cannelton	Perry	A. Hallabach	....do	....do

ILLINOIS—LIMESTONE.

1	300 yards south of Roseclair	Hardin	W. W. Wright	Limestone	Magnesian and bituminous limestone.
2	44 miles above Roseclair	....do	C. Howard & Sons	-- do	
3	2 miles from Roseclair, Jacks Point	....do	Gus A. Craigen	-- do	Limestone
4	5 miles from Roseclair, Shetluville.	....do	....do	....do	
5	Chester village	Randolph	John Hern	....do	Limestone
6	1 mile north of Chester village	Randolph	Southern Illinois penitentiary	Limestone	Limestone
7	3 miles north of Chester village	....do	John Hern	....do	....do
8	City of Belleville	Saint Clair	G. F. Liehnert	....do	
9	....do	-- do	John Kloes	....do	
10	½ mile east of Columbia	Monroe	Peter Frierdich & Son	....do	Limestone
11	6 miles north of Bruse station	Clinton	Joseph Taylor	Limestone	Siliceous magnesian limestone
12	Saline	Madison	Stephen Bardill	Black lime	Calcareous dolomite
13	½ mile below Grafton	Jersey	Grafton Quarry Company	Limestone	
14	City of Quincy	Adams	F. W. Monck	....do	
15	City of Kankakee	Kankakee	Taylor & Orr	....do	
16	City of Kankakee	Kankakee	Kankakee Stone and Lime Company	Limestone	Dolomite
17	1½ miles southwest of Lemont	Will	Excelsior Stone Company	....do	....do
18	1½ miles northeast of Joliet	....do	Joliet Stone Company	....do	....do
19	2 miles east of center of Joliet	-- do	E. C. Hagar & Co	....do	
20	5th ward, Joliet	-- do	Charles Warner	....do	Dolomite.
21	3d ward, Joliet	Will	Simon Hausser	Limestone	
22	West side of Joliet	....do	J. Whittier & Co	....do	
23	....do	....do	Joseph Warner	....do	
24	1½ miles from C. H., Joliet	....do	Davidson Bros	-- do	Dolomite
25	End of Cass station, Joliet	....do	Joliet Stone Company	-- do	-- do
26	2½ miles north of Joliet	Will	Isaac Nobes	Limestone	Dolomite
27	North of Joliet	-- do	William Kronmeyer	....do	....do
28	...do	-- do	Bruce & Co	....do	....do
29	2½ miles north of Joliet	-- do	Sanger & Moody	-- do	....do
30	1 mile east of Lemont	Cook	Chicago and Lemont Stone Company	....do	....do
31	1½ miles east of Lemont	Cook	Illinois Stone Company	Limestone	Dolomite
32	½ mile northeast of Lemont	....do	The Singer-Talcott Company	....do	....do
33	Village of Lemont	....do	Chicago and Lemont Stone Company	....do	....do
34	½ mile southwest of Lemont	-- do	Earnshaw & Bodenschatz	....do	....do
35	1 mile southwest of Lemont	....do	Singer & Talcott	....do	....do
36	City of Batavia	Kane	F. F. Brady	Limestone	
37	....do	....do	O. P. Barker & Son	....do	
38	City of Aurora	....do	Anthon Berthold	....do	Dolomite

ILLINOIS—SANDSTONE.

1	Golconda	Pope	C. M. Cole	Sandstone	Sandstone
2	Chester	Randolph	Southern Illinois penitentiary	-- do	....do
3	2½ miles from Pinckneyville	Perry	John D. Day	White sandstone	....do
4	Xenia	Clay	William Haug	Sandstone	....do
5	Mississippi river, 4 miles up Hop Hollow.	Madison	J. W. Crawford	....do	....do

MICHIGAN—LIMESTONE.

1	2½ miles southeast of Raisinville	Monroe	Fritz Rath	Limestone	
2	2½ miles from Raisinville	....do	John Knaggs	....do	
3	Dundee	....do	Nagor & Bemis	....do	
4	Sibley's station	Wayne	F. Sibley	....do	
5	Alpena	Alpena	Owen Fox	White and blue limestone.	

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

INDIANA—Marble and Limestone—Continued.

Color.	Structure.			Geological age of formation.		Year in which opened.	
	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.		
Drab	Semi-crystalline	Wavy and massive	Even, thin	Upper Silurian		1871	61
....do	....do	.. do	....do	....do		1874	62
Gray	Granular (oolitic)	Massive	Even and thick	Sub-Carboniferous		1861	63
....do	....do	....do	....do	....do		1840	64
....do	....do	....do	....do	....do		1850	65

INDIANA—Sandstone.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Gray	Coarse	Coarse and massive	Even and thick	Carboniferous	Conglomerate	1860	1
Gray and bluish gray	....do	... do	....do	....do	....do	1873	2
Gray	Fine and medium	Even, fine and coarse	Even, medium thick	Sub-Carboniferous		1850	3
....do	....do	....do	....do	....do		1830	4
Light brown	Medium	Irregular	Even, one 30-foot stratum	Carboniferous		1871	5

ILLINOIS—Limestone.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Drab	Fine, compact, partly oolitic	Variable	Even, medium	Sub-Carboniferous		1867	1
Light gray	Medium, compact	Massive	Even, thick	....do		1877	2
Drab	Fine, compact	....do	....do	....do		1878	3
Dark drab	Medium, fossiliferous	....do	Even, thin to thick	....do		1880	4
....do	Fine, fossiliferous	.. do	Uneven, thin to thick	....do		1880	5
Drab	Fine, fossiliferous	Variable	Medium to thick	Sub-Carboniferous		1877	6
....do	....do	Massive	Even, thin to medium	....do		1877	7
Light drab	Fine, compact	Indistinctly laminated	Irregular, thin to medium	....do		1874	8
Drab	Medium, compact	Massive	Even, thin to medium	....do		1873	9
Gray	Medium, crystalline	....do	Even, thick	....do		1856	10
Gray	Fine, fossiliferous	Massive	Even, thin to medium	Sub-Carboniferous		1879	11
Dark gray	Medium, fossiliferous	....do	Even, thick	....do		1867	12
Gray	Variable	....do	Even, medium	Upper Silurian		1859	13
....do	Variable, crystalline	....do	Thin to medium	Devonian		1874	14
Light drab	Medium, vesicular	....do	Even, thick	Upper Silurian		1867	15
Light drab	Medium, vesicular	Massive	Medium to thick	Upper Silurian		1855	16
....do	Fine, compact	Indistinctly laminated	Even, thick	....do		1867	17
.... do	Compact	....do	....do	....do		1874	18
Drab	....do	....do	....do	....do		1880	19
Light drab	Fine, compact	....do	Even, thin to thick	....do		1871	20
Light drab	Fine, vesicular	Indistinctly laminated	Even, thin to thick	Upper Silurian		1856	21
....do	Fine, compact	... do	Thin to thick	....do		1867	22
....do	... do	....do	Medium to thick	....do		1881	23
Drab	....do	....do	Even, thin to thick	....do		1853	24
Light drab	....do	.. do	Even, thin to medium	....do		1874	25
Drab	Fine, compact	Indistinctly laminated	Even, thin to thick	Upper Silurian		1855	26
....do	....do	....do	....do	....do		1852	27
....do	....do	....do	....do	....do		1852	28
Light drab	....do	....do	... do	....do		1866	29
....do	....do	.. do	....do	....do		1854	30
Light drab	Fine, compact	Indistinctly laminated	Even, thin to thick	Upper Silurian		1852	31
....do	....do	....do	Even, medium to thick	....do		1854	32
....do	....do	....do	... do	....do		1878	33
....do	....do	... do	....do	....do		1869	34
Drab	....do	....do	Even, thin to thick	....do		1869	35
Drab	Variable	Massive	Even, thin to thick	Upper Silurian		1872	36
....do	Fine, compact	....do	....do	....do		1848	37
Light drab	Medium, compact, and vesicular.	....do	Even, medium to thick	....do		1848	38

ILLINOIS—Sandstone.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Buff	Coarse	Massive	Even, thick	Sub-Carboniferous		1879	1
....do	Fine, compact	Irregular	Even, thin to thick	....do		1878	2
Gray	Medium, compact	Massive	Even, thick	Carboniferous		1866	3
....do	Compact	Indistinctly laminated	....do	... do		1873	4
Drab	Medium, compact	Massive	....do	Sub-Carboniferous		1876	5

MICHIGAN—Limestone.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Drab	Medium, compact, semi-crystalline.	Massive	Even, thin to thick	Devonian		1880	1
....do	Fine, compact	....do	....do	....do		1880	2
Gray	Fine, fossiliferous	....do	Uneven, thick	Upper Silurian		......	3
Light drab	....do	....do	Even, thick	Devonian		1824	4
Gray	Medium	....do	Even, thin to thick	....do		1879	5

Table IV.—TABLES INDICATING THE AMOUNT AND KINDS

MICHIGAN—Sandstone.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone. Popular name.	Scientific name.
1	Lulu	Monroe	Henry McCarthy	Sandstone	
2	Stony Point	Jackson	Michigan Stone Company	...do	
3	Ionia township	Ionia	C. S. Marsh & Co	...do	
4	...do	...do	W. E. Avery & Co	...do	
5	Marquette	Marquette	Watson & Palmer	...do	

WISCONSIN—Sandstone.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Popular name.	Scientific name.
1	3 miles west of Waterloo (a)	Dane	Chicago and Wisconsin Granite Quarrying Company.	Sandstone	
2	Madison, 3 miles from capitol building.	...do	David Stevens	...do	
3	Madison, 3 miles west of capitol building.	...do	August Pennack	...do	
4	Mazomanie	...do	Fred. Stickney	Calciferous sandstone	
5	Ableman	Sauk	Chicago and Northwestern Railway Co	Sandstone	
6	Mauston	Juneau	C. W. Potter	Sandstone	
7	...do	...do	H. V. Train	...do	
8	3 miles northwest of Alma	Buffalo	Beef Slough Company	...do	
9	4½ miles west of Grand Rapids	Wood	J. Edwards & Co	...do	
10	Plover	Portage	Mrs. E. L. Baker	...do	
11	Stevens Point	Portage	J. A. Avery	Sandstone	
12	...do	...do	A. D. Sager	...do	

a This quarry was considered of sufficient importance to tabulate, though opened in 1881.

WISCONSIN—Limestone.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Popular name.	Scientific name.
1	2½ miles west of center of Racine.	Racine	C. Fox & Sons	Limestone	Dolomite
2	...do	...do	William Beswick	...do	
3	1½ miles west of C. H., Janesville city.	Rock	Andrew Byron	...do	
4	2 miles west of C. H., Janesville city.	...do	Cornelius Stout	...do	
5	1½ miles northwest of Beloit	...do	Samuel Goss	...do	
6	½ mile east of Westport	Dane	William Veerhusen	Limestone	
7	Westport, 2½ miles north of Mendota.	...do	P. O'Malley	...do	
8	3 miles west of Madison	...do	Andrew Keimear	Magnesian limestone	Magnesian limestone
9	Waukesha	Waukesha	Hadfield & Co	Limestone	Dolomite
10	3½ miles west of bridge, Milwaukee.	Milwaukee	A. F. Manegold & Bro	...do	
11	Wauwatosa	Milwaukee	Story Bros	Limestone	
12	Kildare station	...do	Schweickart & Manegold	...do	
13	3 miles northwest of Watertown	Dodge	Herman Bentert	...do	
14	3 miles east of La Crosse	La Crosse	Frank Wekkert	...do	
15	...do	...do	Leypold Ebner	...do	
16	3 miles east by south of La Crosse	La Crosse	Richard Waggoner	Limestone	
17	3 miles east of La Crosse	...do	John Neilson	...do	Dolomite
18	3 miles south of east of La Crosse	...do	Magnus Nelson	...do	...do
19	2 miles east of La Crosse	...do	Royall Reynolds	...do	
20	7 miles southeast of Fond du Lac	Fond du Lac	Nast Bros. & Co	...do	Dolomite
21	7 miles southeast of Fond du Lac	Fond du Lac	Marblehead Lime Company	Limestone	Dolomite
22	4¾ miles southeast of Fond du Lac	...do	James Sylvester	...do	...do
23	4½ miles southeast of Fond du Lac	...do	Matthew V. Butler	...do	...do
24	Byron, 4½ miles south of Fond du Lac	...do	S. Sylvester	...do	...do
25	Byron, 2 miles from Fond du Lac	...do	S. Sylvester, jr	...do	...do
26	2½ miles northeast from Oak Centre	Fond du Lac	C. E. Town	Limestone	
27	6 miles from Fond du Lac	...do	Christian Geiger	...do	Dolomite
28	Waupun	...do	John McCune	...do	...do
29	2 miles northwest of Sheboygan	Sheboygan	H. E Roth	...do	...do
30	Sheboygan Falls	...do	Kelhagen Bros	...do	...do
31	6 miles west of north of Manitowoc.	Manitowoc	Lewis Miller & Co	Limestone	Dolomite
32	Menasha	Winnebago	Orville J. Hall	...do	
33	Neenah	...do	Charles Gerhardt	...do	
34	...do	...do	Patrick McGarth	...do	Dolomite
35	...do	...do	T. T. Moulton	...do	
36	2 m. southwest of center of Oshkosh	Winnebago	Schneider & Frank	Limestone	Dolomite
37	Oshkosh	...do	Frank Last	...do	...do
38	River Falls	Pierce	Thomas Walker	...do	...do
39	North side of Fountain City	Buffalo	Richtman & Kerckner & Mattansch	Sandy limestone	...do
40	Alma	...do	Matthias Braun	...do	
41	Kaukauna	Outagamie	United States Government	Limestone	Dolomite
42	Ledyard village	...do	Kaukauna Water Power Company	...do	...do
43	Appleton	...do	Waters & Green	...do	
44	3½ miles south of C. H., Appleton	...do	Y. B. Waters	...do	
45	Hortonville	...do	H. W. Thompson	...do	
46	Duck Creek station	Brown	Manuel Baunette	Limestone	Dolomite
47	...do	...do	Chicago and Northwestern Railway Co	...do	...do
48	6 miles east of Hudson	Saint Croix	Henry Gibson	...do	

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

MICHIGAN—SANDSTONE.

Color.	STRUCTURE. Texture.	Stratification.	Jointing, bedding, or natural surface.	GEOLOGICAL AGE OF FORMATION. Period.	Epoch.	Year in which opened.	
Buff	Medium, compact, uniform	Massive	Medium to thick	Devonian		1876	1
....do	Medium	....do	Even, thick	Sub-Carboniferous		1870	2
				Carboniferous		1865	3
				....do		1879	4
Brown	Medium, uniform	Massive	Thin to thick	Lower Silurian		1871	5

WISCONSIN—SANDSTONE.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Light gray	Fine	Massive	Uneven, thick	Archæan		1881	1
Buff	....do	....do	Thin to thick	Lower Silurian		1858	2
....do	Fine, compact	....do	Even, thick	... do		1876	3
....do	Coarse	....do	Even, medium to thick	....do		1850	4
Light pink	Fine, compact	Indistinct	Even, thick	....do		1880	5
Light gray	Fine, compact	Indistinct	Even, thin to thick	Lower Silurian		1880	6
... do	....do	... do	....do	....do		1872	7
Buff	Medium to coarse	Massive	Even, thin to medium	....do		1879	8
Light gray	Compact	Indistinctly laminated	Uneven, thin to thick	....do		1874	9
....do	Medium	Irregular	Even, thin to medium	....do		1868	10
Light gray	Medium	Irregular	Even, thin to thick	Lower Silurian		1872	11
....do	....do	....do	....do	....do		1859	12

WISCONSIN—LIMESTONE.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Drab	Variable, vesicular	Massive	Even, thin to medium	Upper Silurian		1879	1
... do	....do	....do	....do	....do		1850	2
....do	Medium, vesicular	....do	Variable, thin to thick	Lower Silurian		1840	3
....do	....do	....do	Even, thin to thick	....do		1878	4
....do	Coarse, variable	....do	Uneven, thin to thick	....do		1860	5
Buff	Medium, compact	Massive	Medium to thick	Lower Silurian		1857	6
Light buff	Fine, compact	....do	Variable, thin to thick	....do		1869	7
Buff	Variable	....do	Even, medium to thick	....do		1855	8
Drab	Fine, compact	....do	....do	Upper Silurian		1871	9
....do	Variable	....do	Even, thin to thick	....do		1873	10
Drab	Variable	Massive	Even, thin to thick	Upper Silurian		1856	11
....do	Coarse	... do	....do	....do		1845	12
....do	Variable	....do	Even, medium to thick	Lower Silurian		1878	13
Light drab	....do	Even, parallel	Even, medium to thin	....do		1870	14
....do	... do	Irregular	Uneven, medium to thin	....do		1880	15
Light drab	Variable	Irregular	Even, medium to thin	Lower Silurian		1879	16
... do	....do	... do	Even, medium	....do		1860	17
....do	....do	Even, parallel	Even, thin to medium	... do		1872	18
....do	....do	....do	....do	... do		1850	19
....do	... do	....do	Uneven, thin to medium	Upper Silurian		1855	20
Light drab	Variable	Even, parallel	Even, thin to medium	Upper Silurian		1880	21
....do	Fine, compact	....do	....do	....do		1850	22
....do	... do	....do	....do	....do		1858	23
....do	....do	....do	... do	....do		1864	24
....do	....do	....do	Thin to medium	... do		1864	25
Drab	Medium to fine	Massive	Even, thin to medium	Upper Silurian		1878	26
....do	Fine, compact	Even, parallel	....do	....do		1873	27
....do	Fine, vesicular	... do	....do	... do		1850	28
Light drab	Fine, crystalline	Massive	Even, thin to thick	....do		1854	29
....do	....do	Indistinct	....do	....do		1879	30
Drab	Fine, compact	Massive	Uneven, thin to medium	Upper Silurian		1868	31
....do	Medium, crystalline	Irregular	Uneven, thin to thick	Lower Silurian		1876	32
....do	Coarse	....do	Uneven, thin	....do		1876	33
....do	....do	... do	... do	... do		1872	34
....do	....do	....do	Uneven, thin to medium	... do		1857	35
Drab	Medium	Indistinct	Even, thin to thick	Lower Silurian		1864	36
....do	....do	....do	Even, medium to thick	....do		1857	37
Drab and buff	Medium, vesicular	Variable	Even, thin to medium	... do		1871	38
Light gray	....do	Massive	Even, medium	....do		1880	39
Gray	....do	... do	....do	... do		1877	40
Drab	Medium, vesicular	Irregular	Even, medium to thick	Lower Silurian		1867	41
....do	Fine, porphyritic	... do	... do	... do		1880	42
....do	Variable	Massive	Uneven, thin to thick	....do		1880	43
....do	... do	Irregular	Uneven, thin to medium	....do		1860	44
... do	Fine, compact	Massive	Even, thin to medium	....do		1875	45
Drab	Fine, porphyritic	Irregular	Even, thick	Lower Silurian		1857	46
....do	....do	... do	....do	... do		1879	47
....do	Medium, fossiliferous	Massive	Even, medium to thick	....do		1879	48

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

MINNESOTA—CRYSTALLINE SILICEOUS ROCKS.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone.	
				Popular name.	Scientific name.
1	Sauk Rapids	Benton	G. S. Reeder	Granite	Hornblende-biotite granite
2	East Saint Cloud	Sherburne	Breen & Young	...do	Hornblende granite
3	Taylor's Falls	Chisago	Minneapolis and Saint Louis Railroad Co	"Trap"	Olivine diabase

MINNESOTA—MARBLE AND LIMESTONE.

1	Stillwater	Washington	David Prescott	Limestone	Siliceous dolomite and dolomite
2	...do	...do	D. Donahue	...do	...do
3	...do	...do	Ed. McGee	...do	Siliceous dolomite
4	...do	...do	John Conkling	...do	Siliceous dolomite and dolomite
5	Saint Paul	Ramsey	M. Roche	...do	Magnesian limestone
6	Saint Paul	Ramsey	William Zollman	Limestone	Magnesian limestone
7	...do	...do	William Dawson, lessor	...do	...do
8	...do	...do	Breen & Young	...do	...do
9	...do	...do	A. Gotzian	...do	...do
10	...do	...do	William Dawson, lessor	...do	...do
11	Saint Paul	Ramsey	William Dawson, lessor	Limestone	Siliceous magnesian limestone
12	West Saint Paul	...do	Adam Rau	...do	Magnesian limestone
13	Minneapolis	Hennepin	W. W. Eastman	...do	...do
14	...do	...do	Franklin Cook	...do	...do
15	...do	...do	Ole Dahl	...do	...do
16	Minneapolis	Hennepin	Charles Sandhoff	Limestone	Magnesian limestone
17	...do	...do	Weeks & Holscher	...do	...do
18	...do	...do	James Baxter	...do	Magnesian limestone and siliceous dolomite.
19	...do	...do	Foley & Herbert	...do	...do
20	Red Wing	Goodhue	G. A. Carlson	...do	Dolomite
21	Red Wing	Goodhue	R. S. Berglund	Limestone	Dolomite
22	Frontenac	...do	Fosterin & Co	...do	...do
23	Cannon City	Rice	Phillip Cromer	...do	Calcareous dolomite and limestone
24	Kasota	Le Sueur	J. W. Babcock	Sand-rock	Dolomite
25	...do	...do	Breen, Young & Co	...do	...do
26	4 miles north of Mankato	Blue Earth	J. R. Beatty & Co.	Sand-rock	Dolomite
27	Mankato	...do	O. R. Mather	...do	...do
28	...do	...do	J. H. Beatty	Limestone	...do
29	Clinton Falls	Steele	Lindersmith & Son	Lime-rock	Siliceous dolomite
30	Mantorville	Dodge	H. Hook, P. Mantor, A. Doig	Limestone	...do
31	Stockton	Winona	Chicago and Northwestern Railroad Company.	Sand-rock	Dolomite
32	Winona	...do	C. H. Porter	Limestone	...do
33	...do	...do	John O'Dae	...do	...do

MINNESOTA—SANDSTONE.

1	Fond du Lac	Saint Louis	M. Boyle	Sand-rock	Sandstone
2	Hinckley	Pine	Saint Paul and Duluth Railroad	...do	...do
3	Jordan	Scott	Phillip Kipp	...do	...do
4	...do	...do	F. Nicolin	...do	...do
5	Courtland	Nicollet	Fritz Meyerding	Quartzite	Quartzite

IOWA—MARBLE AND LIMESTONE.

1	Lansing	Allamakee	City of Lansing	Limestone	Dolomite, siliceous
2	...do	...do	John Nelson	...do	Dolomite
3	1 mile southeast of Waukon	...do	Frank Sohn	...do	...do
4	½ mile north of Decorah	Winneshiek	D. B. Ellsworth	...do	Magnesian limestone
5	...do	...do	M. Steyer	...do	...do
6	1 mile south of Osage	Mitchell	David Armstrong	Limestone	Dolomite
7	½ mile northeast of Mason city	Cerro Gordo	Poyfeir & Son	...do	Limestone
8	½ mile east of Mason city	...do	A. T. Lien & Brother	...do	Magnesian limestone
9	½ mile southeast of Mason city	...do	J. L. Parker	...do	Dolomite
10	¾ mile northwest of Marble Rock	Floyd	Boone Brothers	...do	Limestone
11	1 mile southeast of Charles city	Floyd	J. S. Trigg	Limestone	Argillaceous-magnesian limestone
12	4 miles northeast of Clermont (Fayette county).	Clayton	E. H. Williams	...do	Siliceous dolomite
13	McGregor	...do	A. C. Boyle	...do	
14	1 mile west of Bristow	Butler	E. Frick	...do	Dolomite
15	Humboldt	Humboldt	C. A. Lonbeer	...do	...do
16	Humboldt	Humboldt	A. B. Snyder	Limestone	Dolomite
17	1 mile southeast of Dakota City	...do	Miner & Howell	...do	...do
18	Fort Dodge	Webster	John Linehon	...do	Magnesian limestone and dolomite
19	1½ miles west of Iowa Falls	Hardin	George W. Chapman	...do	Dolomite
20	Iowa Falls	...do	A. A. Wells & Son	...do	...do

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

MINNESOTA—Crystalline Siliceous Rocks.

Color.	Structure.			Geological age of formation.		Year in which opened.	
	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.		
Dark gray	Medium	Massive	Horizontal and vertical	Archæan		1870	1
Dark gray and red	Fine	do	Irregular	do		1868	2
Black	Medium	do (*a*)	do	Lower Silurian		1880	3

a Two other granites of a different structure and appearance quarried at this place.

MINNESOTA—Marble and Limestone.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Light buff	Medium, vesicular	Irregular	Even, thin to thick	Lower Silurian	Saint Lawrence	1854	1
do	do	do	Even, medium to thick	do	do	1854	2
do	do	do	do	do	do	1857	3
do	do	do	Even thin to medium	do	do	1847	4
Light blue	Fine, semi-crystalline	do	do	do	Trenton	1856	5
Light blue	Fine, semi-crystalline	Irregular	Even, thin to medium	Lower Silurian	Trenton	1856	6
do	do	do	do	do	do	1870	7
do	do	do	Even, thick	do	do	1856	8
do	do	do	Even, thin to medium	do	do	1870	9
do	do	do	Even, medium	do	do	1869	10
Light blue	Fine, semi-crystalline	Irregular	Even, thin to medium	Lower Silurian	Trenton	1858	11
do	do	do	Even, medium	do	do	1871	12
do	Fine, compact	Massive	Even, thick	do	do	1865	13
do	do	Irregular	Even, thin to medium	do	do	1873	14
Light blue and drab	do	Massive	Even, thin to thick	do	do	1879	15
Drab	Fine, compact	Irregular	Even, medium	Lower Silurian	Trenton	1876	16
Light blue	do	do	Even, medium to thick	do	do	1864	17
do	Fine, vesicular	Massive	Even, thin to thick	do	do	1878	18
do	do	Irregular, wavy	Thin to medium	do	do	1879	19
Buff	Fine, vesicular, & compact	Massive	Even, medium to thick	do	Saint Lawrence	1868	20
Light drab	Fine, vesicular, & compact	Massive	Even, thin to thick	Lower Silurian	Saint Lawrence	1868	21
Light gray	Medium, vesicular	do	Even, thick	do	do	1855	22
Drab	Fine, compact	do	Even, thin to thick	do	Trenton	1865	23
Buff	Semi-crystalline, vesicular	Irregular	Even, thick	do	Shakopee	1870	24
do	do	do	Even, thin to medium	do	do	1868	25
Buff	Semi-crystalline, vesicular	Irregular	Even, medium to thick	Lower Silurian	Shakopee	1879	26
do	do	do	Even, thin to thick	do	do	1853	27
do	Fine, semi-crystalline	do	Even, thin to medium	do	do	1854	28
Drab	Fine, compact	do	do	do	Hudson River	1868	29
Light buff	Variable, vesicular	do	Even, medium to thick	do	Galena	1856	30
Light drab	Fine, vesicular	Irregular	Even, thin to medium	Lower Silurian	Saint Lawrence	1876	31
Drab	do	do	Even, thin to thick	do	do	1870	32
do	do	do	Even, thick	do	do	1854	33

MINNESOTA—Sandstone.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Brown	Medium	Massive	Even, thin to thick	Lower Silurian	Potsdam	1870	1
Red	do	do	Even, medium	do	Saint Croix	1870	2
Light gray	Fine, friable	Irregular	Even, thin to medium	do	Jordan	1862	3
do	do	do	do	do	do	1858	4
Red	Fine, compact	Massive	Even, thin to thick	do	Potsdam	1857	5

IOWA—Marble and Limestone.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Light drab	Coarse	Massive	Even, medium thick	Lower Silurian	Potsdam	1880	1
do	Coarse, vesicular	do	do	do	Lower magnesian	1870	2
Mottled gray	Fine, homogeneous	do	Uneven, thin	do	Trenton	1880	3
do	Semi-crystalline, vesicular	Wavy, irregular	Even, thin to medium	do	do	1879	4
do	do	do	Even, medium thick	do	do	1860	5
Bluish gray, mottled, and buff.	Fine, compact, porphyritic	Irregular	Even, medium thick	Devonian	Hamilton	1874	6
Light drab	do	Massive	do	do	do	1872	7
Drab and light drab mottled.	Variable	Massive and irregular	do	do	do	1876	8
Drab with buff tint	Crystalline, compact, and vesicular.	Irregular	do	do	do	1872	9
Dark drab and light buff	Semi-crystalline	Irregular and massive	Even, thick to medium	do	do	1875	10
Drab with buff patches	Semi-crystalline, fossiliferous.	Irregular	Uneven, thin to medium	Devonian	Hamilton	1874	11
Light buff	Vesicular	do	Even, thick to medium	Upper Silurian	Niagara	1854	12
do	Coarse, vesicular	Massive	Uneven, thick	Lower Silurian	Lower magnesian	1872	13
Drab and yellowish drab	Semi-crystalline, porphyritic.	do	Even, medium thick	Devonian	Hamilton	1880	14
Drab mottled with buff	Fine, compact	Irregular	do	Sub-Carboniferous	Kinderhook	1870	15
Drab	Fine, semi-crystalline	Irregular	Uneven, thin	Sub-Carboniferous	Kinderhook	1879	16
Light brown, or olive and drab.	Fine, compact	Massive	Even, thick to medium	do	do	1859	17
Drab	do	Irregular	Uneven, medium to thick	Carboniferous	Lower Coal Measures.	1868	18
Light brown	Porous	Massive	Even, thick	Sub-Carboniferous	Kinderhook	1865	19
do	Variable	do	Even, medium thick	do	do	1854	20

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

IOWA—MARBLE AND LIMESTONE—Continued.

	Location of quarry.	County.	Name of the corporation, company, or individual.	SPECIFIC VARIETY OF STONE.	
				Popular name.	Scientific name.
21	1 mile southeast of Iowa Falls	Hardin	L. L. Kelly	Limestone	Limestone and dolomite
22	Conrad	Grundy	William T. Crealius	do	Limestone
23	1 mile northwest of Waterloo	Black Hawk	William Love	do	Siliceous dolomite
24	Cedar Falls	do	Edwin Carpenter	do	Dolomite
25	¾ mile west of La Porte	do	G. A. Knowles	do	do
26	½ mile east of Independence	Buchanan	James Forrester	Limestone	Limestone
27	3 miles southeast of Manchester	Delaware	Charles A. & S. A. Davis	do	Dolomite
28	1 mile north of Farley	Dubuque	B. N. Arquitte	do	do
29	1 mile east of Farley	do	C. E. De Rome & Co	do	do
30	Dubuque	do	Martin & Strane	do	do
31	do	Dubuque	Speer & Lee	Limestone	Dolomite
32	do	do	Joseph Hug	do	do
33	do	do	William Rebman	do	do
34	do	do	F. W. Kringle	do	do
35	Near Sabula	Jackson	E. A. Woods	do	Ferruginous dolomite
36	4 miles east of Maquoketa	Jackson	A. Connel	Limestone	Ferruginous dolomite
37	Maquoketa	do	Blush, Seaner, Becker & Dunham	do	do
38	½ mile east of Hale	Jones	O. Horton	do	Bituminous dolomite
39	1½ miles south of Hale	do	Solomon & J. N. Garrison and others	do	do
40	1¼ miles southeast of Olin	do	A. Rummel	do	do
41	1¾ miles southeast of Olin	Jones	J. Easterly	Limestone	Bituminous dolomite
42	do	do	William Gordon	do	do
43	1 mile northeast of Monticello	do	J. S. Fuller	do	Dolomite
44	2 miles northwest of Anamosa	do	Iowa State penitentiary	do	do
45	Stone City	do	John A. Green	do	do
46	do	Jones	James & Ronan	Limestone	Dolomite
47	do	do	Henry Dearborn	do	do
48	1½ miles north of Central City	Linn	S. T. Granger	do	
49	½ mile southeast of Mount Vernon	do	D. S. Hahn	do	Dolomite
50	2 miles southeast of Cedar Rapids	do	Three Bohemians	do	
51	1½ miles southeast of Cedar Rapids	Linn	E. J. C. Bealer	Limestone	
52	½ mile south of Vinton	Benton	R. H. Quinn	do	Bituminous limestone
53	3 miles northwest of Vinton	do	Samuel Aungst	do	do
54	¾ mile east of Garrison	do	Kokbrick & Frazer	do	Bituminous limestone and dolomite
55	4½ miles northwest of Garrison	Benton	Stouley & Co	do	
56	1 mile northeast of Le Grand	Tama	Le Grand Quarry Company	Limestone	Magnesian limestone
57	Quarry	Marshall	do	do	Calcareous dolomite and limestone
58	1½ miles north of Dillon	do	do	do	Limestone
59	2, 3, and 4 miles north of Ames	Story	P. R. Craig, R. Coe, and R. Hannum	do	Dolomite
60	3 miles northeast of Earlham	Dallas	Laird & Royce	do	Limestone
61	Iowa City	Johnson	Edward Crowley	Limestone	Siliceous limestone
62	do	do	L. O. Hoffman	do	Dolomite and limestone
63	10 miles north-northwest of Iowa City.	do	Penn Quarry Company and D. A. Schaeffer.	do	Limestone
64	3½ miles south of Mount Vernon	do	John P. McCune	do	Bituminous dolomite
65	3½ miles southwest of Tipton	Cedar	M. Carey and Charles Miller	do	Limestone
66	3½ miles southwest of Tipton	Cedar	Shearer & Gray	Limestone	Limestone and dolomite
67	Rochester	do	Rochester Quarry	do	Limestone
68	Cedar Bluff	do	Cedar Bluff Quarry	do	do
69	5 miles northwest of Wilton	do	Kott & Hornie	do	do
70	4 miles northeast of Dixon	Clinton	J. D. Binford	do	Ferruginous dolomite and bituminous dolomite.
71	2 miles southeast of Grand Mound	Clinton	J. Collenbaugh	Limestone	Ferruginous dolomite
72	Lyons	do	Klaus Nagel	do	do
73	do	do	William Bell	do	do
74	Clinton	do	John Anthony	do	do
75	do	do	Thomas Purcell	do	do
76	8 miles east of Long Grove	Scott	Hans Topp	Limestone	Ferruginous dolomite
77	1 mile north of Le Claire	do	Edward Theleman	do	do
78	Davenport	do	A. C. Fulton	do	Limestone
79	do	do	William L. Cook	do	do
80	1 mile west of Davenport	Scott	E. S. Glaspell	do	do
81	do	do	Heinrich Schmiedt	Limestone	Limestone
82	Buffalo	do	Christian Metzger	do	Calcareous dolomite
83	3 miles northeast of Muscatine	Muscatine	A. M. Hare	do	do
84	3½ miles northwest of Washington	Washington	James Eckles and James Saville	do	Limestone
85	do	do	Minnick & Donovan	do	do

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

IOWA—MARBLE AND LIMESTONE—Continued.

Color.	Structure. Texture.	Structure. Stratification.	Structure. Jointing, bedding, or natural surface.	Geological age of formation. Period.	Geological age of formation. Epoch.	Year in which opened.	
Drab	Variable	Massive	Even, medium to thick	Sub-Carboniferous	Kinderhook	1855	21
Light drab	Granular (oolitic)	Regular	...do	...do	...do	1854	22
Light buff and olive	Fine, semi-crystalline	Irregular	...do	Devonian	Hamilton	1877	23
Drab	...do	Massive	Even, thin	...do	...do	1865	24
...do	Medium, fine and compact	Irregular	Even, medium thick	...do	...do	1856	25
Mottled and light buff	Porphyritic, fossiliferous	Irregular	Uneven, thin	Devonian	Hamilton	1860	26
Pale green and drab mottled.	Semi-crystalline, porous	...do	Uneven, variable thickness	Upper Silurian	Niagara	1866	27
Light drab and buff mottled.	Porous	Even and wavy	Even, medium thick	...do	...do	1860	28
Light drab	Vesicular	Uneven	...do	...do	...do	1878	29
Buff and drab	Semi-crystalline, vesicular	Massive	...do	Lower Silurian	Trenton	1871	30
Buff	Semi-crystalline, vesicular	Massive	Even, medium thick	Lower Silurian	Trenton	1860	31
Buff and drab	...do	...do	...do	...do	...do	1850	32
Mottled drab	Semi-crystalline, vesicular, and porous.	Irregular	Even and thick	...do	...do	1869	33
Buff	...do	...do	Even, medium to thick	...do	...do	1870	34
...do	Finely semi-crystalline	...do	Even, medium thick	Upper Silurian	Niagara	1847	35
Buff	Semi-crystalline and porous.	Massive	Even, medium thick	Upper Silurian	Niagara	1870	36
...do	...do	...do	Even, thick	...do	...do	1860	37
Light buff	Finely crystalline, vesicular.	Even and parallel	Even, thin to medium	...do	...do	1851	38
...do	Porous and vesicular	Wavy	...do	...do	...do	1855	39
...do	...do	...do	...do	...do	...do	1868	40
Light buff	Porous and vesicular	Wavy	Even, thin to medium	Upper Silurian	Niagara	1870	41
...do	...do	...do	...do	...do	...do	1872	42
...do	Porous	Even and parallel	...do	...do	...do	1863	43
Buff	Semi-crystalline and vesicular.	Fine, even, and parallel	Even, medium to thick	...do	...do	1879	44
Light drab	Fine, vesicular	Massive	Even, medium thick	...do	...do	1869	45
Light buff	Fine, homogeneous	Massive	Even, medium thick	Upper Silurian	Niagara	1869	46
Light buff and light drab	Semi-crystalline, vesicular	...do	Even, thick	...do	...do	1869	47
Drab with pink spots	...do	Irregular	Even, medium thick	...do	...do	1880	48
Buff	Fine, porous	Even and massive	Even, thick	...do	...do	1873	49
Drab	Variable	Irregular	Uneven, medium thick	Devonian	Hamilton	1860	50
Drab	Variable	Irregular	Uneven, thick to medium	Devonian	Hamilton	1872	51
Light gray or buff	Semi-crystalline, porous, and compact.	Irregular and massive	Even, medium thick	...do	...do	1861	52
...do	...do	...do	Even, medium to thick	...do	...do	1858	53
Drab and mottled drab	Fine, compact, porphyritic.	Irregular	Even, medium thick	...do	...do	1868	54
...do	Medium and fine	...do	...do	...do	...do	1872	55
Bluish gray	Semi-crystalline, partly oolitic.	Irregular	Even and thick	Sub-Carboniferous	Kinderhook	1866	56
Light drab and buff reddish brown.	Granular	Irregular and massive	Even, medium to heavy	...do	...do	1866	57
...do	...do	Massive	Even and thick	...do	Keokuk	1876	58
Drab and buff	Fine, compact	...do	Uneven, medium thick	...do	Saint Louis	1862	59
Light drab	Semi-crystalline, fossiliferous.	...do	Even, medium thick	Carboniferous	Upper Coal Measures.	1872	60
Plain and mottled drab	Semi-crystalline	Irregular	Heavy bedded	Devonian	Hamilton	1869	61
Light and dark drab	Compact and semi-crystalline.	Massive	...do	...do	...do	1868	62
Pinkish gray	Semi-crystalline, porous	Irregular	...do	...do	...do	1844	63
Light buff	Fine, finely porous	Even and massive	Even and thick	Upper Silurian	Niagara	1848	64
...do	Vesicular	Even and parallel	Even, medium thickness	...do	...do	1865	65
Light buff	Vesicular	Even and parallel	Even, medium thick	Upper Silurian	Niagara	1868	66
...do	...do	...do	Even, medium thickness	...do	...do	1875	67
...do	...do	...do	...do	...do	...do	1855	68
...do	...do	...do	...do	...do	...do	1853	69
Light buff and dark buff	Semi-crystalline and porous	Even and massive	Even, thin to medium	...do	...do	1840	70
Light buff and dark buff	Semi-crystalline and porous	Even and massive	Even, medium thickness	Upper Silurian	Niagara	1865	71
Deep buff	Finely semi-crystalline and vesicular.	Irregular	Even, medium to thick	...do	...do	1865	72
...do	...do	...do	Even, medium thickness	...do	...do	1870	73
...do	...do	...do	Even, medium to thick	...do	...do	1864	74
...do	...do	...do	...do	...do	...do	1858	75
Light buff	Finely semi-crystalline	Massive	Even, medium thickness	Upper Silurian	Niagara	1861	76
...do	...do	...do	Even, variable thickness	...do	...do	1877	77
Drab	Vesicular, conchoidal fracture.	Wavy	Uneven, thick to medium	Devonian	Hamilton	1873	78
Mottled drab	Semi-crystalline, fossiliferous.	Irregular and massive	Uneven, thin to medium	...do	...do	1848	79
...do	...do	Massive	Uneven, medium thickness	...do	...do	1866	80
Light mottled drab	Semi-crystalline, fossiliferous.	Massive	Uneven, thin to medium	Devonian	Hamilton	1871	81
Bluish-gray mottled	Porphyritic and fossiliferous.	Irregular	Uneven, medium thickness	...do	...do	1857	82
Drab	Semi-crystalline	...do	Uneven, medium thick	...do	...do	1860	83
Light gray and buff	Granular and highly crystalline.	Massive	Even, thin to medium	Sub-Carboniferous	Saint Louis	1858	84
...do	...do	...do	Irregular, thin to medium	...do	...do	1855	85

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

IOWA—MARBLE AND LIMESTONE—Continued.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone. Popular name.	Scientific name.
86	Near Brighton	Washington	Brighton Quarries	Limestone	Limestone
87	Sigourney	Keokuk	Rowland Pilkington	do	do
88	3 miles north of Sigourney	do	William S. Booton	do	do
89	1 mile south of Given	Mahaska	Francis Castles	do	Ferruginous and siliceous limestone
90	4 miles north-northeast of Pella	Marion	F. C. Mathes	do	Limestone
91	2½ miles northwest of Durham	Marion	C. C. Collins	Limestone	Bituminous limestone
92	1½ miles southwest of Tracy	do	Regan Brothers & McGorrisk	do	Limestone
93	3 miles northwest of Knoxville	do	J. Johnson	do	Siliceous limestone
94	½ mile south and southeast of Winterset.	Madison	G. W. Hetzler	do	Limestone
95	do	do	T. F. Mardis	do	do
96	Winterset	Madison	City of Winterset	Limestone	Limestone
97	6 miles southwest of Winterset	do	W. H. Lewis	do	do
98	2 miles east of Earlham	do	Regan Brothers & McGorrisk	do	do
99	2½ miles east of Earlham	do	Robertson & Willoughby	do	do
100	Carson	Pottawattamie	Charles Törneböhm	do	do
101	Macedonia	Pottawattamie	Miles Quarry	Limestone	Limestone
102	1 mile southwest of Macedonia	do	Sylvester Dye	do	do
103	Crescent City	do	Crescent City Quarry	do	
104	Stennett	Montgomery	Wayne Stennett	do	Limestone
105	Near Corning	Adams	Law & Oak (2 quarries)	do	Siliceous limestone
106	5 miles northwest of Osceola	Clarke	F. J. Dean	Limestone	
107	½ mile south of Chillicothe	Wapello	Samuel Strawn	do	Limestone
108	4 miles northwest of Ottumwa	do	S. L. Wiley Construction Company	do	do
109	3 miles northwest of Ottumwa	do	Chilton & Kendall	do	do
110	3 miles west of Ottumwa	do	James Kelly	do	do
111	2½ miles west of Ottumwa	Wapello	B. W. Jeffries	Limestone	Limestone
112	Ottumwa	do	Thomas Rogers	do	do
113	do	do	John Pasneu	do	do
114	Dudley	do	Beckwith & Winters	do	do
115	5 miles west of Fairfield	Jefferson	Saul Stieber	do	Micaceous limestone
116	5 miles west of Fairfield	Jefferson	J. Ziegler	Limestone	Micaceous limestone
117	1½ miles south of Mount Pleasant	Henry	Beckwith & Winters	do	Limestone
118	do	do	John Rukgaber	do	do
119	2 miles south of Mount Pleasant	do	Patrick O'Connor	do	do
120	Burlington	Des Moines	—— Hüsling	do	do
121	Burlington	Des Moines	Hoppman Bros. (2 quarries)	Limestone	Limestone
122	Keokuk	Lee	Miscellaneous	do	Dolomite
123	do	do	Patrick Tigue	do	do
124	do	do	James McNamara	do	
125	4 miles northeast of Franklin	do	Charles Graner	do	Ferruginous dolomite; also limestone.
126	Bentonsport	Van Buren	G. W. Jack	Limestone	Limestone
127	6 miles west of Keosauqua	Van Buren	Jacob Creasy	do	do
128	Bedford	Taylor	H. W. Greenleo	do	do

IOWA—SANDSTONE.

1	4 miles northeast of Muscatine	Muscatine	John Starke	Sandstone	Sandstone
2	3 miles northeast of Muscatine	do	A. M. Hare	do	do
3	¾ mile southwest of Lewis	Cass	Jehu Woodward	do	Ferruginous sandstone

MISSOURI—CRYSTALLINE SILICEOUS ROCKS.

1	Knob Lick	Saint François	Allen & Smith	Granite	Hornblende granite
2	4 miles west of Iron Mountain	Iron	Philip Schneider & Co	do	Granite

MISSOURI—MARBLE AND LIMESTONE.

1	City of Saint Louis	Saint Louis	Moran's Quarry	Limestone	Dolomite
2	do	do	Daniel Caveuagh	do	do
3	do	do	Tim Evans	do	do
4	do	do	Joseph Webber	do	Limestone
5	do	do	Michael Kinealy	do	Dolomite limestone
6	City of Saint Louis	Saint Louis	James McGrath	Limestone	Dolomite limestone
7	do	do	A. O. Engelmann & Co	do	Dolomite
8	do	do	Diederich Schariughaus	do	Magnesian limestone and limestone
9	do	do	Jos. O'Meara & Brother	do	
10	do	do	William Gorman	do	

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

IOWA—MARBLE AND LIMESTONE—Continued.

Color.	Structure.			Geological age of formation.		Year in which opened.	
	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.		
Drab	Not homogeneous	Massive	Variable	Carboniferous	Lower Coal Measures.	1870	86
Light drab	Fine, compact, and porous	Massive and irregular	Even and thin	Sub-Carboniferous	Saint Louis	1861	87
...do	...do	...do	Even, thin to medium	...do	...do	1874	88
Buff	Porous	Massive	Even, medium thickness	...do	...do	1870	89
Light drab	Granular and porous	...do	Even, thick to medium	...do	...do	1856	90
Light drab	Granular and porous	Massive	Even, medium thick	Sub-Carboniferous	Saint Louis	1880	91
Light and dark drab	Compact and porous	...do	...do	...do	...do	1880	92
Dark gray	Coarse, semi crystalline	...do	Uneven, thick to medium	...do	...do	1862	93
Light drab	Granular, fossiliferous	...do	Uneven, medium thick	Carboniferous	Upper Coal Measures.	1860	94
...do	...do	...do	...do	...do	...do	1878	95
Light drab	Granular, fossiliferous	Massive	Even, thick to medium	Carboniferous	Upper Coal Measures.	1860	96
...do	...do	...do	Even and thick	...do	...do	1876	97
Light and dark drab	Semi-crystalline	Irregular	Even, medium thick	...do	...do	1869	98
...do	...do	Massive	...do	...do	...do	1873	99
Light drab	Semi-crystalline and porphyritic.	Irregular	...do	...do	...do	1880	100
Light drab	Semi-crystalline and porphyritic.	Irregular	Even, medium thick	Carboniferous	Upper Coal Measures.	1878	101
...do	...do	...do	Uneven, medium thick	...do	...do	1856	102
...do	...do	...do	Even, medium thick	...do	...do	1879	103
...do	Granular	Massive	Even and thick	...do	...do	1880	104
Light drab and buff	Semi-crystalline, fossiliferous.	...do	Even and thin	...do	...do	1860	105
Gray	Fine, homogeneous	Massive	Even, thin	Carboniferous	Upper Coal Measures.	1874	106
Mottled drab	Semi-crystalline	Irregular	Even and thin	Sub-Carboniferous	Keokuk	1879	107
Drab	Granular	Massive	Even, thin to medium	...do	...do	1877	108
Mottled drab	Semi-crystalline	Irregular	Even and thin	...do	...do	1879	109
Drab	Granular	Massive	Even, medium thick	...do	...do	1863	110
Mottled drab	Semi-crystalline	Irregular	Even, thin to medium	Sub-Carboniferous	Keokuk	1871	111
...do	...do	...do	Even and thin	...do	...do	1877	112
...do	...do	...do	Even, medium thickness	...do	...do	1880	113
Light drab and mottled drab.	...do	...do	Uneven, medium thickness	...do	...do	1866	114
Bluish gray and reddish gray.	Coarse, compact	Massive	Medium thick	...do	Saint Louis	1872	115
Bluish gray and reddish gray.	Coarse, compact	Massive	Medium thick	Sub-Carboniferous	Saint Louis	1878	116
Light drab and buff	Semi-crystalline, porous	...do	Medium, even thickness	...do	Keokuk	1855	117
...do	...do	...do	Even, variable thickness	...do	...do	1866	118
...do	Semi-crystalline	...do	Medium thick	...do	...do	1877	119
Light drab and mottled gray.	Variable	...do	Medium thickness	...do	Burlington	1867	120
Light drab and mottled gray.	Granular	Massive	Heavily bedded	Sub-Carboniferous	Burlington	1867	121
Olive gray	Variable	...do	Uneven, medium thick	...do	Keokuk	1857	122
...do	Porous and compact	Uneven	Even and thick	...do	...do	1866	123
Gray	Coarse, porous	Irregular	Uneven, medium thick	...do	...do	1857	124
Buff and light drab	Porous	Massive	Even, medium thick	...do	...do	1837	125
Light and dark gray	Semi-crystalline, fossiliferous.	Irregular	Even, medium to thick	Sub-Carboniferous	Keokuk	1856	126
Drab	Semi-crystalline, finely granular.	Even, oblique	Even and thick	...do	Saint Louis	1850	127
Buff	Semi-crystalline	Massive	Even, thick	Carboniferous	Upper Coal Measures.	1857	128

IOWA—SANDSTONE.

Dark brown	Coarse, friable	Coarse, oblique	Thick	Carboniferous	Coal Measures	1860	1
...do	...do	...do	...do	...do	...do	1876	2
...do	...do	Massive	Medium, thick	Cretaceous		1871	3

MISSOURI—CRYSTALLINE SILICEOUS ROCKS.

Gray and red	Medium	Massive	Parallel and vertical	Archæan		1872	1
Red	Coarse	...do	...do	...do		1873	2

MISSOURI—MARBLE AND LIMESTONE.

Drab	Fine, fossiliferous	Massive	Even, medium to thick	Sub-Carboniferous	Saint Louis	1875	1
...do	Fine, compact	Even and wavy	...do	...do	...do	1866	2
...do	Medium, fossiliferous	Massive	...do	...do	...do	1879	3
...do	Fine, compact	...do	...do	...do	...do	1875	4
...do	Fine, fossiliferous	...do	Medium thick	...do	...do	1875	5
Drab	Medium, semi-crystalline	Massive	Even, medium to thick	Sub-Carboniferous	Saint Louis	1845	6
...do	Fine, fossiliferous	Irregular	...do	...do	...do	1871	7
...do	...do	...do	...do	...do	...do	1875	8
...do	...do	...do	...do	...do	...do	1875	9
...do	...do	Massive	...do	...do	...do	1872	10

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

MISSOURI—MARBLE AND LIMESTONE—Continued.

	Location of quarry.	County.	Name of the corporation, company, or individual.	Specific variety of stone.	
				Popular name.	Scientific name.
11	City of Saint Louis	Saint Louis	Hugh Carlin	Limestone	Limestone
12	....do	....do	Bowdern & Chs. Hogan	....do	....do
13	....do	....do	Bambrick & Morihan	....do	....do
14	....do	....do	Schrainka & Veiths	....do	....do
15	....do	....do	Philip F. Stifel	....do	Dolomite
16	City of Saint Louis	Saint Louis	Henry Perkinson	Limestone	Limestone
17	....do	....do	John McKenna	....do	....do
18	....do	....do	John Bowdern & Son	....do	....do
19	....do	....do	J. O'Meara	....do	....do
20	....do	....do	Gottleib Eyermann	....do	Dolomite
21	Rosedale	Saint Louis	Nicholas Lamb	Limestone	Limestone
22	Jefferson City	Cole	H. W. Kolkmyer	....do	Siliceous dolomite and dolomite
23	Boonville	Cooper	Russell Quarry	....do	Limestone
24	Sedalia	Pettis	Richard Anderson, lessee of Smith's quarry	....do	Magnesian limestone; also dolomite
25	4 miles south of Clinton	Henry	C. B. Jordan	Flag-stone	Argillaceous limestone
26	East of Kansas City	Jackson	John Bauman	Limestone	Magnesian limestone
27	Bluffs of Kansas City	....do	James Dowling	....do	Limestone

MISSOURI—SANDSTONE.

1	Miami Station	Carroll	White Rock Quarry Company	Sandstone	Sandstone (calcareous)
2	Warrensburg	Johnson	Bruce & Veitch	....do	....do
3	....do	....do	Pickle Brothers	....do	
4	Clinton	Henry	Gebhardt Quarry	....do	
5	4 miles southwest of Sainte Genevieve.	Sainte Genevieve	Sainte Genevieve Sandstone and Granite Company.	....do	

KANSAS—SANDSTONE.

1	7 miles west of Fort Scott	Bourbon	Gilfillan Brothers	Sandstone	Sandstone (calcareous)
2	4 miles southwest of Pawnee	Crawford	Pawnee Flagstone Company	....do	....do

KANSAS—MARBLE AND LIMESTONE.

1	Bigelow	Marshall	H. F. Gallagher	Limestone	Limestone
2	Frankfort	....do	Joseph Wilson	....do	....do
3	Atchison	Atchison	Reddington & Co	....do	....do
4	Manhattan	Riley	Ulrich Brothers	....do	....do
5	Topeka	Shawnee	Mulvane & Higginbotham	....do	Dolomite and limestone
6	2 miles from Dunlap	Morris	Wolf, Pickens & Co	Limestone	Magnesian limestone
7	Lane	Franklin	Hanway Brothers	....do	Limestone
8	3 miles east of Cottonwood	Chase	L. W. Lewis	....do	....do
9	2 miles east of Cottonwood	....do	Tweeddale & Parker	....do	Magnesian limestone
10	Cottonwood	....do	Emslie & Rettiger	....do	....do
11	1 mile west of Cottonwood	Chase	Lantry & Burr	Limestone	Limestone
12	Marion Center	Marion	Groat Brothers	....do	Dolomite
13	Florence	....do	A. F. Horner	....do	Magnesian limestone
14	Augusta	Butler	J. C. Haines	....do	Magnesian and siliceous limestone
15	Fort Scott	Bourbon	W. L. Wilkinson	....do	Magnesian limestone and limestone
16	2 miles east of Winfield	Cowley	Charles Schmidt	Limestone	Siliceous and bituminous limestone
17	2½ miles southeast of Winfield	....do	Hodges, Moore & Co	....do	Limestone

CALIFORNIA—CRYSTALLINE SILICEOUS ROCKS.

1	Penryn	Placer	Griffith Griffiths	Granite	Hornblende-biotite granite
2	Petaluma	Sonoma	John Codden & Bros. and others	Basalt	Basalt

WASHINGTON TERRITORY—CRYSTALLINE SILICEOUS ROCKS.

1	Wilkeson	Pierce	Northern Pacific Railroad Company	Granite	

WASHINGTON TERRITORY—SANDSTONE.

1	Belligham Bay	Whatcom	C. Seidel & Co	Sandstone	

NEBRASKA—MARBLE AND LIMESTONE.

1	Roca	Lancaster	Keys & Bullock	Limestone	Limestone

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

MISSOURI—Marble and Limestone—Continued.

Color.	Structure.			Geological age of formation.		Year in which opened.	
	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.		
Drab	Fine, semi-crystalline	Massive	Even, medium to thick	Sub-Carboniferous	Saint Louis	1864	11
do	Fine, fossiliferous	do	do	do	do	1860	12
do	Fine, compact	do	do	do	do	1878	13
do	Fine, semi-crystalline	do	do	do	do	1850	14
do	Fine, fossiliferous	Irregular	Even, thick	do	do	1873	15
Drab	Fine, semi-crystalline	Massive	Even, medium to thick	Sub-Carboniferous	Saint Louis	1860	16
do	Fine, fossiliferous	do	Medium, thick	do	do	1860	17
do	do	do	Even, medium thick	do	do	1875	18
do	Fine, semi-crystalline	do	do	do	do	1845	19
do	Fine, compact	Irregular	do	do	do	1850	20
Drab	Fine, fossiliferous	Irregular	Medium, thick	Sub-Carboniferous	Saint Louis	1878	21
Light drab	Fine, vesicular	Massive	Even, thin to medium thick	Lower Silurian	Potsdam	1870	22
Dark drab	Medium, fossiliferous	do	Even, medium thick	Sub-Carboniferous	Saint Louis	1856	23
Brown and drab	do	do	Even, thick	do	Burlington	1866	24
Dark drab	Fine, compact	Even and wavy	Even, thin to medium	Carboniferous	Lower Coal Measures.	1878	25
Gray	Granular, fossiliferous	Massive	Uneven, medium to thick	Carboniferous	Upper Coal Measures.	1869	26
Drab	Fine, fossiliferous	do	Thin to medium	do	do	1865	27

MISSOURI—Sandstone.

Light gray	Medium	Massive	Thick	Carboniferous	Lower Coal Measures.	1839	1
Gray	do	do	Even, thick	do	do	1871	2
do	do	do	do	do	do	1871	3
Light brown	do	do	Uneven, thick	do	do	1877	4
Light buff	Fine	do	Even, thick	Sub-Carboniferous	Chester	1869	5

KANSAS—Sandstone.

Light gray	Fine	Massive	Even, thin to medium	Carboniferous		1866	1
Greenish	Medium	do	Even, medium	do		1880	2

KANSAS—Marble and Limestone.

Light drab	Variable	Irregular	Even, medium	Permian		1870	1
do	Coarse, vesicular	Massive	do	do		1874	2
Drab	Fine	Irregular	do	Carboniferous		1870	3
Buff	Coarse, vesicular	Massive	Even, thick	Permian		1865	4
Drab	Fine, fossiliferous	do	Uneven, thick	Carboniferous		1870	5
Light drab	Medium, vesicular	Irregular	Even, thin to thick	Permian		1878	6
Gray and buff	Medium, oolitic, & vesicular	do	Uneven, thin to thick	Carboniferous		1878	7
Light drab	Medium, fossiliferous	Massive	Uneven, thick	Permian		1880	8
do	Fine, fossiliferous	do	Even, medium to thick	do		1879	9
do	Medium, fossiliferous	do	Even, thick	do		1873	10
Light drab	Coarse, vesicular	Massive	Even, thick	Permian		1878	11
do	Medium, vesicular	do	Even, thin to thick	do		1880	12
do	do	Irregular, wavy	do	do		1875	13
do	do	Massive	Even, medium to thick	do		1880	14
Dark drab	Fine, semi-crystalline	Irregular, wavy	Even, thin to medium	Carboniferous		1879	15
Light drab	Fine, vesicular	Even, parallel	Even, thin to medium	Permian		1880	16
do	do	Irregular, wavy	Even, thick	do		1877	17

CALIFORNIA—Crystalline Siliceous Rocks.

Black, dark gray, and white	Medium	Massive	Vertical	Archæan		1864	1
Dark gray	Fine	do	Irregular	do		1864	2

WASHINGTON TERRITORY—Crystalline Siliceous Rocks.

Dark gray	Fine	Massive	Irregular	Archæan		1879	1

WASHINGTON TERRITORY—Sandstone.

Greenish gray	Medium	Massive	Uneven, thick	Carboniferous		1872	1

NEBRASKA—Marble and Limestone.

Drab	Medium	Massive	Even, thick	Permian		1870	1

TABLE IV.—TABLES INDICATING THE AMOUNT AND KINDS

DAKOTA—SANDSTONE.

	Location of quarry.	County	Name of the corporation, company, or individual.	Specific variety of stone.	
				Popular name.	Scientific name.
1	Sioux Falls	Minnehaha	George Boardman	Quartzite	Quartzite

COLORADO—VOLCANIC ROCKS.

1	Castle Rock	Douglas	B. Hammer	Eruptive rock	Rhyolite
2	2½ miles from Castle Rock	....do	G. F. Girardot	... do	... do
3	Douglas	....do	S. W. Madge	....do	....do

COLORADO—SANDSTONE.

1	7 miles southwest by west of Fort Collins.	Larimer	E. B. Yont	Sandstone	
2	Morrison	Jefferson	Garfield & Co	... do	
3	2½ miles south of Morrison	....do	A. H. Garfield & Co	....do	

OF ROCKS QUARRIED IN THE DIFFERENT STATES.

DAKOTA—SANDSTONE.

Color.	Structure. Texture.	Structure. Stratification.	Structure. Jointing, bedding, or natural surface.	Geological age of formation. Period.	Geological age of formation. Epoch.	Year in which opened.	
Reddish purple	Fine, compact	Massive	Even, medium	Lower Silurian		1872	1

COLORADO—VOLCANIC ROCKS.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Gray	Vesicular	Massive	Irregular			1878	1
Drab	....do	....do	....do			1877	2
Gray	Fine	....do	....do			1875	3

COLORADO—SANDSTONE.

Color.	Texture.	Stratification.	Jointing, bedding, or natural surface.	Period.	Epoch.	Year in which opened.	
Gray	Medium	Even, parallel	Even, thin to medium	Cretaceous		1871	1
White	Fine	Massive	Even, thick	Jurassic		......	2
Red	....do	Irregular	Uneven, thin	....do		......	3

TABLE V.—SHOWING THE EXTENT OF STONE CONSTRUCTION IN

	City.	State.	NUMBER OF STONE BUILDINGS.				NUMBER OF BUILDINGS OF THE DIFFERENT CLASSES OF STONE, WITH LOCATION OF QUARRIES.					
							Sandstone chiefly.		Marble or limestone chiefly.		Granite or crystalline siliceous rocks.	
			Total.	Entirely of stone.	With stone fronts only.	Percentage of all buildings.	No.	Location of quarry.	No.	Location of quarry.	No.	Location of quarry.
1	Akron	Ohio	24	11	13	0.75	24	Akron and Berea				
2	Albany	N. Y.	125	13	112	0.76	115	Connecticut brownstone	1	Trenton	4	Maine
3	Allegheny	Pa	45	15	30	5.34	40	Freeport, Pa., Massillon, Ohio.				
4	Allentown	Pa	15	12	3	0.37	1	Pennsylvania	14	Vicinity		
5	Altoona	Pa	10	3	7	0.30	10	Vicinity and Amherst, Ohio.				
6	Amsterdam	N. Y.	22	20	2	1.83	17	Amsterdam	5			
7	Atlanta	Ga	8	3	5	0.11					8	Stone mountain and vicinity.
8	Auburn	N. Y.	77	25	52	1.75	1	Connecticut	76	Vicinity		
9	Baltimore	Md	229	28	201	0.38	85	Connecticut, New Jersey, and Ohio.	178	Maryland and Virginia	31	Maryland, Virginia, and Maine.
10	Bangor	Me	10	3	7	0.42					10	Frankfort and Penobscot islands.
11	Binghamton	N. Y.	5	5		0.13			5	Syracuse		
12	Boston	Mass	771	93	678	1.50	346	Connecticut valley, New Jersey, Ohio, and provinces.	68	Vermont	312	Concord, cape Ann, and Chelmsford.
13	Bridgeport	Conn	39	16	23	0.87	27	Portland			12	Greenwich
14	Buffalo	N. Y.	86	51	35	0.33						
15	Burlington	Iowa	100	95	5	2.00	1	Amherst, Ohio	99	Burlington		
16	Cambridge	Mass	14	13	1	0.17	1	Nova Scotia	1	Roxbury	11	Quincy and Rockport.
17	Camden	N. J	35	20	15	0.40	10	Trenton and Connecticut	16	Vermont		
18	Canton	Ohio	35	4	31	1.33	35	Massillon				
19	Cedar Rapids	Iowa	7		7	0.28			7	Stone City		
20	Charleston	S. C.	8	1	7	0.11	8	Connecticut				
21	Chattanooga	Tenn	4	1	3	0.14			3	Vicinity	1	Georgia
22	Chelsea	Mass	4	2	2	0.125	2	Vicinity			2	Cape Ann
23	Chester	Pa	30			1.00					30	Vicinity
24	Chicago	Ill	5,003	453	4,550	5.00	500	Ohio and Michigan	4,500	Cook county and Rutland, Vt.	2	Maine
25	Chillicothe	Ohio	8	7	1	0.40	8					
26	Cincinnati	Ohio	2,500	100	2,400	8.00	1,499	Portsmouth	1,000	Cincinnati, Dayton, and Indiana.	1	Maine and Missouri
27	Cleveland	Ohio	250	170	80	0.78	249	Amherst, Independence, and Euclid.	1	Sandusky		
28	Columbus	Ohio	40	10	30	0.43	34	Berea, Waverly, Black Lick, and Sugar Grove	6	4 miles west of Columbus		
29	Concord	N. H.	6	6		0.24					6	Concord
30	Cumberland	Md	8	6	2	0.50	8	Vicinity				
31	Davenport	Iowa	50	30	20	1.14	2		48	Davenport, Buffalo, Le Claire, and Stone City.		
32	Dayton	Ohio	125	25	100	1.64	50	Portsmouth and Berea	75	Dayton		
33	Denver	Colo	50	12	38	0.83					8	Castle Rock
34	Derby	Conn	12	12		0.65					12	Ansonia and Birmingham.
35	Des Moines	Iowa	12	2	10	0.27			12	Earlham, Pella, and Tracy.	1	Sauk Rapids, Minn., Iron Mountain, Mo., Grundy and Buchanan counties.
36	Detroit	Mich	75	15	60	0.27	60	Amherstburg, Essex county, Ontario, and Berea, Ohio.	15	Trenton and Kelley's island, Ohio.		
37	Dubuque	Iowa	200	150	50	4.00			200	Dubuque and Farley, and Nauvoo, Ill.		
38	Easton	Pa	35	20	15	1.40	15	New Jersey and Pennsylvania.	10	Vicinity		
39	Elizabeth	N. J	15	3	12	0.27	15	Newark and Belleville				
40	Elmira	N. Y.	15	3	12	0.37	2	Vicinity	1	Syracuse		
41	Erie	Pa	5	4	1	0.13	2	Medina and Amherst	3	Dorset, Vt		
42	Evansville	Ind	100	1	99	1.66			100	Ellettsville and Bedford		
43	Fall River	Mass	67	50	17	1.09					45	Fall River
44	Fitchburg	Mass	4	2	2	0.19					4	N. H. and Fitchburg
45	Fort Wayne	Ind	5	2	3	0.17	1	Amherst, Ohio	4	Joliet, Ill., Wabash		
46	Galveston	Tex	102		102	3.40					102	Conn
47	Gloucester	Mass	10	6	4	0.33					10	Gloucester
48	Grand Rapids	Mich	12	3	9	0.19	9	Buena Vista and Amherst, Ohio, and Ionia county, Mich.	3	Vicinity		
49	Hamilton	Ohio	8	3	5	0.25	5	Near Portsmouth, Ohio.	3	Hamilton		
50	Harrisburg	Pa	17	13	4	0.28	6	York and Lancaster counties and Hummelstown.	10	Texas, Maryland, and Cumberland county, Pa.	1	Bluehill, Me., and near Richmond, Va.
51	Hartford	Conn	136	36	100	1.94	112	Portland	9	East Canaan	15	Westerly, R. I., and Glastonbury.
52	Haverhill	Mass	16	1	15	0.64						
53	Indianapolis	Ind	234	9	225	1.59	7	Portsmouth, Ohio	227	Indiana		
54	Ithaca	N. Y.	15	15		0.60	15	Vicinity				
55	Janesville	Wis	10	5	5	0.30			10	In city		

SOME OF THE PRINCIPAL CITIES OF THE UNITED STATES.

Stone employed for foundations.	Stone pavements. Street. Extent used.	Stone pavements. Street. Location of quarries.	Stone pavements. Sidewalk. Extent used.	Stone pavements. Sidewalk. Location of quarries.	Stone commonly used for curb.	
Sandstone	Little	Medina	Largely	Berea, Ohio	Sandstone	1
Limestone	Largely	New England	do	Hudson river	Blue-stone	2
Sandstone	do	(Cobble-stone) Allegheny river.	Considerable	Allegheny and Fayette counties.	Sandstone	3
Lime and mountain stone.	Little	(Cobble-stone) river	Little	Lehigh and Wyoming valleys and North river.	Limestone	4
Sandstone and conglomerate.	Largely	(Cobble-stone) streams	do	Eastern Pennsylvania	Sandstone	5
Limestone			Largely	Vicinity	Limestone	6
Granite and gneiss	10 miles	Stone mountain and vicinity (macadamized).	One-half	Stone mountain and vicinity	Granite	7
Limestone	Little	Medina	Largely	East bank Cayuga lake	Sandstone	8
Gneiss	About three-fourths	Baltimore county and Jones' falls and vicinity.	do	Rondout, N. Y	Gneiss	9
Slate and bowlders	Little	Mount Desert, islands of Penobscot.			Granite	10
Limestone			Largely	Pennsylvania		11
Granite, slate, and Roxbury stone.	67 miles	Quincy, Bergen Hill, N. J., Rockport, Me.	do	North river. Rockport, Bolton, Conn., and Quincy.	Granite and blue-stone	12
Gneiss	Little	New Haven	Considerable	North river	Blue-stone and gneiss	13
	Largely	Medina	Largely	Medina	Sandstone	14
Limestone	Little	Vicinity	Little	Sagetown, Ill., and Mount Pleasant.	Limestone, Sagetown, Ill., and Mt. Pleasant.	15
Slate, diabase, and granite.	100 miles	Quincy	do	Hudson river	Granite and blue flag-stone.	16
Gneiss	Largely	Connecticut	do	Williamsport, Pa	Granite	17
Sandstone	Considerable	Vicinity	Considerable	Berea, Ohio	Sandstone	18
Limestone			Little	Stone City	Limestone, Stone City and Farley.	19
			Largely	New York	Blue-stone	20
Limestone	Largely macadamized.	Vicinity	Little	Vicinity	Limestone	21
Granite	Little	Cape Ann and Quincy			Granite	22
Gneiss	do	(Cobble-stone) Delaware river.	Little	North river	Gneiss	23
Limestone	2 miles paved, 25 miles macadamized.	Waterloo, Wis., Lockport, N. Y., and other parts of New York.	36 miles	Lemont, Cook county	Limestone, Lemont	24
Sandstone	Little	Vicinity			Sandstone	25
Limestone	Largely	(Cobble) vicinity	Largely	Vicinity of Portsmouth	Limestone	26
Sandstone	do	Medina	do	Euclid and Newburgh	Sandstone	27
Corniferous limestone	Considerable	Vicinity	do	Columbus, Berea, and Waverly.	Corniferous limestone	28
Granite	Little	Concord	Little		Granite	29
Sandstone	Largely	(Bowlders) Potomac river	do	Southampton, Pa	Sandstone	30
Limestone	Largely macadamized	Davenport	Little	Stone City and Joliet	Limestone and sandstone, Stone City and Joliet, Ill.	31
do	Largely	Dayton	Largely	Dayton	Limestone	32
Rhyolite and sandstone			Little	Fort Collins		33
Gneiss			do	North river	Blue-stone and gneiss	34
Limestone	Little macadamized	River gravel	do	Joliet, Ill	Limestone, Joliet, Ill., Earlham and Pella.	35
Limestone	Little	Medina	Largely	Cleveland and Euclid, Ohio, and Medina, Mich.	Limestone, Medina	36
do	5 % paved, balance macadamized.	Dubuque	Little	Stone City and Farley, and Joliet, Ill.	Limestone, Dubuque, Stone City, and Farley.	37
do	Little	(Cobble-stone) Delaware river.	do	Meshoppen	Limestone	38
Brownstone	Largely	Hudson river and New England.	Largely	North river	Blue-stone	39
Sandstone	Two blocks	Medina	Little	Trumansburg	do	40
Sandstone	Largely	Medina	Little	Euclid, Ohio	Sandstone	41
Limestone	Little	Vanderburgh county	Largely	Bedford and North Vernon	do	42
Granite	do	Freetown	Little	North river, N. Y	Granite	43
do	do	Fitchburg			do	44
Limestone	do	Wabash	Little	Berea, Ohio, and Joliet, Ill	Limestone	45
Sandstone, limestone, and granite.	Little	Cobble, ship ballast	Little	Connecticut, England, and Germany.	Limestone, sandstone, and granite.	46
Syenite	do	Gloucester			Syenite	47
Bowlders and some limestone.	do		Little	Lemont and Joliet, Ill., and Cayuga county, N. Y.	Limestone, Joliet, Ill	48
Limestone	do	(Cobble) vicinity	do	Hamilton	Limestone	49
do	do	(Cobble) Susquehanna river.	do	Hoboken, N. J	Brownstone and granite	50
Sandstone	Largely	Southwest of Hartford	Largely	North river and Bolton	Gneiss and blue-stone	51
Granite	Little	Cape Ann			Granite	52
Limestone	do	(Bowlders) vicinity	Largely	Decatur county	Limestone	53
Sandstone			do	Vicinity	Blue-stone	54
Limestone	3 miles	In city	1½ miles	In city	Limestone	55

TABLE V.—SHOWING THE EXTENT OF STONE CONSTRUCTION IN

	City.	State.	Number of stone buildings.				Number of buildings of the different classes of stone, with location of quarries.					
			Total.	Entirely of stone.	With stone fronts only.	Percentage of all buildings.	Sandstone chiefly.		Marble or limestone chiefly.		Granite or crystalline siliceous rocks.	
							No.	Location of quarry.	No.	Location of quarry.	No.	Location of quarry.
66	Johnstown	Pa	10	2	8	0.27	9	Connecticut valley and vicinity of Johnstown.				
57	Joliet	Ill	500	300	200	10.00			500	Vicinity		
58	Kansas City	Mo	95	15	80	1.00	70	Warrensburg, Carroll county, and Barnard, Kans.	25	Junction City, Kans		
59	Keokuk	Iowa	18	12	6	0.75	3	Sonora, Ill	9	Vicinity		
60	Kingston	N. Y	54	50	4	1.47	1	Vicinity	36	do		
61	La Crosse	Wis	20	12	8	0.57			20	East of city		
62	La Fayette	Ind	7		7	0.33			7	Bedford, Ind		
63	Lancaster	Pa	21	15	6	0.41	2	Lancaster county	16	Vicinity and Montgomery county.		
64	Lawrence	Mass	5	5		0.10					4	Concord, N. H
65	Leavenworth	Kans	3	3		0.09			3	Leavenworth		
66	Lockport	N. Y	280	185	101	7.50	150	Vicinity	35	Vicinity		
67	Logansport	Ind	60	50	10	3.75			60	Logansport		
68	Louisville	Ky	400	25	375	1.92	40	Portsmouth, Ohio	360	Bowling Green, Ky., and Bedford, Ind.		
69	Lowell	Mass	46	43	3	0.51	34	Lowell	1	Rutland, Vt	11	Concord, N. H., and Westford.
70	Lynn	Mass	28	5	23	0.41					6	Cape Ann and Peabody
71	Madison	Wis	76	48	28	4.00	73	3 miles west of city and Indiana.	3	Bridgeport and Westport, Ind.		
72	Manchester	N. H	3	1	1	0.10						
73	Mansfield	Ohio	3	1	2	0.15	3					
74	Memphis	Tenn	10	2	8	[illegible]	2	Ohio and Alabama	7	Alabama and Kentucky.	1	
75	Middletown	Conn	21	14	7	1.05	20	Portland			1	Haddam
76	Minneapolis	Minn	242	224	18	3.18	1	Fond du Lac	241	Minneapolis and Lemont, Ill.		
77	Mobile	Ala	1	1		0.02					1	Massachusetts
78	Nashua	N. H	3	3		0.11					3	Nashua
79	Nashville	Tenn	97	7	90	1.24	4		93	Bowling Green, Ky		
80	New Albany	Ind	15	3	12	0.45	2	New Albany	13	Salem		
81	Newark	N. J	216	76	140	1.05	210	Newark and Ohio	6			
82	New Bedford	Mass	25	22	3	0.57					22	Rockport, Quincy, and vicinity.
83	New Brunswick	N. J	11	11		0.31	9	Newark and Connecticut			1	New York
84	Newburgh	N. Y	13	10	3	0.36	1	Kingston	12	Vicinity and Ulster county.		
85	Newburyport	Mass	2	2		0.10	1	Springfield			2	Cape Ann
86	New Haven	Conn	09	27	42	0.63	59	Portland, East Haven, and Ohio.	1		9	Long island, East and West Rocks.
87	New London	Conn	18	14	4	1.05	2	Portland	1		15	New London and Groton.
88	Newport	R. I	40	30	10	1.33	14				25	Newport
89	Newton	Mass	7	7		0.22	5	Ohio and Massachusetts.			2	Westford
90	Norristown	Pa	35	30	5	1.34	28	Pottstown and vicinity of Norristown.	7	Montgomery county	7	
91	North Adams	Mass	6	6		0.30	2		3	Adams		
92	Northampton	Mass	4	2	2	0.21	2	Longmeadow, Mass., and Portland, Conn.				
93	Norwich	Conn	14	6	8	0.42	10	Portland and Ohio			4	Massachusetts and vicinity.
94	Ogdensburg	N. Y	260	250	10	13.00	2	Ohio	258	Vicinity		
95	Orange	N. J	25	25		0.50	22	Orange			3	Orange
96	Oshkosh	Wis	5		5	0.14	1	Marquette	4	Vicinity		
97	Oswego	N. Y	55	51	4	1.28	46	Oswego and vicinity	2	Onondaga county	2	Vicinity
98	Paterson	N. J	50	50		0.68	50	Little Falls and Paterson				
99	Pawtucket	R. I	6	5	1	0.33	1	Nova Scotia			5	Vicinity
100	Petersburg	Va	3	1	2	0.05	2	Connecticut			1	Dinwiddie county
101	Philadelphia	Pa	10,518	6,000	4,518	6.25	3,518	Connecticut, Trenton, N. J., Ohio, and Hummelstown.	2,500	Montgomery county, Massachusetts, and Vermont.	3,500	Quincy, cape Ann, Mass., Fox island, Me., New Hampshire, Rhode Island, Virginia, and Philadelphia, and Delaware county, Pa.
102	Pittsburgh	Pa	90	30	60	0.34	81	Pennsylvania, Massillon, Ohio, Baden, Homewood, and Freeport.	2	Lemont, Ill		
103	Pittsfield	Mass				0.25			3	New York state and Sheffield.	2	Longmeadow and Quincy.
104	Portland	Me	30	10	20	1.00	10	Nova Scotia	1	Vermont	19	Hallowell, Biddeford, vicinity of Portsmouth.
105	Portsmouth	N. H	4	4		0.13					4	

SOME OF THE PRINCIPAL CITIES OF THE UNITED STATES—Continued.

Stone employed for foundations.	Stone pavements. Street. Extent used.	Street. Location of quarries.	Sidewalk. Extent used.	Sidewalk. Location of quarries.	Stone commonly used for curb.	
Sandstone	Largely	(Cobble-stone) streams			Sandstone	56
Limestone			Largely	Vicinity	Limestone in vicinity	57
....do	Principal streets, also macadamized.	Medina, N. Y	Little	Winfield, Fort Scott, Florence, Kans., and Joliet, Ill.	Limestone, Kansas City.	58
....do		•	....do	Vicinity	Limestone in vicinity	59
Flagging	Little		60 miles	Kingston, Ulster, and Hurley	Blue-stone	60
Limestone	2 miles	East of city	Little	East of city	Limestone	61
....do	Little	(Bowlders) vicinity	....do	Greensburg	....do	62
....do	Largely	Vicinity	Largely	Wyoming county	Dolerite	63
Granite	....do	Cape Ann and Westford	Little	Cape Ann	Granite	64
Limestone	....do	Vicinity	....do	Fort Scott (near)		65
Limestone	Little	Medina	Little	Vicinity	Sandstone	66
....do	....do	(Bowlders) vicinity	Largely	Southern Indiana	Limestone	67
....do	Largely	Louisville	Little	Bowling Green	....do	68
Granite	....do	Westford, Mass., and Concord, N. H.	....do	Westford	Granite	69
....do	Considerable	Cape Ann			....do	70
Sandstone	Considerable	Vicinity	Little	Joliet, Ill., and Ohio	Sandstone	71
						72
Sandstone	Largely	Vicinity	Largely	Warren	Sandstone	73
	15 miles	Illinois, Kentucky, Alabama, and Tennessee.	Little	Alabama	Limestone	74
Sandstone			Largely	Haddam and Meromas	Gneiss	75
Limestone	Little	Cobble, from drift	Little	Joliet, Ill., and vicinity of Minneapolis.	Limestone, Minneapolis.	76
	Business portion partly paved and macadamized.	Ballast, foreign vessels			Limestone	77
Granite	¼ mile	Nashua	Little		Granite	78
Limestone	Largely macadamized.	Vicinity	....do	Vicinity	Limestone	79
Limestone	Largely	New Albany	Little	New Albany and North Vernon.	Limestone	80
Sandstone	....do	Hudson river and New England.	Largely	Ulster county	Blue-stone	81
Granite	....do	Vicinity	....do	North river, N. Y	Granite	82
Sandstone	....do	West Connecticut	....do	....do	Blue-stone	83
Limestone	2 miles	Cobble-stone, vicinity	....do	Ulster county	....do	84
Granite	Little	Maine			Granite	85
Trap and sandstone	Largely	East and West Rocks	Little	North river and Bolton	Blue-stone and granite.	86
Bastard granite	Little	Groton	Principal streets	North river	Granite	87
Granite	....do	Block island and Nova Scotia.	Little	Hudson river	....do	88
Wallstone			....do	Westford	....do	89
Sandstone	Little	Quincy	Considerable	North river	Granite, gneiss	90
Limestone	Chiefly on Eagle street		One block		Blue-stone, limestone, and quartzite.	91
Sandstone	Little		Little	Smith's Ferry	Granite	92
Talcose	....do		Largely	North river	Blue-stone	93
Limestone		Potsdam and Hammond	Little	Potsdam	Potsdam and limestone	94
Sandstone	Little	Vicinity	Largely	Ulster county	Blue-stone	95
Limestone			Less than ¼ mile	Fond du Lac, Joliet, Ill		96
Sandstone	Little	Vicinity	Little	Cayuga	Sandstone and limestone	97
....do	Largely	....do	25 miles	North river and Sullivan county.	Blue-stone	98
Blue and red slate	Little	Diamond Hill	Little	Hudson river	Granite and blue-stone.	99
Granite	....do	(Cobble) vicinity	....do	Petersburg	Granite	100
Limestone and gneiss	Largely	(Cobble) Delaware river, (rubble) local, Richmond and eastern granite.	Main streets in old portion of city.	North river and Wyoming valley.	Granite	101
Sandstone	....do	(Cobble) Allegheny river.	Considerable	Allegheny and Fayette counties.	Sandstone	102
			One-half of business streets.	Catskill	Blue flagging	103
Ledge stone	Largely	Yarmouth, Hallowell, Fox island, and east Maine.	Little	Hudson river	Granite	104
Granite	Little	Sea-shore			....do	105

TABLE V.—SHOWING THE EXTENT OF STONE CONSTRUCTION IN

	City.	State.	Number of stone buildings.				Number of buildings of the different classes of stone, with location of quarries.					
			Total.	Entirely of stone.	With stone fronts only.	Percentage of all buildings.	Sandstone chiefly.		Marble or limestone chiefly.		Granite or crystalline siliceous rocks.	
							No.	Location of quarry.	No.	Location of quarry.	No.	Location of quarry.
106	Portsmouth	Ohio	5		5	0.24	5	Vicinity				
107	Pottsville	Pa	50	49	1	1.89	47	Trenton, N. J., Connecticut and vicinity.				
108	Poughkeepsie	N. Y	24	5	19	0.96	16	Ohio and Portland	3	Westchester county	5	Vicinity
109	Providence	R. I	100	65	35	0.64	35	Connecticut, Nova Scotia, and New Jersey.	2	Tuckahoe, N. Y	59	Smithfield, Quincy, Westerly, Cranston, and Providence.
110	Quincy	Ill	100	20	80	2.00	28	Cleveland and Berea, Ohio, Warrensburg, Mo.	72	Vicinity		
111	Quincy	Mass	7	7		0.40					7	Quincy
112	Racine	Wis	4	3	1	0.08	1	Lake Superior	3			
113	Reading	Pa	40	20	20	0.44	20	Vicinity				
114	Richmond	Ind	20		20	0.50	20	Berea, Ohio				
115	Richmond	Va	5	4	1	0.05					5	Vicinity and Massachusetts.
116	Rochester	N. Y	197	146	51	1.13	31	Ohio and Medina	100	Vicinity	2	
117	Rockford	Ill	100	100	10	1.66			100	....do		
118	Rock Island	Ill	3	3		0.07			3	Rock Island		
119	Rome	N. Y	9	5	4	0.50	3	Verona, N. Y	3	Onondaga and Oneida counties.		
120	Saint Joseph	Mo	15		15	0.23	15	Warrensburg, Mo				
121	Saint Louis	Mo	1,525	105	1,420	3.22	903	Warrensburg and Sainte Genevieve, Mo., and Carroll county.	610	Saint Louis, Grafton, Joliet, and Chicago, Ill.	12	Missouri
122	Saint Paul	Minn	344	324	20	4.91	3	Kasota	336	Saint Paul and Frontenac.		
123	Salem	Mass	7	5	2	0.18	1	Springfield			4	Cape Ann and Peabody
124	Salt Lake	Utah	40	30	10	0.62	37	Red Buttes, Albany county, Wyoming Territory.			3	
125	Sandusky	Ohio	200	180	20	6.25	20	Amherst	180	City quarries		
126	San Francisco	Cal	29	4	25	0.08	4	New Castle island, B. C., and Angel island.			24	China and Placer county.
127	Saratoga Springs	N. Y	8	8		0.40			8	Vicinity		
128	Savannah	Ga	2	2		0.04					2	Massachusetts
129	Schenectady	N. Y	4	3	1	0.16	4	Vicinity				
130	Scranton	Pa	14	4	10	0.17	12	Catskill mountains and Luzerne county.	2	Syracuse, N. Y		
131	Springfield	Ill	16	5	11	0.27	5	Amherst, Ohio, and vicinity of Springfield.	10	Joliet and Springfield	1	Virginia
132	Springfield	Mass	12	8	4	0.19	6	Longmeadow			6	Monson
133	Springfield	Ohio	25	5	20	0.63	1	Near Portsmouth	24	Springfield and Dayton		
134	Steubenville	Ohio	12	2	10	0.50	12	Steubenville				
135	Taunton	Mass	10	8	2	0.33	5	Vicinity			3	Acushnet
136	Terre Haute	Ind	100		100	1.92			100	Ellettsville and Bedford		
137	Toledo	Ohio	12	4	8	0.12	10	Amherst and Berea	2	Sandusky		
138	Topeka	Kans	750	700	50	12.50	12	Warrensburg, Mo	738	Cottonwood, Junction City, Cowley county, and Topeka.		
139	Trenton	N. J	95	71	24	1.46	95	Greensburg and Ohio				
140	Troy	N. Y	738	8	730	9.71	716	Portland and Connecticut.			7	Niskayuna
141	Utica	N. Y	27	10	17	0.39			6	Utica and Trenton		
142	Waterbury	Conn	5	4	1	0.17	1	Portland			4	Plymouth granite, county and vicinity.
143	Watertown	N. Y	24	22	2	0.96			24	City		
144	Wheeling	W. Va	16	4	12	0.31	10	Vicinity				
145	Wilkesbarre	Pa	16	6	10	0.34	12	Luzerne county and Meshoppen.	4	Syracuse, N. Y		
146	Williamsport	Pa	12	10	2	0.32	12	Hummelstown and vicinity.				
147	Wilmington	Del	22	10	12	0.26	9	Connecticut, Ohio, and New Jersey.	5	Cockeysville and Texas, Md.	6	Brandywine creek
148	Winona	Minn	10	10		0.59			10	Winona		
149	Woonsocket	R. I	20		2	1.33	2			Woonsocket		
150	Worcester	Mass	24	10	14	0.33	5	Longmeadow			19	Fitzwilliam, N. H
151	Yonkers	N. Y	6	2	4	0.19	4	Ohio and Portland			2	Vicinity
152	York	Pa	8	3	5	0.29	6	York county and Connecticut valley.	2	York	1	Richmond, Va
153	Zanesville	Ohio	12	4	8	0.36	9	Zanesville	3	Zanesville		

1. Serpentine has been used for building stone to a limited extent in a few of the above cities, but its importance is not sufficient to warrant giving it a place in the table. It may be mentioned that in the cities of Baltimore, Md., Wilmington, Del., Camden, N. J., Pottsville and Lancaster, Pa., there are a few buildings of this material, while in Philadelphia the number is estimated at 1,000.
2. For cities of New York and Washington, see detailed tables in the text.

SOME OF THE PRINCIPAL CITIES OF THE UNITED STATES—Continued.

Stone employed for foundations.	Stone pavements. Street. Extent used.	Stone pavements. Street. Location of quarries.	Stone pavements. Sidewalk. Extent used.	Stone pavements. Sidewalk. Location of quarries.	Stone commonly used for curb.	
Sandstone	Little		Little	Vicinity	Freestone	106
Conglomerate			Considerable	...do	Conglomerate	107
Limestone	Little		Largely	North river	Blue-stone	108
Cranstone stone and slate	16 miles	Diamond Hill, Westerly, Connecticut, and Maine.	Little	Hudson river and cape Ann.	Granite	109
Limestone	Largely	Vicinity	...do	Lemont and Joliet	Limestone	110
Syenite					Syenite	111
Limestone	Little	Racine	Little	Joliet, Ill		112
Limestone and sandstone			...do	Hudson river	Limestone and blue flag.	113
Limestone			...do	New Paris, Ohio	Limestone	114
Granite	Business streets	(Cobble) near Richmond	...do	Lynchburg, and Rondout, N. Y.	Granite	115
Limestone	Largely	Albion	Largely	Albion	Blue-stone	116
...do	...do	Vicinity	Little	Vicinity	Limestone, Joliet	117
...do	Macadamized	Rock Island	...do	Joliet	Limestone, Rock Island.	118
Limestone and sandstone	Little		Largely	Cayuga, Chenango, and Hudson river.		119
Limestone	Macadamized	4 miles north of city	Little	Cottonwood Falls, Kans	Limestone, 4 miles north of city.	120
Limestone	Largely macadamized	Saint Louis and southeast Missouri.	Little	Saint Louis and Joliet, Ill	Limestone, Saint Louis	121
...do	Little		Considerable	Saint Paul	Limestone, Saint Paul	122
Granite	Considerable	Cape Ann and Maine			Granite	123
Sandstone and granite						124
Limestone	Little		Largely	City quarries	Limestone	125
Granite rubble	4½ miles	Sonora and Penryn	Little	Folsom and Vermont	Granite	126
Limestone	Largely		Business streets	North river and Vermont	Blue-stone and marble	127
	Business streets	Cobble, ballast from vessels, and New York.	Little	Hudson	Flag-stone	128
Sandstone	Largely	Glenville	Largely	Helderberg		129
Seral conglomerate	Little	(Cobble-stone) vicinity	Considerable	Lehigh and Susquehanna counties.	Sandstone	130
Limestone			Largely	Joliet	Limestone, Joliet and Alton.	131
Sandstone	Macadamized with trap	Westfield	Little	Hudson river and Monson	Sandstone and gneiss	132
Limestone	Little	Springfield	...do	Springfield and Dayton	Limestone	133
Sandstone	... do	(Cobble-stone) Ohio river	... do	Steubenville	Sandstone	134
Wallstone	... do	Fields in vicinity	... do	Acushnet	Granite	135
	Largely	Spencer	Largely	Bedford and Ellettsville	Limestone	136
Limestone	Little	Medina	Little	Berea and Euclid	Sandstone and limestone	137
...do			.. do	Osage county and near Fort Scott.	Limestone, Safford	138
Sandstone	Little	Lambertville	Considerable	North river	Blue-stone	139
Shale	Largely	Clark's island, Me	Largely	Hudson river	...do	140
Sandstone	Largely	Medina and Hammond	Largely	Cayuga and Hudson river	Sandstone	141
Granitic rock			One-half of principal streets.	North river	Blue-stone, North river.	142
Limestone			Little	Watertown	Limestone	143
Sandstone	Largely	(Cobble) Ohio river	...do	Buena Vista	Sandstone	144
Red sandstone	Little	(Cobble) Susquehanna river.	Largely	Vicinity	Red sandstone	145
Sandstone	Little	Vicinity	Little	Meshoppen	Slaty and conglomerate.	146
Granite	One-third of streets	...do			Granite	147
Lime-rock			Little	Winona	Lime-rock, Winona	148
Granite and mica-schist	Little	Vicinity and Massachusetts.	...do	Hudson river	Granite, gneiss	149
Gneissoid granite	Main business streets	Fitzwilliam, N. H.	Business streets	Local and Fitzwilliam, N. H	Gneiss	150
Trap and gneiss	Little	Tomkins Cove	Largely	North river	Blue-stone	151
Limestone	Largely	Vicinity	Little	York county	Brown sandstone	152
Sandstone	...do		Considerable	Berea	Blue limestone and sandstone.	153

CHAPTER VI.—DESCRIPTIONS OF QUARRIES AND QUARRY REGIONS.

GENERAL REPORT ON THE BUILDING STONES OF RHODE ISLAND, MASSACHUSETTS, AND MAINE.

BY PROFESSOR N. S. SHALER.

In the following report I propose to give a short general account of the geological conditions in which the building stones of these states occur, with some remarks on the conditions that have retarded or favored the development of quarrying industry within their limits. This discussion will not include any matters of a purely scientific character, nor will it have to do with the statistical matters presented in the tables. The end in view will be the presentation of the most important facts connected with the quarrying industries that have not been made clear in the statistical reports.

GENERAL CONDITIONS OF THE BUILDING STONES OF NEW ENGLAND.

It is a fact well known to geologists that the New England peninsula, or the region east of the Hudson and of lake Champlain, has a more varied geological structure than is found in any other region of equal area within this continent. In the manifold nature of its geological elements it more nearly resembles the territory of old England than that of the rest of America. As the possible variety of the building stones in any country depends upon the number of kinds of rock that appear at the surface of the earth, this variety in the geological structure of New England has exercised a beneficial influence on the quarrying industry within its bounds. A much greater variety of rocks is quarried within its limits than in any other equal area of America. The greater part of these quarry products is derived from the very ancient rocks which owe their utility to the extensive metamorphism to which they have been subjected by the action of heat and pressure. Nearly all the rocks in this region have lost their original character, being much denser and more crystalline, and are frequently penetrated by joints and cleavage planes that at certain places and for certain purposes are a great advantage to the quarryman.

The following list of native quarried stones used in New England for building will give an idea of the variety of materials existing within this area. In the list the distinctly-bedded rocks which have been but little changed from their original condition are given first; below these the more highly metamorphosed materials. Considerable as this list is, it affords but an inadequate idea of the actual variety of these materials, inasmuch as it is not possible to set out in such a list the lesser differences that often serve greatly to alter the appearance and the use of particular stones. Moreover the purposes to which the stone is applied are often too numerous to be set forth in such a brief statement.

LIMESTONES.

WHITE MARBLE.—Ranging from qualities only a little less perfect than that of Carrara to blotched and variegated stone; used for building stone and the various minor constructural and ornamental purposes to which such stone is usually applied.

RED MARBLE.—Mostly used for building purposes and for table-tops, floors, etc.

BLACK MARBLE.—For inlay work, floors.

All the limestones that are quarried in New England are crystalline in their texture and are tolerably free from admixture of clay or magnesia; they are therefore all available for making lime and are largely used for this purpose. In their distribution they follow somewhat peculiar conditions. They are most abundant in western New England; *i. e.*, the western parts of Connecticut, Massachusetts, and Vermont, yet they appear again in considerable abundance on the eastern face of this region. In Rhode Island north and east of Providence occur large areas of limestone, probably belonging to the Lower Coal Measures or the sub-Carboniferous limestone, and in eastern Massachusetts, in the counties of Middlesex and Essex, some small areas of crystalline limestone of Archæan age occur, but not in sufficient quantities to afford a basis for industries. On the coast of Maine we have very important deposits of limestone that afford the basis for the largest industry in lime-making that has been developed within an equal area in the United States; but the physical conditions of the rock do not favor the quarrying of building or ornamental stones at this point.

None of these limestones are well suited for road-making materials, as their distinct crystalline structure causes them to shatter and fall into a powdery state beneath the wheels.

I estimate the area occupied by workable limestones in New England at not exceeding about 500 square miles; in Massachusetts, Rhode Island, and Maine the area is less than 200 square miles.

SANDSTONES AND CONGLOMERATES.

These rocks occupy an area considerably more extensive than that occupied by the limestones; it probably amounts to not less than 800 square miles of surface in all New England, and in Massachusetts, Rhode Island, and Maine includes about 600 square miles of area. The varieties and uses are approximately as follows:

FINE-GRAINED, REDDISH, AND BROWN SANDSTONES.—Used for flagging and the external walls of houses principally the latter.

CONGLOMERATES AND COARSE GRITS.—Used only for external walls.

Of these building stones the first group is very limited in extent, being confined to the immediate vicinity of the Connecticut river, between the northern part of Massachusetts and the mouth of the stream. The greater part of the material is composed of very uniform sand, in which oxide of iron is plentifully mingled. The material, quarries easily and works well under the chisel and the hammer; its endurance to weathering is, however, but slight in the variable climates of the northern United States, yet, on account of the ease with which these stones are worked and their very rich color, they have come into very extensive use in all the eastern cities north of Virginia. There are lighter colored and more flag-like stones of this same series that occur most abundantly in the region near Turner's Falls. These beds have been, at various times, worked for sidewalk flags, yet their use has not been large; it is from the rocks of this age and character that the foot-prints of various amphibians have been so plentifully obtained.

The conglomerates of New England have a very wide extension, but only in a few regions have they been worked to any extent. The only region where an extensive quarrying industry has been based upon them is in the neighborhood of Boston, Massachusetts. They are the building stones most accessible to that city, and so have come into very extensive use for wall work in buildings of a costly character. This stone is extremely durable and of a handsome reddish-yellow or gray color. Owing, however, to the infrequency of the joints in the rock the process of dressing is costly, the stone being perhaps the most expensive of any that has ever come into considerable use in this country. Its peculiar pebbly structure makes it singularly unsuitable for ornamental purposes, as it cannot be worked into any other than a flat surface. Except in Rhode Island, where the inferior carboniferous conglomerate is somewhat used for rough walling, the neighborhood of Boston is the only place where conglomerate has been extensively used for any building purposes; indeed we may say that conglomerates have been more generally used there than in any other city, European or American.

SLATES AND CLAY-STONES.

This group of rocks is very abundantly developed in New England, and has been made the basis of very extensive industries. The area occupied by workable rocks of this class is probably not less than 1,500 square miles in all New England, and perhaps exceeds 700 square miles in the states especially considered in this report. This group of very argillaceous rocks is to be divided into the two classes of slates proper and clay-stones on the basis of the relative fissility of the material given by the joints or cleavage planes. The slates proper are affected by true cleavage, and are almost indefinitely divisible by the cleaving-tools of the quarrymen. The clay-stones have only a jointed structure and are not indefinitely divisible in this fashion. The following are in brief the uses of these two stones:

CLAY-SLATES.—Used for roofing slates, billiard and other table tops; chimney mantels (with or without artificial overfalls); flagging stones, school slates, bath-tubs, wash-tubs, etc.

CLAY-STONES OR ARGILLITES.—Used only for wall work. The geographical distribution of these slates and clay-stones is rather peculiar; they occur in one form or another over all parts of New England, yet the area of the deposits of workable quality is small and widely scattered. Of true slates Massachusetts has no workable deposits that have yet been discovered, and I think it very unlikely that any will be found; none are known in Rhode Island, though it is not impossible that both there and in Connecticut available deposits may yet be found. In Vermont and in Maine there are large areas of good roofing slates, and their development has been the basis of extended industries. The clay-slates have only been occasionally used, principally for road material and rough, dry walls. About Boston there are some quarries that have recently been used as sources of building material for churches and other large edifices. As yet, however, this class of stones has been much neglected. The first quarries in this country, certainly the first in Massachusetts, were opened in stones of this description. These are the quarries in Neponset, formerly Milton. The material was used for grave-stones, mile-stones, and, to a small extent, for flagging. (See second part of this report.)

HIGHLY METAMORPHOSED ROCKS.

Under this head I shall, for convenience, include all those rocks that have lost their original character by fusion or by a very complete metamorphism. The classification has no other merit than convenience. First in importance among these is:

GRANITIC ROCKS.—Used for a great variety of constructive and ornamental work.

SCHISTOSE ROCKS (GNEISS AND MICA SCHIST).—Little used for building save for rough walls. No important industries resting upon them.

TRAPPEAN ROCKS.—Very little used save for road material.

SERPENTINES AND STEATITES (VERD-ANTIQUES AND SOAPSTONES).—Extensively used, particularly the latter, for stoves, chimney-guards, etc.

This group of highly metamorphic rocks makes up the greater part of New England; perhaps three-quarters of its whole surface is composed of them, but the several kinds are found in very different proportions. The granitic group occupies several thousand square miles, and the schistose group an even larger area; the trappean rocks are found almost everywhere in small masses penetrating through the other groups of rocks, while the steatites and serpentines occupy the least area of any of the New England rocks, their whole surface not exceeding a few square miles.

The granitic rocks of workable quality lie principally in the eastern parts of New England, and are found in their best shape along the coast of Rhode Island and the coast-lines of Massachusetts and Maine. They are the cores or centers of old mountain ranges which have been worn down to their very bases, principally by the long-continued action of the sea and the glaciers of the ice times. Some excellent granites and syenites occur also in the New Hampshire district and in central Maine. Although the granitic rocks of Scotland afford some ornamental varieties that are more beautiful than those of New England, I know of no region in the world where this class of rocks can be found in greater abundance or in more workable forms than here. It is possible in several of the syenite quarries of Massachusetts to break a single block from the quarry that shall have a length of 150 feet, a depth of 10 feet, and a width of 30 feet, the whole mass without a flaw.

The schistose rocks of this district, like those in other countries, have few qualities that fit them for any architectural purpose, and the same may be said of the trappean rocks. These old lavas in this district are invariably characterized by the presence of many joints that tend to make them cleave in various directions. These joints are readily opened by the weather, and so the rock crumbles into small polygonal blocks. This material is used only for road material, for which use the ease with which it is fractured and the great hardness of the ultimate masses peculiarly fit it. The large amount of iron oxide it contains also serves to bring about cementation of the macadamized material in the road-bed.

In the serpentines and steatites of New England we have the foundation of some small but interesting industries which promise a very great development in the future. In Massachusetts the most important localities for this class of materials are near the west end of Hoosac tunnel, and in the eastern part of the state between Lynnfield and Newburyport. At both these points a little work has been done in former years, but bad management shipwrecked the works before they obtained any considerable development.

It now remains to notice a class of building materials which has not been considered in the preceding list, viz: The drift or glacial bowlders that abound in New England. If we consider the whole of the existing walls in New England, those used for fencing as well as those in the more important foundation walls of the wooden or masonry buildings of the region, we shall find that at least 95 parts of the whole are composed of this glacial waste. Sometimes the stones, where the work is to be bound with mortar, are riven with wedges so as to give a better face for the attachment of the cement; usually, however, the stones are used without any such precaution. I know of no other district where these rude stones have been of as great service in the rough economic architecture of a country, although this use of glacial pebbles is common in other parts of America and in the glacial districts of Europe, from the lands of Scotland to the valley of the Po.

A GENERAL ACCOUNT OF THE DEVELOPMENT OF THE QUARRY INDUSTRIES OF THE DISTRICT.

Whoever has made himself acquainted with the singularly great variety of the building stones that exist in New England must in the end be surprised at the limited extent to which those resources have been applied to the arts of the country. Although the finest quarries in the country exist within its limits, there are fewer masonry houses in proportion to its wealth and population than in any other region of like extent in the world. By far the larger part of the houses are of wood, and when stone is used, save in the larger cities, it is unwillingly taken as a building material, and is generally brought from a distance, though better sorts may be close at hand. Thus in Cambridge, Massachusetts, a city of 60,000 people and of very considerable wealth, there are but a dozen stone buildings, and none in which the material has been made the basis of any considerable ornamentation. In other words, there is but one stone building to each 5,000 inhabitants. There is not a single dwelling-house of stone, not more than a few hundred of brick, and these generally of a very inferior sort. Despite its considerable cost and perishable nature, timber has remained the principal building material for dwelling-houses and shops. In the university that owns the best edifices of the city, out of about thirty important buildings only five are of stone, the rest being of brick; yet within 10 or 12 miles of the place there are many beautiful building stones, some of which have been known for half a century.

This neglect of stone as a building material may be understood after a little consideration of the history of architecture in New England. The first settlers of this country brought little wealth with them, and a love for architectural effect was the least of their pretensions. Until the rapid development of mechanical industries at the beginning of this century wealth did not begin to accumulate, or the culture to take on a type favorable for the development of a taste in architecture. During the first two centuries timber was the natural material for construction; it was by far the cheapest material, and required the least skill for its working. Wherever architecture develops, as it had to develop here, in a plentifully-wooded country the first stage of its progress gives us purely wooden edifices. All or nearly all the earliest Christian churches north of the Alps were of timber, and the houses of the common people were of the same material down to the time when timber became scarce. It is the opinion of many students of architecture that the original types of the Greek temples were also built of wood. The continuance of wood as the principal building material in New England was favored by the fact that during the first two centuries after the settlement of this country the people found themselves exposed to earthquakes of considerable severity. Those of 1685, 1727, and 1755 were of such force that, happening at the present day, they would do no small damage to masonry buildings. Many hundred chimneys in Boston were overturned. It is not unlikely that these shocks had some effect in causing the people to adhere more firmly to the old fashion of building. But the conservatism of art, in nothing so manifest as in architecture, will sufficiently explain the retention of ancient methods in the architecture of New England. During the seventeenth and eighteenth centuries there were positively no beginnings made in quarrying industries. The only quarries I have been able to trace back to the eighteenth century are some few of clay-stones near Boston. These were very small, and only furnished a part of the grave-stones, a few lintels, and a few mile-stones. Stones for cellar walls were obtained from the glacial bowlders, which were used either in their natural state or after being riven with wedges. Even down to the time of the Revolutionary war a considerable part of the grave-stones and masonry blocks were still brought from the mother country, probably as ballast in vessels that carried away timber or fish to Europe.

The first New England stones abundantly quarried were the syenites near Boston and the sandstones of the Connecticut valley. These stones began to come into considerable use in the second decade of this century. As yet these kinds of stones, with the various deposits of slate and marble that occur in Vermont and Maine, afford the only quarry materials extensively produced. The advance made in their development has been very great, and is likely to continue for a long time to come. In the present state of wealth and of taste the demand for building stones is taking other directions from those which of old led to the working of the few materials that have been brought in use. The syenites that have hitherto satisfied the needs of simple strength and cheapness in architecture have little variety of color, and an intense hardness that quite unfits them for the ordinary uses of the decorative architect. There is needed a wider range of stones for use in the decorative parts of our buildings, which shall contribute to embellishment in either of two ways: by means of their attractive colors, or by having a constitution that fits them for the use of the carver who may work them into embellishments. In the following pages I propose to call attention to the various sources of supply whence these qualities of stone may be obtained, as far as they have become known to me during the inquiries which have been made during the present census year or in the twenty years during which I have been a student of New England geology. These resources will for convenience be enumerated under the heads of the several states. It should be noted that these lists are not in any regard exhaustive accounts of materials suited for building stones, but only designate varieties and localities as far as they have found a place in my note-books or in those of my assistants, Messrs. Davis, Wolff, and Chase.

RHODE ISLAND.

The only stones of this state that have attracted my attention are the syenites, conglomerates, and limestones. The quarries in the syenites of Westerly are among the best of New England, the excellent quality of the stone being one element of their success, another being the advantageous position that these quarries occupy with reference to New York and other large markets of the sea-coast. On the point of land south of Bristol other syenites occur, distinguished by the amethystine nature of the quartz they contain. They have never been quarried for exportation, but they seem to me to offer a promising field for inquiry. North of Providence there are some crystalline limestones that are extensively worked for lime. Although these limestones have their mass extensively rent by joints, as is the case with all the limestones known to me in New England east of the Connecticut river, they may with proper search disclose some beds sufficiently free from this defect to give building stones, or at least stones suitable for certain particular uses in architecture. This region affords the best promise of such results of any known to me near the Atlantic coast.

The conglomerates of the Coal Measures are extensively developed in Rhode Island, but they have never been to any extent used for building purposes. Although they vary much in the different localities where they appear, they are generally as well fitted for architectural purposes as the similar but more ancient deposits near Boston. These rocks are abundantly exposed near Providence and at various points along the shores of Narragansett bay, whence they could be readily conveyed by ships or barges, or by rail to Boston. They seem to me to invite experiment.

MASSACHUSETTS.

In this state the variety of unused stones is very great. In the group of granite rocks a fair amount of search has been given to the field; yet some classes of this group have been entirely neglected. The blue-gray Quincy syenite having first established its reputation, all subsequent search has been given to the finding of stones sufficiently like it to command the same market. This search has been so well rewarded that at half a dozen other points in Massachusetts good syenites of the same grade have been found, while other and handsomer stones have been passed by. These other granitic rocks occur at various points, but I shall only mention one district which seems to me to offer a profitable field for inquiry. In the ranges of hills which lie to the west of Boston, extending from Melrose through Arlington to Dedham, there exists a great variety of reddish and yellowish blotched granites or syenites that have never been quarried, and are only known to me by chance sections. I am satisfied that these stones can be found in workable masses, and, though they want that evenness of grain that makes the Quincy syenites and other similar rocks so easy to work, I believe they can be quarried without undue expense. I am sure that when polished their extremely effective colors will give them a high place among our decorative stones.

In this connection and on the same field I may note the existence of a large area of porphyrites. This field extends from Malden through Saugus and Lynn to Marblehead. These stones are as handsome and as varied in hue as those of the Mediterranean, which have furnished the supply for decorative uses to Europe for two thousand years or more. In fact, they are as handsome as such stones well can be. They have not been quarried, but it is probable that large blocks without many flaws can be obtained. The peculiar hardness of these stones, which has always been an obstacle to their extensive use, is now less of a disadvantage than of old, for the modern appliances for the use of power very much reduce the cost of working such stones. These materials are in excellent positions for working, forming cliffs of considerable height above the sea. At Marblehead neck it is possible at high tide to load the material directly from the quarry into vessels of considerable burden. This class of stones is found nowhere else in the United States in similarly beautiful forms, and nowhere else in the world, so far as my knowledge goes, in such a favorable position for exportation.

In Stoneham there are some deposits of marble that have been the object of several desultory efforts at working at various times in this century. So far all the stone found, though of an admissibly pure white color, is too much cut up by joints to be useful in the arts. Despite these failures I am not without hope that other deposits now covered beneath the mantle of drift that envelops this region may yet be discovered.

In this same section of eastern Massachusetts there is yet another source of building materials that is full of promise. I refer to the extensive deposits of serpentine that lie in the country between Lynnfield and Newburyport. This deposit has long been known to exist, and nearly half a century ago it was worked at one point as a source of supply of material from which Epsom salts were made. This serpentine has never been fairly opened save at one point, in Lynnfield, where a pit 15 feet deep has been sunk into it. From this opening some beautiful blocks of serpentine have been obtained, which show that the rock is well fitted for architectural purposes. Near Newburyport the rock seems to be more divided by joints, but it is of harder and more beautiful texture. Near Lynnfield it appears to be of a softer nature, yet not too soft for the best uses, and the blocks are of larger size than elsewhere. As yet the means of observing this deposit are too limited to afford the basis for exact statements, yet I know in America no other rock of equal promise.

In the vicinity of the east end of the Hoosac tunnel, in close geological relation with the well-known deposits of steatite that occur there, exists an extensive deposit of serpentines in which quarries have never yet been opened. The quality of the polished specimens I have seen seems very good indeed, and the deposit seems well worth a careful investigation.

I may also commend to the consideration of quarrymen the many varieties of clay-slate that occur at various points in Massachusetts, particularly near Boston. These clay-slates have long been worked for road materials, but have not been much used for construction purposes. These stones generally break well in the quarry, and are tolerably well suited for hammer-facing. Their main joint-planes are generally richly colored by iron oxide, which gives them a handsome effect in a wall. The only important edifice that has been constructed of this variety of stone is the Shepherd Memorial church in Cambridge. The cost of quarrying the stone was much less than that required for the Roxbury conglomerate, and when placed in the wall the actual cost was only about one-half as great as the conglomerate in the Mason chapel, a very similar edifice a few yards away. The distance of the buildings from the quarries where the stones were obtained is about the same. The general effect of these stones is nearly alike.

In the neighborhood of Boston there are some trappean rocks that are free from the general objection that must usually be held against New England traps in general, and which are capable of making excellent building stones. I refer to the amygdaloids of the Brighton district. These rocks occupy but a small area, not exceeding about half a square mile, yet they lie well for quarrying, the joint-planes being quite favorable for working. The color is a dark mottled green, which would seem to enliven the architecture of the structures built of the similar colored stones that prevail in this region. In the same series of rocks, apparently also of trappean nature, are some deposits of a lively green color. These are best shown near Newton Upper Falls. They seem to me to promise a useful decorative stone.

In western Massachusetts, although the district lies beyond the limits of the work specially undertaken by the survey, I may notice a few of the most important features connected with the prospective quarry industries. In this section we have none of the free-splitting granitic rocks which are so remarkably abundant in the coast region of New England. The rocks most like them have a gneissic form that causes them to break irregularly. They were splendidly exhibited in the central portions of the Hoosac tunnel, and their extreme resistance to the action of powder as well as to the drill made that great work very costly. This rock is well exposed at the surface in the district just south of the tunnel in positions favorable for quarrying. Although it is not easy to work in the heading of a drift, such as a tunnel requires, I believe that a skillful and ingenious quarryman would manage to deal with it in an open working. The stone is extremely handsome, having the peculiar banded structure of gneiss, with a semi-opalescent quartz in large crystals. It is exceedingly resistant to transverse pressure, its structure making it, when strained across the fiber, almost as elastic as wood. It should not be used as a decorative stone in any position where it would require dressing, but it is very suitable for long lintels, and I believe it would furnish excellent edge-stones. As some of its faces are smooth it could also be had in forms suitable for rough walls, even in buildings of the highest grade.

At present the American taste is rather opposed to the use of stones that do not show the use of the hammer upon them. This is, however, a mere prejudice, for some of the handsomest structures in the world are built of undressed stones. The city of Florence, in many regards the most beautiful city in Europe, has its finest architectural triumphs built of unhewn stone. The Strotze and Pitti palaces owe to their rough stones the wonderful dignity that makes them nobler in aspect than thousands of more costly structures. When our builders accept a similar simplicity as the worthy object of their efforts it will open this class of rocks to use.

There are some good white marbles in this section that deserve more attention than has been given to them. They are somewhat worked about North Adams, but are perhaps too much jointed and of too coarse a grain to come into general favor.

After considering all the other resources in the way of building stones that are found in Massachusetts, we come again to the granitic rocks as the most extensive and surest basis of its quarry industry, and until the taste for such stones changes they are sure to be the most valuable of all its rocks.

The principal fields for these stones have already been occupied. The most important of the regions which may be designated are the Milton and Quincy district, the district of cape Ann, the district of Fitchburg, and that of Fall River. The Milton and Quincy district gave the beginning to the granite industry of New England. Its first success was great, and to this day it has more quarries within a given area than any other district in New England, or perhaps in the United States; yet it was not naturally the best locality in the New England region. As far as the quality of the stone is concerned, it is surpassed by the quarries on cape Ann and by those in Maine. The stone lies well for working, as it occupies a set of steep-faced hills divided by several valleys of considerable depth. The site is near the sea, with which it is connected by the first railway built in this country, and it is also upon the extensive railway system of the Old Colony railroad. It is thus one of the few granite-quarry districts of New England having the advantages of both methods of transportation. At present the product of this district does not seem to increase as rapidly as that of cape Ann or that of the Maine coast. The general structure of the stone appears to make the production and shipment of the stone a little more costly than in other regions. There are few large rocks now produced there, the greater part of the work being cemetery monuments and other decorative work.

Cape Ann was the next district opened to work. The quarries at that point give an excellent but little tried sort of stone. The only hinderance has been the absence of good harbors and of satisfactory railway connections. The lack of harbors near the quarries has been met by the construction of breakwaters built from the waste stone, but the provision is yet inadequate, and the cost of new harborage is too great for small capitalists.

South of Boston harbor, in Cohasset and a part of North Scituate, there are excellent sites for quarries. The stone is of a light red color, and works well, but the difficulty of harborage at the quarry point has led to the failure of several experiments in quarry work. At present the land along this shore is so valuable for villa-sites that it is not likely to be used for quarry purposes. The Fitchburg and Fall River districts, as well as the large area of granitic rocks along the line of the Boston and Albany railway, are capable of extensive development. That near Fall River is, however, the only one that is likely to secure cheap water transportation—an absolute need in the case of any new granite district seeking to compete with those already established in New England. So far the Fall River quarries have supplied only the considerable local demand. They seem to me, however, to be the best placed for extensive shipment of any in Massachusetts except those of cape Ann.

The stone in the district along the line of the Boston and Albany railway is of good quality. It is, however, of a rather gneissoid structure.

Lastly, I may notice the fitness of the abundant glacial pebbles to the construction of more important walls than those to which they have been applied. So far these stones that lie about nearly every New England field have not been much used save for dry walls or fences and for foundations. Their rounded form does not readily lend itself to the mason's use, yet by sizing the stones and using them with a little patient skill it is possible to make a strong and handsome wall from these fragments. The only considerable structure which I know that is made of bowlders is a church in the town of Medford. It is a handsome and ornamental structure, and I am told that the walls cost less than if built of any other masonry.

In the valley of the Po, in northern Italy, glacial pebbles of small size, often not exceeding 3 inches in diameter, are extensively used for building. Sometimes a frame-work of timber is first built to take the strain of the roof, and then these pebbles are built in between the timbers. In all New England these stones left by the glacial period are always very enduring, for the reason that the rough handling withstood in their making fully tested their strength. They are often very smooth, and show their natural colors to great advantage. It is to me remarkable that so simple and evident a source of construction stones has been neglected for generations in a region where good, easily-worked materials for masonry are not generally accessible. It is only to be explained by the natural conservatism of architecture, a field of activity where the penalties for rashness are often great and the profit from any one successful experiment is usually very small.

MAINE.

The building stones of this state are less known than those of any other New England state. There has been but little demand for them save for export purposes, and the distance of carriage is so great that but few of the great variety to be found there have ever been brought into use. Along the coast the limestone of Rockland and the neighborhood has long been quarried for lime, and at certain points the excellent syenite that abounds in this region has been quarried for southern markets; but nothing like a search has yet been made for the available building stones of this coast. This region is peculiarly adapted to afford a great variety of building stones. The shore is formed by the extremities of many mountain ridges, which have been planed down by the sea and by glaciers so that they no longer appear as mountains. These old mountains, which are evident only to the geologist, stood at right angles to the shore. This disposition of the rocks causes a singularly great variety of stones to be exposed at the coast-line. The harbors are numerous and deep, so that the products of the quarries can generally be loaded directly into large vessels. These conditions make this region more favorable for the development of a large quarry industry than any other region known to me in this country or in other countries.

It is much to be desired that a careful study of the stones on this coast should be made. In the meantime the following notes which have been gathered during the census, and other studies, may have a certain value as indices of the resources in the way of building stones that may be found there. Beginning at the eastern extremity of the state we may note that in the neighborhood of Calais and thence toward Perry and Eastport there are extensive beds of a very reddish feldspathic rock, probably to be classed with the granites, which deserve far more attention than they have yet received. In the town of Perry and in the towns that border upon it there are some distinctly-bedded rocks that are likely to furnish good flag-stones of fair hardness. The same may be said of the region about the winding shores of the South bay, an extensive sheet of water near Eastport. We find there many beds that would yield good flagging stones. There are some very red conglomerates in this district that might be useful on account of their brilliant colors, but they are too much jointed for the most favorable working.

Passing to the westward from Passamaquoddy bay we are for a great distance principally in granitic rocks. There are, however, many distinctly-bedded rocks of a much metamorphosed character at various points which may afford flag-stones. It is impossible to give particular localities, as the rocks have never been quarried, but the section between Lubec and Doverboro' seems to me the most promising region for search. Between Machiasport and Harrington the granitic rock is the only important material. The stone in this section, like that near Calais, is of a reddish color. Indeed, this seaward face of Washington county is characterized by the reddish tint of its metamorphic rocks, which in turn has given a reddish cast to the slates and conglomerates that have been formed from them. The best of the granites of Washington county are found in these red granites, which are probably all of about the same age. This set of rocks extends far into the interior, but they are so much more available along this shore district that it is not worth while to seek them elsewhere. I am satisfied that when the diverse qualities of these reddish granites have been determined by proper exploration it will be found that this part of Maine will afford a wider variety of these stones than any other district in New England.

Near Addison there are quarries of diabase. These rocks are commonly classed as dark-colored granites, which they somewhat resemble. The principal objection to this block granite for building stone is that in some localities it shows a tendency to decay with great rapidity. A similar stone exists near Boston, in Somerville, Melrose, and Medford, Massachusetts; but, though handsome and easily worked, it is unfit for out-of-door use, as it will often lose color in a few years and fall away in flakes. This objection does not seem to hold against the stone from this part of Maine.

Between Harrington and Gouldsboro' there are excellent exposures of granite of various colors which have not yet been quarried. We next find worked quarries at Sullivan. At this point the granite has a set of cleavages which causes it to break out in long rectangular prisms, a form peculiarly favorable for the quarryman's work. Connected with this easy breakage we have numerous slight veins in the stone that seem to make it break too easily for the best uses, and somewhat affect the color of the blocks. The rather reddish granites outcrop along the coast to the westward. On the shores of Somes sound, a deep inlet that penetrates the island of Mount Desert, there are quarries of a light red granite. Here, as elsewhere along the shore, the best quarries are found in the sides of the hills. As these hills are the parts of the rock that have best resisted erosion, it follows that they are the most solid and enduring of the rocks of the country. It may be said that throughout New England the thickly-bedded enduring rocks are in the hills, the softer and more thinly bedded in the valleys. It seems never worth while to seek for good granite in the valleys since a slight depression shows some element of weakness that makes the rock unsuitable to the quarryman's use.

Excellent granite quarries exist at the head of Bluehill bay, to the west of Mount Desert. Deer island and Vinal Haven island have exterior quarries of the same stone. On the latter island the stone splits in larger blocks than anywhere else in New England, except perhaps in the quarries of cape Ann.

On the west side of Penobscot bay there are exterior quarries in Thomaston and Saint George, near Richland. West of the Penobscot the quarries are not limited to the coast-line, but some are situated on the Kennebec, at a distance of 60 or 70 miles from the sea. This is not because the granite is particularly better or more abundant there than in the inland region of the Penobscot, but because there is more local demand for stone and the means of shipment by railways are much greater. There are also considerable quarries of roofing slates in this section of the state west of the Penobscot river; they lie, however, much north of the belt of granite quarries. The granitic character of the coast is continued to the New Hampshire line, and the numerous small and a few large quarries attest the general goodness of the stone. It will be noticed that the only building stones quarried along the coast of Maine are granites, or crystalline rocks closely related to them. It must not, however, be supposed that no other kinds of stone occur along this coast. The limitation of the production to this single quality of stone is to be explained in part by the fact that this stone is the only one for which there is an extensive market, and the search has naturally been first made for it. Even more, however, must be attributed to the fact that the continuation of marine and glacial erosion which has gone on upon this shore has worn away almost all the softer rock exposed to its action. The larger part of the limestones, slates, sandstones, etc., that find their geological position on the folds along this coast have been so worn away that they lie beneath the surface of the deep indentations of the sea which are so conspicuous here.

These granitic quarries afford very excellent conditions for working. The stone opens easily, having the peculiar inchoate joints that are such striking features in the syenite or granite of New England. There are generally at least two of these rift-lines. Then there is a more or less complete division by what appear to be true beds, as well as joints, so that the division of the rock is as complete as could be desired. At the same time the lines of weakness in the rock are not so numerous as often to make the quarried masses too small for use, as is sometimes the case in other districts. The impurities in the way of spots and veins, which often seem to mar the appearance of granitic rocks, are not found in any great abundance save at a few points. Added to these advantages this shore affords a frontage in its islands and inlets of not less than 2,000 miles, the larger part of which lies in workable granite or kindred rocks, though of course not always of the best kind.

Although the extreme erosion has left little of the more wearable rocks along the coast-line of Maine, the inland regions seem likely to yield a good variety of stones. The principal trouble at present is that the coating of forest and the layers of drift mask the greater part of the surface, except where the very hardest rocks occur

MACHINERY AND LABOR.—In the larger New England quarries steam cranes or derricks are generally used to move the stone to the carriage that carries it away from the quarry heading. In the smaller quarries the hand-crane alone is used. These cranes are generally conveniently arranged for their work.

In the latter class of quarries wagons for conveying the stone to the shaping- or dressing-grounds and to the shipping-grounds are no longer employed. The road out of the quarry is generally occupied by a tramway, and locomotives, generally of the light dummy pattern, are used to drag the carriages to the shipping-point or to the dressing-grounds.

From a considerable knowledge of the European quarries I believe that the amount of manual labor used in their quarry work is at least twice as great as that required in the better class of American stone pits. The result is that we can furnish rough stone at a lower price than that at which it can be produced in Europe, despite the higher price of labor here. In the treatment of the stone after it leaves the quarry the American methods show no advance upon those of Europe; and it is in this part of the work of preparing building stones that the cost most rapidly increases. The wages for all sorts of hand-work in dressing are very dear, and so far little effort seems to have been made to replace these methods by mechanical contrivances. When stone is to be dressed into ornamental shapes it does no seem practicable to gain much by any mechanical processes; but when the aim is merely to polish the flat face of the stone or to bush- or face-hammer them, it ought to be possible to replace hand-work by automatic machinery. One reason why more effort has not been made in this direction is doubtless that mechanical power derived from steam is generally costly in the quarrying districts of New England. This may perhaps be met by the use of tidal water-powers that abound along all this coast-line. These water-powers can often be brought into use at a very small cost for plant, and as they do not depend on drought, and generally involve no damages for flowage, they will be much cheaper than fresh-water power. Their general utility is sufficiently proved by the frequent use made of them on this shore for ordinary milling purposes.

TRANSPORTATION.—The carriage of the quarried stones to market is generally effected by rail or water. The quarries near the sea-board have a great advantage over those upon the railways, inasmuch as they can ship at much less cost, the carriage by sailing-vessel being only a small fraction of that which must be charged by railway. On these vessels the stone is generally laden upon the deck, except the smaller sorts, such as paving stones, which are stored in the hold. It seems to me that vessels of the sort known as catamarans, *i. e.*, those with two distinct bodies, with a pavement covering the whole, would make safer forms of ships for this carriage, as it is the heavy deck burden that makes an ordinary ship very top-heavy and liable to accidents.

GENERAL RELATIONS OF NEW ENGLAND BUILDING STONES TO THE MARKETS OF THE UNITED STATES.

It is worth while to notice the general relations of the New England quarry industries to the rest of the country, as we may thereby gain the basis for a forecast of their future.

A glance at a geological map will show that the rocks that characterize New England are not found in an equally extensive development in any other district south of the Saint Lawrence and east of the Rocky mountains. The same highly-metamorphosed series of rocks is continued in a less extensive way south along the whole chain of the Appalachians as far as northern Alabama; but it leaves the sea-board region at New York, and south of that point is not readily accessible to tide-water navigation. Moreover, when we get even as far south as New York we find that, owing to the progressively less and less considerable development of glacial action in southern regions, the rocks show the effect of decay to a much greater depth than they do in New England, where the last glacial period stripped away all the incoherent decayed portion of the rocks, leaving only that which was well suited to the use of the quarryman. The result is that even near New York, and in a greater degree for every step eastward, the stone is decayed along the joints to such an extent that we can rarely find good solid blocks within from 20 to 50 feet of the present surface. This deep "cap" of decayed rock is a serious hinderance to the development of good quarries of crystalline rocks in a large part of the southern Appalachian mountains.

These two advantages, the neighborhood of the crystalline rocks to the sea and the absence of any worthless decayed upper part, will always give the New England rocks of the granitic group a very great advantage over those of any other part of the eastern United States.

It should also be noticed that the cost of quarrying granite of good quality is perhaps less than that of any other work of the same general utility, certainly much less than the cost of our other principal building stones, so that, for all large structures where rude strength is the only need, quarries of this stone are always likely to be at a great advantage in production.

There are no other sources of supply of granite that are ever likely to compete with this stone district of New England. The same qualities of stone are found in southern Nova Scotia with the same advantages of quarrying; but this region is on the average several hundred miles farther from the principal points of consumption, so that the tax due to distance will always amount to about as much as the present profits of the New England quarries. The cost of carriage on a ton of stone from Nova Scotia above that from cape Ann, supposing the distribution to be to New York or Philadelphia, is at the present low rates of freight about 50 cents. This is probably more than the average profit that is made upon the stone itself. Thus there could be no effective competition save for such stones as have been carved or finished, so that the actual value bears a very large proportion to the original cost of quarrying and conveying to market. It is quite clear, therefore, that the position of the New England granite quarries is particularly favorable, and that they are likely to command the market for cheap stones for a great while in the future.

The same may be said, though in a less emphatic way, for the other building stones of this region. The roofing slates, particularly those of Maine, the exploration for which has hardly begun, are very well placed for marketing, as they have the same advantage, arising from the small amount of waste rock on their surfaces, that the granite quarries have. The slates have rather more drift matter upon them than the granite quarries have for the reason that they generally lie in rather lower ground; still this drift is loose material requiring no other than pick-and-shovel work before the profitable work is attained. In Maine, especially, these quarries lie near enough to tide-water to share the advantages arising from their method of carriage, being not more than from 30 to 60 miles away from the nearest tide-water navigation.

There are no certain supplies of good marble within a remunerative distance of the shore-line of New England, the nearest approach thereto being the extensive deposits of serpentine rocks that lie in Middlesex and Essex counties, Massachusetts. Between Lynnfield and Newburyport there is an extensive deposit of this character that will afford a material suitable for the carver's art.

I am not without hope that it will be possible to find some marbles suitable for building purposes in Rhode Island or in Maine, and it is greatly to be desired in the interests of American architecture that more good carving stones should be brought into market. Though New England abounds with excellent and beautiful construction stones, it leaves much to be desired in the way of stones fitted for the work of the sculptor. None of its marble is really fit for the best statuary purposes.

DETAILS REGARDING QUARRIES.

MAINE.

[Compiled mainly from notes of John Eliot Wolff.]

The Red Beach granite quarried near Red Beach, Jonesboro', and Calais, Washington county, is used principally for monuments, and to some extent for general building purposes. It is quite largely used for polished columns. The principal markets are Boston, Providence, New York city, Baltimore, Philadelphia, Buffalo; Cincinnati, Cleveland, Zanesville, and Columbus, Ohio; Springfield and Chicago, Illinois; Milwaukee, Saint Louis, Saint Joseph, Kansas City; Charleston, South Carolina; Wheeling, West Virginia; Washington, District of Columbia, and San Francisco.

In the Red Beach quarries there are two sets of principal joints, both nearly vertical, which seem to be continuous through the granite of this region. The finest set has a direction S. 55° W., and the other 65° E. There are also some less regular cut-off joints running S. 60° W. and slanting east. The sheets are fairly regular, running from 7 to 4 feet and less; the jointing is remarkably regular for granite, and the almost rectangular intersection of the vertical joints gives the blocks a cubical and rectangular form rare in granite. The stone is free from blemishes as seen in the quarry. Little quartz veins and black concretions (one of which when tested appeared to be principally magnetite of small size) are the principal ones. The rift of the stone is parallel to the S. 65° E. joints. On the surface rock this stone weathers with a snow-white appearance. The feldspar, both red and dirty white in color, turns to a dazzling white, the quartz remaining unaltered, while the mica and magnetite and other minerals become inconspicuous. The granite-workers here are very largely Aberdeen Scotchmen, and some of the polishing-machines are adapted from Scotch models.

The stone compares very favorably in appearance with the Peterhead Scotch granite and the Nova Scotia red granite. The rock is a biotite granite, is a good working stone, and quite hard and brittle, taking a high polish. Blocks 7 by 7 by 2 feet thick have been shipped, and blocks 30 by 15 by 2½ feet might be quarried.

The columns of the court-house at Providence, Rhode Island, and those of the custom-house at Kansas City, Missouri, the Centennial block at Portland, Maine, and a portion of the basement of the custom-house at Fall River, Massachusetts, are of this stone.

At Jonesboro' the quarries are shallow and extend over a comparatively broad area on the top of the hill on which the quarries are situated. The sheets thin out, but deepen on going downward. There seems to be but one good set of joints, standing nearly vertical and running north about 80° east. The rift of the stone does not seem to have a very determinate direction, but approximates to a parallel with these joints. The grain is horizontal, the sheets become thicker at the bottom of the quarry, and run from 5 to 3 feet and less in thickness. The stone splits well and straight in any direction, and by drilling and wedging rectangular blocks are obtained. Both light and dark patches appear in the stone.

The greatest defect of the stone, which causes considerable "grout", is the frequent occurrence of red stripes or veins of red feldspar crossing the stone. Some of these stripes appear to be small, very tight seams, along which the stones have become sappy, giving the red color. Veins or dikes of fine red granite run through the quarry in one or two places; often the tongues running out from them are red on the outside and white inside, resembling the patches in appearance. This belt of red granite is locally thought to be continuous with that found at Red Beach, on the eastern edge of the county, and also to cross into New Brunswick and form the Macadare red granite, becoming redder toward the east. Wellington Brothers' building, Boston, and the Hunnewell building, New York city, are among the buildings in the construction of which the Jonesboro' red granite was used.

The trap dikes in Washington county, furnishing white and black granite, properly a diabase or olivine diabase, are quarried chiefly for monumental purposes and shipped to New York city, Brooklyn, Boston, Washington, Montreal, and Quebec. It was used to some extent in the construction of the inclosure-walls of the Capitol grounds, Washington city, for a bank in Montreal, and extensively for monumental purposes in Greenwood cemetery, Brooklyn. Blocks 16 by 10 by 20 feet have been moved in the quarries, and natural blocks 90 by 10 by 15 feet occur. Six miles southeast from Madison point, on Pleasant river, one of the principal quarries in this rock is located; it is a remarkably favorable location, being at the water's edge, and the waste is easily used in extending the wharf. The stone is extremely hard and takes a good polish. The principal defects causing the waste stone are the so-called "knots", consisting of irregular patches of very coarse, white feldspar, mixed with fine, large, black hornblende crystals; little seams also occasionally split off part of a block, but the stone usually presents a uniform surface, free from the frequent patches and other irregularities of ordinary granite. The stone seems to weather remarkably well for one containing so much hornblende. This quarry is called by the quarrymen a "block quarry"—that is to say, the horizontal or concentric sheets of ordinary granite are few. There are two sets of vertical sheets, the best run due east and west and give blocks, as far as the quarry has been developed, from 15 feet down in length. There are also north and south vertical joints less perfect, but more frequent than the others. The rift or easiest splitting direction runs parallel to the east and west joints; the grain, or next easiest, north and south, while the lift or horizontal splitting is hardest of all. Hence the natural blocks are approximately rectangular in shape.

Near West Sullivan, Hancock county, a light gray biotite granite, sometimes having a pinkish tint, is quarried for general building purposes, for paving and curbing, and is employed to some extent for monuments. The principal markets thus far have been Boston, New York, Brooklyn, Albany, Philadelphia, Washington, and other places on the Atlantic coast accessible by water transportation. Blocks 25 by 25 by 2 feet thick have been quarried; the sheets of stone vary from 6 to 3 feet in thickness and have a slight dip to the north. The rift of the stone is, as the quarrymen express it, "on the lift," that is, horizontal or parallel to the sheets, and this is usually the case in the Sullivan granite region. The grain is vertical, running S. 70° E., and has a remarkably straight and plane cleavage, so that the stone frequently comes out in long rectangular prisms. It may be said here that these beautiful cleavages are among the characteristics of the Sullivan granite and are of great advantage in making paving blocks, as the blocks are shaped from the material with ease, a few slight blows often sufficing to reduce the stone to a proper shape. There are also vertical joints running across the grain S. 20° W. The principal defects are the black patches, and some of the stones have very thin seams called by the workmen "pencil-mark" seams, from their appearance; these are an element of weakness.

A mile north of West Sullivan is located a typical sheet quarry, the sheets running from 2 to 6 feet in thickness, having a very smooth almost plain though gently-curved surface, dipping slightly to the northwest. Vertical joints are few. The rift is on the lift, or parallel to the sheets, and the grain is vertical. There are some large vertical joints running through the quarry; some of the quarrymen distinguish seams running across the grain obliquely as "grain" seams; seams oblique to the grain as "tight" seams, and certain seams coated with decomposed feldspar as "chalk" seams. There are several very large black inclusions seen in the granite.

A quarry producing excellent splitting stock is situated three-quarters of a mile north of Sullivan. The sheets run from 7 down to 3 feet in thickness. There are some large vertical joints running northeast occasionally filled with trap dikes. The stone has a somewhat conchoidal fracture and shows the usual black patches. The rift is parallel to the sheets, and the grain runs east and west at right angles with the vertical jointing.

Near Franklin, Hancock county, a light gray, massive, biotite granite is quarried for curbing, paving, and cemetery work. The principal markets are Boston and New York city. The texture of the stone is medium fine and porphyritic. Blocks 30 by 14 by 3½ feet thick have been quarried.

On Somes sound, 2½ miles south of Somesville, Mount Desert island, Hancock county, a light gray, massive, biotite granite is quarried for general building purposes, bridge construction, and paving. The stone was used in the construction of the Brooklyn approaches and towers to the East River bridge, and in the arches and foundations, and the new bridges in Back Bay park, Boston. Blocks 150 by 50 by 18 feet thick have been loosened in the quarry. The position of the quarries on Mount Desert island is peculiarly good for shipping, as they lie near the head of Somes sound along a narrow and very deep fiord, running several miles inland from the southwest harbor, between the mountains. One of the quarries is situated on the side of a hill and at the water's edge. The sheets of stone are very thick in some cases, one being 18 feet in thickness. The sheets have a steep dip from the summit of the hill down to the water's edge. There are a few north and south vertical joints or headings, usually not less than 60 feet apart. The rift is on the lift of the sheets, and the grain as usual is parallel to the great north and south joints. In connection with the dip of the sheets away from the hill, considerations concerning the form of the granite hills of New England suggest themselves. It is held by some that these hills have been rounded into their present shape by ice, while others believe that their form is due to the structure of the granite.

In Maine not only are the quarries of great extent and depth, and generally located on hills, but these are generally sufficiently bare of vegetation to conceal the outline. Many of the larger quarries of Maine are sheet quarries, and in every case where vertical joints are not present, breaking up the sheets to such an extent as to conceal their direction, the round form of the hill is plainly seen to be due to the gentle curve of the sheets.

Two miles south of Somesville there is a granite quarry, the opening of which is yet shallow, and the sheets are consequently thin. The rift is on the lift and the grain is approximately east and west; the infrequent joints are mostly north and south.

Near East Bluehill, Hancock county, a light gray, sometimes pinkish-gray, massive, biotite granite is extensively quarried for general building purposes and for paving. It has been used in the construction of the city hall (trimmings), the art gallery in Fairmount park, and the Pennsylvania Railroad bridge, Philadelphia; in the East River bridge, New York city; the post-offices in Chicago and in Harrisburg; and the Thomas monument in Washington city. In texture the stone is medium-fine porphyritic. Blocks 90 by 80 by 6 feet have been moved in the quarry; a block of 80 tons was loosened and moved out some feet in one of the quarries. It is a compact, good, safe, and free-working stone, and takes a good polish. Specimens were tested at the centennial exhibition at Philadelphia which showed a crushing resistance of 108,000 pounds to a 2-inch cube. The quarrying here has been to a considerable extent done on the surface, although there are some large openings. The stone lies in sheets, often irregular, from 3 to 10 feet in thickness, and the jointing is sometimes irregular in many of the openings. In one of the quarries there are sheets 9 feet in thickness, though the usual thickness is from 4 to 5 feet. The stone contains a few black patches, the joints are not frequent, and their direction when present is east and west.

In another quarry the sheets are from 6 to 8 feet in thickness, the dip steeply southeast; the rift is east and west with the dip of the sheets, and the grain north and south. The vertical jointing is irregular; patches and occasional veins of white granite are present. At another opening the sheets reach a thickness of 20 feet; the long seams cut down through the mass, but are usually far apart.

Near Deer island, Hancock county, a light gray, indistinctly-laminated biotite granite is quarried for general building purposes, bridge construction, and paving. It has been used in the construction of the Broadway bridge, South Boston; base of columns of elevated railroads in Brooklyn; and grain elevator of the New York Central railroad, New York city. Blocks 14 by 8 by 20 feet have been loosened in the quarries, and the dimensions of some of the natural blocks are as much as 150 by 15 by 15 feet. It is a compact, good, safe, and free-working stone, and takes a good polish. The sheets in one of the quarries reach a thickness of 18 feet, though the usual thickness is from 6 to 12 feet. They extend into the hill nearly horizontally, and are intersected by occasional vertical joints. The rift here is vertical, running north and south, parallel to the joint; the grain at right angles, or east and west.

In another opening the stone lies in very thick and broad sheets, nearly horizontal, with a slight dip toward the water; the sheets are from 6 feet downward in thickness, and are intersected by a few joints. The rift here runs north and south, and most frequent vertical joints also run north and south.

Another quarry in this vicinity lies in a steep hill, the slope running down to the water's edge. Where they are now working the sheets average 3 feet in thickness, the maximum being 5 feet and the minimum 1 foot. The dip is very steep from the top of the hill to the water's edge. There are few vertical joints; the rift runs best toward the top of the hill. At the north end of the quarry the sheets are horizontal, of great thickness, one being over 20 feet thick, and having considerable length and width as well.

In another of the principal quarries the sheets occasionally reach a thickness of 20 feet; the vertical joints have an east and west direction, and are found at intervals varying from 5 to 60 feet.

A mile and a half south of Frankfort, Waldo county, a gray, massive biotite granite is quarried for general building purposes, bridge construction, monuments, paving, and polished columns. It is sent as far as Mobile and New Orleans. It was used in the construction of East River bridge, New York; basement of the State, War, and Navy building, Washington city; art gallery at the centennial exhibition, Philadelphia; art museum, Central park, New York city; Saint Louis bridge across the Mississippi river; pedestal of the statue of Admiral Farragut, Washington city; forts Knox, Popham, George, Preble, Schuyler, Constitution, and other fortifications. The texture of the stone is coarse and porphyritic. Blocks 80 by 40 by 20 feet have been moved; a block of 30 tons was cut and shipped. It is estimated that blocks 150 by 50 by 12 feet might be moved in the quarry. The principal quarry is situated on mount Waldo, overlooking the Penobscot river, and at an elevation of some 320 feet above high tide. It is a situation allowing of easy disposition of the waste; the stone lies in immense sheets dipping off from the mountain, varying in thickness from 1 foot to 20 feet, the usual thickness being from 4 to 5 feet. The quarry is traversed by frequent head joints running S. 75° E., but there are comparatively few joints at 90°.

The rift is on the lift, or parallel to the sheets; the grain runs S. 75° E., or parallel to the headings. Two varieties of stone are obtained—coarse and fine; the local impression is that a belt of fine granite runs through the coarse prevailing granite. This stone was used in the construction of many of the eastern forts before the late war, but a year or so of the war demonstrated the comparative inferiority of stone for this purpose and caused the building of stone forts on the Atlantic coast to be discontinued, and the business of several of the Maine quarries was for a while diminished through this cause.

Near Prospect, Waldo county, a gray, massive biotite granite is quarried to a limited extent for street work, basin heads, platforms, and bridge construction. It was used in the construction of the railroad bridge at Bangor, and in the East Boston dock. The texture of the material is rather coarse; the stone lies in sheets, and the rift is on the lift; there are two sets of joints. Blocks 6 by 4 by 4 feet have been shipped, and blocks 30 by 35 by 10 feet might be moved in the quarry.

Near Swanville, Waldo county, gray biotite granite is quarried for cemetery work, paving, platforms, and columns. The principal markets are New York city, and Boston and Quincy, Massachusetts. It was used in the construction of a soldiers' monument at Buffalo, New York. Blocks 20 by 9 feet by 1 foot and 10 by 10 by 2 feet have been cut, and blocks 40 by 20 by 2 feet might be moved. The stone here is uniform in texture, free from blemishes, and is a compact, good, safe, and free-working stone, taking good polish, and lies in regular sheets varying in thickness from 1 foot to 4 feet. The quarry is located on a hill, and has not as yet been developed to any great depth. The rift is vertical, and runs north and south, the grain east and west; the vertical joints cut through the quarry east and west parallel to the grain.

At Lincolnville, Waldo county, about 6 miles west of Camden, a very light gray, massive muscovite-biotite granite is quarried to a limited extent for underpinnings and local stone-work generally. Thus far it has been used only in Camden and vicinity. Blocks 12 by 2 by 6 feet have been quarried; blocks 50 by 25 by 6 feet might be moved. This stone has a good appearance, is uniform in texture, and is a good, safe, and free-working stone, taking good polish. It does not lie in sheets, but rather in blocks. There are frequent vertical joints in one direction. The rift is vertical and about parallel to the vertical joints. The quarry lies near the base of a mountain near Camden, but it is small and not worked regularly.

The extensive quarries at Vinal Haven, in Knox county, produce granite for general building purposes, monuments, and paving. It was used in the construction of the East River bridge; half of the Masonic temple, Philadelphia; Sailors' Snug Harbor, Staten island; half of the railroad bridge at Saint Louis; basement of the State, War, and Navy departments, Washington; custom-house and post-office, Cincinnati; polished work in Chicago court-house and city buildings; part of polished work in Philadelphia city buildings; a portion of the basement and quadrangle of the Patent Office building, Washington city; the Butler monument at Greenwood Cemetery mausoleum; and smaller monuments in various parts of the country. The color of the predominating material in these quarries is light gray; the texture is medium coarse. There is a dike of trap in one of these quarries, producing what is locally called "black granite", and used to some extent for building material. In what is known as the Harbor quarry the rift is very good, and is vertical, having a direction east and west; there is a very frequent vertical jointing in this same direction, giving long, narrow blocks; north and south joints are less frequent. The sheets vary from 3 to 8 feet in thickness, and immense masses of stone entirely free from joints occur.

The Sands quarry, adjoining the Harbor quarry, is bounded by two sets of great vertical head joints, running respectively northwest and southeast, and the easiest rift is vertical, parallel to these joints. In the center of the quarry there are not many joints; the sheets average from 4 to 5 feet in thickness, but some are 7 and 8 feet thick; they have a slight dip west, with quite smooth surfaces. The obelisk sent from this quarry to serve as a monument to General Wool, at Troy, New York, is said to be the largest quarried in modern times. Its dimensions are 60 by 5 by 5½ feet. Four long blocks were quarried before a satisfactory one was obtained; one of these lies on exhibition near the quarry. Natural blocks 240 by 32 by 8 feet can be seen in the quarries. Occasional black micaceous patches occur in the stone, which, together with vertical dikes of light-colored stone, constitute the principal defects seen. The East Boston quarry is a sheet quarry of fine-grained stone, the sheets running from 2 feet downward, and dipping slightly east. The rift is horizontal; some long east and west head joints traverse the quarry, but between these the jointing is irregular. The stone has been most used for paving and platforms.

In a quarry at Duschane there are vertical joints running regularly through the quarry at intervals of from 5 to 10 feet, in an east and west direction, and, as the grain of the stone or next easiest rift runs north and south, the blocks come out in rectangular shape. The rift is vertical and parallel to the east and west joints. The hardest splitting direction is on the lift, or parallel to the sheets, and the sheets are irregular. In one case the vertical thickness is 12 feet. The material has a pleasing appearance and is now used for polished work.

In the town of Vinal Haven there is a very small granite quarry, in which the structure of the stone is such as to be a very convenient source of paving material. The stone is extremely good, occurring in regular sheets of from 1 foot to 3 feet in thickness and nearly horizontal. There are occasional black patches; some long east and west vertical head joints bound the quarry, and there are also a few north and south joints. The peculiarity of the stone is its beautiful and even rift, and paving blocks may be shaped from it by a few blows of the hammer.

At Hurricane island, three miles southwest of Vinal Haven, a dark gray granite, sometimes having a pinkish tint, is quarried for ordinary building purposes, monuments, columns, and paving, and has about the same markets as the other Vinal Haven quarries. The stone was used in the construction of the following buildings: All the superstructure of the new post-office and custom-house, Saint Louis; the basement of the new city hall, Providence, Rhode Island; superstructure of the post-office at Fall River, Massachusetts; polished columns of the Chicago city hall and court-house; portion of the Indiana state-house, Indianapolis; Douglas' tomb, Chicago, and numerous monuments at Saint Louis. The structure of the stone differs in different parts of the quarry. In one portion it lies in comparatively thin sheets, while in another there occur immense masses of solid stone extending 50 feet downward without any perceptible jointing. A block of 80 tons has been moved, and a shaft was produced 23 feet 6 inches by 3 by 3 feet, when dressed, and a mass 80 by 40 by 25 feet was loosened in the quarry, and natural blocks 500 feet long, 20 feet wide, and 50 feet deep occur. The east rift runs east and west, while the grain or next easiest splitting direction is horizontal. The principal joints run east and west, but there are occasional north and south joints.

Three miles north by west from Vinal Haven granite similar in appearance to the Hurricane Island granite is quarried for similar purposes. It is used to some extent in the construction of the Brooklyn bridge, Chicago post-office, and the Raymond jail, in Brooklyn. It is a very superior sheet quarry; the stone lies in very smooth, slightly-curved sheets, having a thickness from 5 feet downward, averaging 3 feet. The sheets have a gentle dip to the west, or toward the water. Vertical joints are found in either direction, and the sheets are smooth, so that the stone is eminently fitted for large platforms. The rift is on the lift; the principal defects are patches, which occur occasionally.

At Muscle Ridge plantation, Dix island, Knox county, a dark gray granite was, until recently, quarried for general building purposes and ornamental work, but the quarry is not at present operated. Among the buildings in the construction of which this stone was used are the New York post-office and custom-house, docks at Castle Garden, and retaining-walls for basin and barge office, New York city; Densmore fort, Hyde Park, New York; Philadelphia post-office; Treasury building (extensions), Washington city; and basement of custom-house, Charleston, South Carolina. Nearly the whole of Dix island has been quarried over, large bluffs having been entirely removed, and deep excavations contain over 50 feet of water. The rift of the granite here is on the lift, the jointing irregular. Blocks 17 by 17 feet, and of varying thickness, sometimes weighing as much as 72 tons, have been quarried; natural blocks 25 by 25 by 15 feet may be seen in the quarries. The stone is coarse, porphyritic, and indistinctly laminated or massive. Specimens dressed at the National Museum proved to be of more than usual hardness and took a good polish. Steam-drills are employed in the quarrying.

At South Thomaston, Knox county, at Spruce Head island, 8 miles from Rockland, a dark gray granite is quarried for general building purposes, bridge construction, and for monumental work in the cities throughout the country. Among the structures in which this stone has been used are the Albany, New York, post-office (first story); post-office and court-house at Atlanta, Georgia; forts at Portland, Maine; in the East River bridge, New York, and in the Philadelphia city buildings.

One of these quarries at Spruce Head, known as the Bodwell quarry, which has furnished so much building stone to the coast of New England, is in the form of an excavation, commenced at the water's edge and pushed far into the hill, where it reaches a great depth. It is a sheet-quarry, the sheets increasing in thickness downward, and the thickest ones now exposed are from 9 to 10 feet in thickness, and show superb masses of stone. The sheets incline slightly away from the hill with gently-undulating surfaces. There are few vertical joints, almost the only ones having a north and south direction, and the east and west headings run through the quarry, forming the boundaries on some sides. The rift of the stone is vertical, and east and west, nearly parallel to the head joints. The Spruce Head granite has established a good reputation for its quality of resisting weather exposure and retaining its color. The greatest defects have been the black patches which are conspicuous on a bushed surface. There seem to be fewer of these patches in the present deep sheets.

The Sawyer quarry, adjoining the preceding, is similar. The stone lies in very regular and nearly horizontal sheets, varying from 3 to 12 feet in thickness. There are few vertical joints; but there are two sets of large head joints running respectively north and south and east and west. The rift here is reported as being horizontal, or on the lift, which, if true, is remarkable, since it is vertical in the quarry immediately adjoining.

In the Jameson quarry the stone lies rather irregularly in sheets. There are nearly vertical north and south joints; also east and west seams, to which the rift is parallel. The stone has very few blemishes, and specimens dressed at the National Museum were compact, safe, and free-working stones, taking a good polish. The quarry is drained by means of steam-power, and steam polishers are used in dressing.

Near Saint George, Knox county, there are granite quarries extensively operated for general building purposes, monuments, columns, and paving. The following are among the structures in which the stone has been used: Buffalo city hall; United States custom-house and post-office, Hartford; national bank, Albany; government storehouse at League Island navy-yard, Philadelphia; entrance to Chicago post-office; entrances to Utica, New York, post-office; Albany post-office and custom-house (above the first story); McClintock's building (trimmings), Pittsburgh; pedestal of the La Fayette monument, Union square, New York city; post-office and custom-house at Portland, Maine. This stone is of comparatively fine texture and is sometimes indistinctly laminated. It is a free and safe working stone, taking a good polish. Blocks 30 by 12 by 8 feet have been loosened and moved in the quarry, and natural blocks 75 by 60 by 6 feet exist.

Of the three principal quarries the Long Cove quarry has large parallel joints traversing it S. 70° E. from top to bottom at intervals of from 1 foot to 20 feet, and there are sheets of greater or less depth, so that natural blocks have a somewhat rectangular form. The grain is parallel with these joints. The hoisting is done by steam, dressing by hand, and steam polishing-machines are used in dressing.

In the Clark's Island quarry the arrangement of the stone is in sheets from 6 inches to 15 feet in thickness. The sheets have a gentle and sometimes slightly irregular dip toward the water and away from the crest of the hill. The easiest splitting directions are horizontal and parallel to perfectly vertical joints, which traverse the quarry at intervals of 6 feet and upward.

In the Wild Cat quarry the sheets are thin and rather irregular. There are south and east vertical joints, and the rift is parallel to them.

Four miles east of Saint George there is a quarry which was opened in 1879. Blocks 20 by 10 by 7 feet have been moved in the quarry, and natural blocks about 90 by 30 by 6 feet exist. The granite in the Saint George quarries varies from a light gray biotite granite to a hornblende-biotite granite, which is usually darker in color than the other. Hoisting is done by steam, and cutters, polishing-machines, and circular saws are used in dressing.

One and a half miles west of Waldoboro' is a small quarry the product of which has been used in small quantities in the neighboring towns for underpinnings, steps, posts, bases, and to a limited extent for cemetery work. The stone lies in moderately regular sheets varying from 2½ to 7 feet in thickness. The rift is horizontal and the grain runs northwest. The quarry is quite free from vertical joints and could be made to yield large masses of stone. Blocks 40 by 10 by 4 feet have been loosened, and blocks of perhaps 100 by 30 by 3 feet exist in the quarry. The stone is a fine-grained, indistinctly-laminated biotite granite.

At Jefferson, Lincoln county, 9 miles north of Butter Neck bridge, on the Knox and Lincoln railroad, there is a quarry operated to a limited extent chiefly for monuments and cemetery work. The dressing and polishing of the stone are done at Waldoboro', by water-power, and the material is transported to this place by water. Although called granite commercially, it is more properly a muscovite-biotite gneiss, of a light gray color and fine in texture. Blocks 10 by 20 by 2 feet have been quarried, and natural blocks as large as 20 by 10 by 2 feet are found in the quarry.

Half a mile east of Round Pond and 9 miles south of Damariscotta, Lincoln county, granite is extensively quarried for monumental and for building purposes. Among the structures in which the stone was used are the Seventh Regiment armory, New York city, and several monuments to Admiral Parrott in New Hampshire. The stone in this quarry for 20 feet down is much broken by joints and sheets from 1 foot to 2 feet in thickness. There are frequent vertical joints having a southwest direction, and others at right angles with these occur, but are less frequent, and the grain of the stone is parallel to them. The rift is on the lift, or horizontal. A large dike crosses the quarry parallel to the southwest joints, and large veins of granite coarser in texture than the predominating material occur. The most common rock of this region is gneiss, which outcrops in straight parallel lines after the manner of roofing slate. The gneiss is very curiously interbanded with a massive or gneissoid granite. This is illustrated in the quarry where bands of contorted gneiss, worthless for building purposes, run to the surface at a steep angle in the massive granite quarried. The quarry is so broken up by the irregular sheet-joints and mineralogical accidents that the waste of stone has been very great, and but few large blocks can be quarried at present. The dimensions of the largest block quarried here are 15 by 2 by 2 feet, but blocks about 6 by 6 feet by 1 foot 6 inches may now occasionally be obtained. The material is a dark gray biotite granite, and is a compact, free-working stone, taking a good polish.

Near Augusta, Kennebec county, granite is quarried largely for local use, but some is shipped to New York, Brooklyn, Philadelphia, Boston, and Chicago. The following are some of the structures in which it has been used: The United States arsenal, Cony academy, and a Unitarian church in Augusta, and the Old South church in Hallowell; Mills' building, corner Broadway and Exchange street, and a monument to Recorder Hackett, New York city; Roberts' tomb in Woodlawn cemetery, Long Island; Wood's tomb, Greenwood cemetery, New York. The material is a gray muscovite-biotite granite, massive and of fine texture, is a compact, safe, and free-working stone, and takes a good polish. Blocks 40 by 9 by 2½ feet have been loosened; blocks 20 by 2½ by 2½ feet have been dressed and shipped, and natural blocks 100 by 30 by 7 feet are found in the quarry.

In a quarry 2 miles west of Augusta the stone lies in sheets from 9 feet in thickness downward; east and west head joints traverse it, and the rift is horizontal.

In a quarry 1 mile west of Augusta the rift is on the lift, the grain vertical, having a northwest direction, and the material lies in very regular sheets, usually not over 2½ feet in thickness.

Half a mile to the eastward of this the stone resembles that at Hallowell, and lies in sheets of 1 foot in thickness, with northwest vertical joints.

Near Hallowell, Kennebec county, is a well-known quarry, producing granite very extensively for monuments, columns, trimmings, and general building purposes. Among the structures in which this stone was used are the new capitol, Albany, New York; the Bank of Northern Liberties, Philadelphia; the state capitol and Allen block, Augusta, and the Emery block, Portland, Maine; Odd Fellows' Memorial hall, Equitable building, and part of the old Quincy market, Boston; Ludlow Street jail, the *Tribune* building, and the old Tombs prison, New York city; the statues of the Pilgrims' monument, Plymouth, Massachusetts, said to be the largest statues in the country; the soldiers' and sailors' monument, Boston, and soldiers' monuments at Marblehead, Massachusetts, Portsmouth, Ohio, and Augusta, Boothbay, and Gardiner, Maine; Odd Fellows' monument, Mount Hope, Boston; monuments to General Stedman, Hartford, Connecticut, and Stephen A. Douglas, Chicago, Illinois; the Riley monument, Buffalo, New York; Cowan monument, Lewiston; Allen Lombard monument, Augusta; Lyman Nichols' monument, Auburn; Swazey monument, Bucksport; Mitchell monument, Gardiner; Fuller monument, Hallowell, and Meady pedestal and statue, Pittston, Maine; Tenney monument, Methuen, Massachusetts; Washington Artillery monument and Hernandez tomb, New Orleans, Louisiana.

In this quarry there is no sap on the sheets, or at most a very thin film; there are few vertical joints, and the surface of the sheets is smooth and level, while the stone is remarkably free from black patches, those occurring in the quarry becoming smaller in going down. The sheets increase in thickness downward, and are about 1 foot at the top and 10 feet in thickness at 50 feet from the surface. The sheets have a gentle dip to the north. At certain intervals there occur long vertical joints or headings cutting vertically down through the quarry, having an east and west direction, but north and south joints are rare. There are occasional quartz masses in the stone. The rift is horizontal; the grain east and west or parallel to the main seams. Sheets having level surfaces 36 by 34 by 9 feet deep have been loosened, and natural blocks about 200 by 40 by 9 feet deep are found in the quarry. The material is white or rather very light gray muscovite-biotite granite, and is often indistinctly laminated.

At Wayne, Kennebec county, a coarse, massive biotite granite is quarried to a limited extent for cemetery and general building purposes. The market is local only, the stone being used chiefly at Lewiston and Auburn. It was used in the construction of the Free-Will church, Continental mills, and county buildings, Lewiston. The jointing is irregular. Blocks 12 by 12 by 10 feet have been moved, and there are natural blocks about 40 by 15 by 10 feet. It is a safe, free-working stone, and takes a good polish.

Near Canaan, Kennebec county, granite is quarried to a limited extent for underpinnings, and is used chiefly at Waterville, Canaan, and Skowhegan, Maine, and at Newport and vicinity. The underpinnings of the churches in Skowhegan are of this material. The stone lies in very regular sheets from 1 foot to 2 feet in thickness. There is a very convenient rift, but there are many patches. It is a dark gray biotite granite, rather coarse in texture and indistinctly laminated. It is a safe and free-working stone, taking a good polish.

Near Norridgewock, Somerset county, there are quarries producing granite extensively for general building purposes, foundations, and monuments, and to some extent for polished work. Among the buildings in the construction of which the material was used are the following: Stone-work of the Goff block, Auburn; Dunn block, factory, and bank in Waterville; residence of Captain Holland, Lewiston; Coburn hall, Skowhegan; High Street church, Skowhegan; business block in Dexter, and Langley's monument, Lewiston. The principal quarry lies on the top of a hill; the stone is in sheets of from 2 to 4 feet in thickness. The main seams have an east and west direction, and north and south seams are rare. The rift is horizontal. Blocks 30 by 25 by 7 feet have been loosened in the quarry, and natural blocks 150 by 12 by 4 feet can be seen.

At North Jay, Franklin county, granite is quarried for general building purposes and for railroad construction. It has been used in the construction of factories in Lewiston, chiefly for trimmings, and by the Maine Central railroad. It lies in sheets generally quite thin, from 1 foot to 2 feet in thickness, but the excavations thus far are not deep enough to display the jointing very well. The stone is a fine gray muscovite-biotite granite. Blocks 10 by 4 feet by 16 inches have been cut, and blocks 70 by 12 feet by 6 inches have been loosened in the quarry. The stone works well and takes a good polish.

Four miles east of Chesterville, Franklin county, granite is quarried to a very limited extent, chiefly for underpinning, and is used locally. The underpinnings of some of the houses in Farmington are of this stone. It is medium fine-grained, and occasionally porphyritic, indistinctly laminated, lies in very regular, smooth sheets, and varies from 1 foot to 5 feet in thickness; long east and west joints traverse the quarry at intervals; other joints are very rare; the rift is horizontal and remarkably good. There are few patches, but quartz and feldspar veins disfigure the stone to some extent. It is a good working stone, splits readily in the direction of the lamination, and takes a good polish. Blocks 20 by 3 by 4 feet have been moved, and natural blocks about 100 by 35 by 5 feet are found in the quarry.

Three-quarters of a mile east of Bryant's Pond station, on the Grand Trunk railway, in Oxford county, there is a quarry operated by the railroad for its own construction. It was used in the construction of the Bacon Falls bridge near West Paris. The stone lies in rather irregular sheets, generally from 2 to 4 feet in thickness; there are frequent joints having an east and west direction, and dikes parallel to these joints bound the quarry on two sides. The rift is on the lift, the grain vertical and parallel to the jointing. Quartz and feldspar veins are frequent; some patches occur. Blocks 9 by 2 by 2 feet are the largest that have been shipped from this quarry; blocks 60 by 10 by 7 feet have been started by blasting; there are natural blocks in the quarry 75 by 20 by 4 feet. It is a dark gray, indistinctly-laminated biotite granite, is a safe and free-working stone, and takes a good polish.

Three and a half miles south of Turner, Androscoggin county, there is a quarry producing granite for general building and cemetery work, and used chiefly at Lewiston, Auburn, and vicinity. It was used in the construction of the Lewiston dam, the Episcopal church, Lewiston, and in the Phœnix block, Auburn. The stone lies in sheets of from 1 foot to 6 feet in thickness; the principal joints run northeast, and the grain is parallel to them. The rift is quite good, and is horizontal or in the lift. There are occasional patches in the stone, and white stripes are quite frequent. In producing the material for monumental work these defects cause considerable waste. Blocks 9 by 6 feet by 8 inches have been quarried. It is a dark gray biotite granite, is a good and safe working stone, and takes a good polish.

Two and a half miles south of the dip in Brunswick, Cumberland county, granite is quarried to a limited extent for underpinning and wall work, used at Brunswick, Harpswell, Topsham, and Bath. It was used to some extent in Denison's block, in Brunswick, and in the foundation of Memorial hall, Bowdoin college; Parish church, Portland; Bowdoin College chapel, cotton factory at Brunswick, Exchange building at Bangor, and paper-mill at Topsham.

Memorial hall, Bowdoin college, is quite a large stone structure, with two tall towers, in Norman style of architecture. The stone has stood exposure to the weather very well, but from the use of inferior mortar is greatly disfigured by white efflorescences running down from between the stones. The material itself has a uniform color and the appearance of a quartz in color and splinty cleavage. The mica gives it a glittering appearance, even when seen at a distance. Blocks 40 by 2 feet by 8 inches have been moved, and natural blocks of about 70 by 2 feet by 1 foot are found in the quarry. The stone is a light gray, massive biotite granite, and is a good, safe, free-working stone, taking a good polish.

A few miles south of Pownal Centre granite is quarried for monuments, general building purposes, and street work, and to some extent for columns and polished cemetery work. Paving blocks are sometimes shipped to New York city. The following are some of the buildings in the construction of which the material was used: Gorham normal school; a section of the Lewiston dam; in the lower Lewiston bridge, and the trimmings and foundations of factories there; the stone-work of the Lewiston and the Portland water-works; a portion of the Yarmouth bridge, in Maine, and the larger part of the lower story of the new capitol at Albany, New York.

In one of the quarries the sheets vary from 6 inches to 2 feet in thickness; the rift is on the lift, grain east and west. No sap on the sheets except on the joints, which have an east and west direction, and a dike crosses the quarry parallel to them.

In another quarry the sap is quite thick on the surface of the sheets, remarkably so compared to other quarries in the vicinity, but on the lower sheet it is almost nothing. The sheets are usually less than 5 inches in thickness at the top; the rift is horizontal, the grain has a northeast and southwest direction, the sheets dip east, and great head joints run northeast and southwest through the quarry, though but few of them appear. The stone is quite free from defects. Dikes cross parallel to the headings.

Near Biddeford, York county, granite is quarried for general building purposes and cemetery work, and to some extent for polished columns. It has been used in the construction of sea-walls at Gallup island, point Alton, Long island, and Boston harbor; in the Cross Ledge light-house; the foundation of the new railroad elevator, Jersey City; fine building on Broadway, New York city, in which the material is carved and polished; forts Preble, Scammel, and other forts in Portland harbor, and in numerous breakwaters along the coast; supports of the columns, in part, of the Brooklyn elevated railroad; outside structure of the monument to Abraham Lincoln, Springfield, Illinois; Boone Island light-house, Maine; Whalesback light-house, in Portsmouth harbor, and Cochecho mills, Dover, New Hampshire, and new docks in North river, New York city.

In one of the quarries great seams and occasionally a dike parallel to them traverse it in a northeasterly direction, dipping steeply east, and being perpendicular, with a thickness of 12 feet or less. There are also large joints crossing at right angles in sheets, so that the blocks are irregular in shape. The material contains the usual patches of the Biddeford granite.

In another of the principal quarries frequent northeast and southwest seams traverse it with a steep dip to the east, and run through the quarry from top to bottom, and other, though much less frequent, seams at right angles to these. The stone consequently lies in parallel sheets, dipping steeply, and occasionally so cut by the cross-seams as to be in rhomboidal blocks. The rift is vertical and oblique to both sets of joints. There are black patches.

Adjoining this quarry is another one having very much the same conditions, but there are long, nearly vertical, northeast and southwest seams cutting through the quarry. The rift is oblique to either set of joints. The grain or next easiest splitting direction is horizontal, and the hardest splitting direction is parallel to the main northeast and southwest joints, which is very unusual. There are some horizontal joints also, so that much of the jointing is irregular. In some new openings in the vicinity there are two sets of long joints similar to those described in the preceding, and the stone lies more in horizontal sheets than in the other quarries; these sheets are from 1 foot to 7 feet in thickness. The rift is vertical and oblique to the two sets of joints. The material is a gray biotite granite, is a compact, safe, and free-working stone, and takes a good polish.

Between Kennebunkport and the Boston and Maine railroad, in York county, granite is quarried to a limited extent, chiefly for underpinning, and used at Kennebunkport, Saco, and Biddeford. The stone lies in sheets about 4 feet in thickness and in regular shape; it contains patches and white feldspar streaks. Blocks 15 by 2 feet by 6 inches have been quarried for underpinning. There are natural blocks 75 by 30 by 4 feet. It is a light gray biotite granite, coarse in texture, and massive.

From 7 to 10 miles north and northwest of Kennebunkport there are quarries producing granite for general building purposes, polished columns, monuments, and cemetery work. Among the structures in which the stone was used are the Creshore works at Portsmouth, and the vault of a bank at Exeter, New Hampshire; Newburyport Savings bank, and a Catholic church; and the foundation of the Boston Bridge Company's building, Cambridge, Massachusetts.

In one of the principal quarries the stone lies in rather irregular sheets and is irregularly jointed. The sheets vary in size, one being from 9 to 12 feet in thickness. The most prominent joints run southeast, and the rift is parallel to these, though not well defined in any direction. There are occasional patches. In another one of the quarries the sheets are not well marked, and the stone lies between great headings running N. 50° E., and dipping steeply to the westward. The rift is vertical and at right angles to the course of the headings. There are few patches.

In another quarry the stone lies in sheets varying from 5 to 9 feet in thickness. The principal vertical joints run southwest through the quarry at intervals, and there is a dike crossing it parallel to these joints. There are also some large headings at right angles to these. The rift is vertical and parallel to one set of headings. Patches are few. Blocks 18 by 20 feet by 20 inches have been quarried, and there are natural blocks of 50 by 30 by 12 feet. The stone is a gray biotite granite, massive, and coarse in texture.

Four miles southeast of South Berwick, York county, granite is extensively quarried for general building purposes and cemetery work. The following are some of the structures in which it was used: Stratford Company's house, near Dover, New Hampshire; stone-work of the Cunningham shoe factory, and a large tomb in the cemetery at South Berwick, Maine. This quarry has not been sufficiently developed to show the jointing, which at present seems very irregular. The stone is free from patches and the rift is horizontal.

NEW HAMPSHIRE.

[Compiled mainly from notes of Professor C. H. Hitchcock.]

GRANITES.

At Plymouth, Grafton county, a massive, gray biotite granite is quarried for general building purposes, culverts, and monumental work. The culverts of the Boston, Concord, and Montreal railroad are built of the Grafton granite. Natural blocks 20 by 15 by 10 feet are found in the quarry, and the material of the stone lies in horizontal sheets from 2 to 10 feet in thickness.

At Lebanon, Grafton county, the granite, properly a biotite-epidote gneiss, is quarried for general building and cemetery work. The principal markets are Lebanon and Hanover, Vermont. Natural blocks 10 by 10 by 40 feet are found in the quarry. There are obscure signs of stratification, and dips about 70° northwest. All the quarries here show the same features of dip. The workable granite is in horizontal sheets, and the workmen follow the material horizontally into the hill. The joints dip 70° easterly; one or two have a southeast direction. The rift is horizontal. (See *Geological Report of New Hampshire*, Vol. II, p. 355: "Inverted Dip.")

At Hanover, near Enfield village, Grafton county, a gray, massive biotite granite is quarried for general building purposes. The principal market is Hanover, New Hampshire. The stone lies in sheets varying from 6 inches to 9 feet in thickness. It is coarse in texture and not susceptible of a good polish. Natural blocks 200 by 12 by 9 feet are found, and blocks 23 by 9 by 8 feet have been quarried. Discolored joints are found at all depths to which the stone has yet been quarried.

At Rumney, Grafton county, a gray, massive biotite granite is quarried for monumental and building purposes. The stone was used in the construction of the Franklin monument at Plymouth. It lies in horizontal sheets, and the largest natural blocks are 20 by 5 by 5 feet. It is pronounced by Professor Hitchcock to be of the same horizon (Montalban) as the Concord granite.

At Sunapee, Sullivan county, a massive, biotite-muscovite granite is quarried for monumental and building purposes, and is used principally at Newport and Claremont. There are two principal varieties as to color, a light gray and a dark gray. The sheets have a dip of 25° west. Of the two kinds of granite which have been protruded through the porphyritic gneiss at this place black granite is the oldest, which is known from the fact that pieces of it are found in the light-colored granite. This light granite is really the equivalent of what, in Professor Hitchcock's report on New Hampshire, is called the "Upper Bethlehem", but he pronounces it an eruptive granite. Dr. George W. Hawes, in his first catalogue of lithology for New Hampshire, calls this black granite a mica schist. The black granite has the usual appearance of an erupted mass; the ledge of white granite does not reach 100 feet in width, therefore the quarry is limited though well situated. The seam of epidote lies between the two granites. Both varieties are compact, good, and safe stones to work, and take a high polish.

At West Concord, Merrimack county, a massive, gray biotite-muscovite granite is quarried for general building purposes and cemeteries. Among the prominent buildings in which the stone was used are the Horticultural hall, Security bank, the city hall, and Masonic temple, Boston; the Philadelphia city and county building (part), and the Massachusetts state prison, and the *Herald* building, Boston.

At Concord a massive biotite-muscovite granite is quarried for monumental and building purposes. Among the prominent buildings in the construction of which this stone has been used are the Life Insurance Company's building, Boston; monument to the discoverer of anæsthetics, at Public garden, Boston, and the Cadet monument Mount Auburn cemetery, Cambridge, Massachusetts; soldiers' monument, Concord, Massachusetts; Charter Oak Insurance building, Hartford, Connecticut; Jordan & Marsh's building; soldiers' monument at Manchester, New Hampshire; Equitable Life Insurance and Germania Savings Bank buildings, and the city hall and Horticultural hall, Boston, Massachusetts. It is a good, safe, and free stone to work, and takes a high polish. For commercial purposes this granite is divided into four classes: 1st, the best for monumental work; 2d, the next best for general building purposes, where one good face is sufficient; 3d, second quality of stock, including much of the underpinning for ordinary dwelling-houses, steps, capping for walls, and hitching posts; 4th, foundation stones, piers, and abutments, and other uses in which uniformity of color is not desired.

Some of the principal quarries are situated on what is known as Rattle Snake hill, which elevation consists almost wholly of a granite formation. The stone on the south side is very light colored; that on the north side is darker. The elevation is 600 feet above the Merrimack river, and the distance from the river to the crest of the hill is 2 miles. The surface of the rock is polished down by glacial action as smooth as an earthen plate. There are some patches of a darker color than the prevailing material, some of which are 18 inches in diameter. Masses of quartz from 1 inch to 6 inches in diameter occasionally occur in the stone. The rift inclines to the west about 1 inch to the foot, and the grain is vertical, having a north and south direction. There are also some joints having a southeast and northwest direction crossing the regular east and west joints. In one of the principal quarries on the east side of the hill the stone fractures best with an east and west line.

Oak hill is a similar elevation to Rattle Snake hill, and is also a granite formation, but the material is usually coarser and more broken. Dikes running through the hill cause variations in the structure of the mass.

A massive, gray biotite-muscovite granite is quarried at Allenstown, Merrimack county, for general building purposes and cemetery work. The natural advantages of this quarry are of the very best, and few of the New

Hampshire quarries are better situated for drainage, size of sheets, availability, and convenience to railroad and markets. It is on the Concord railroad, midway between Concord and Manchester. The material is of medium fine texture, and is jointed horizontally and vertically. There are natural blocks 80 by 20 by 10 feet.

At Durham, Strafford county, a massive, gray biotite granite is quarried for foundations and for flagging. It was used in the foundation of Sawyer's mill, and most of the buildings in Dover, and is transported by boat and wagon. It is coarse in texture, and is a good and safe stone to work, taking a good polish. It lies in sheets of from 6 inches to 2 feet in thickness, inclining to the west. There are natural blocks 20 by 15 by 4 feet in thickness. It lies at the horizon called by Professor Hitchcock "Exeter syenite".

At Raymond, Rockingham county, a pinkish-gray, indistinctly-laminated biotite granite is quarried for general building purposes and cemetery work. The principal markets are the large towns in the neighborhood. The stone was used in the foundations of the custom-house at Portsmouth. The texture is medium fine, and has a jointing similar to the granite quarried at Manchester. Blocks 24 feet square have been quarried. This granite works well and takes a good polish. Professor Hitchcock reports this stone as weak and not likely to be much used save where good stone is scarce, as in the lower part of New Hampshire.

At Peterborough, Hillsborough county, a light gray, laminated muscovite-biotite granite is quarried for general building purposes and curbing. The principal markets are Worcester, Lowell, and Lawrence, Massachusetts. This stone is sometimes called a gneiss from its distinctly-laminated structure; it would perhaps be more proper to term it a gneiss than a granite. It splits readily in the direction of the lamination and takes a good polish. The texture is coarse, and the sheets incline 70° to 75° west. Blocks 28 by 6 by 10 feet have been quarried, and natural blocks 36 by 6 by 12 feet are found in the quarry.

At Milford, Hillsborough county, a gray, indistinctly-laminated biotite granite is quarried for general building purposes and cemetery work. The prominent buildings in the construction of which this stone has been used are the Merchants' exchange, Nashua, and the engine-house at Lowell; the town hall at Wakefield and court-house in Worcester, Massachusetts; and the Wilcox block, at Windsor, Connecticut.

There is quite a number of different quarries in this granite near Milford, and the material is generally a good and safe stone to work, taking a good polish. Blocks of any desired size are found in these quarries, and in many places there are irregular, large, vertical dirt joints, and in some of them coarse sand from 2 inches to 2 feet in thickness separates the sheets.

At Mason, Hillsborough county, a gray, indistinctly-laminated biotite granite is quarried for cemetery and street work and general building purposes. The principal markets are Lowell, Worcester, and Walton, Massachusetts. There is quite a number of very coarse granite veins, varying in thickness from 2 inches to 2 feet, which are called "salt veins" by the quarrymen. The larger blocks of granite are quarried with facility, by reason of the existence of these small veins. The stone is of medium-fine texture, is good and safe to work, and takes a very high polish. In one of the principal quarries the typical two sets of joints cross each other, and are very regular, a fact which is not, however, unusual in the granite of this region. Seams of clay sometimes are infiltrated into the joints. With regard to the joints Professor Hitchcock states that all the New Hampshire quarries have usually the following: 1st, a set of horizontal seams or joints, enabling the workmen to raise the stone parallel to the surface; 2d, vertical joints, usually well pronounced; 3d, scattering joints, often causing the rectangular blocks produced by the first two sets to become wedge-shaped. Sometimes only one of these wedges is worked. Invariably these seams that are highly inclined, if pronounced, carry some dirt derived from muddy water. Many quarries have no scattering joints at all. The line governing their occurrence has not yet been discovered.

Near Nashua, Hillsborough county, a light gray, indistinctly-laminated muscovite granite is quarried for foundation and dimension work. This stone is well adapted to foundations, buildings, and street and cemetery work, where simple rock-faced work is required, but is not adapted to ornamental or fine hammered work. For better classes of building purposes in this vicinity the Nashua granite is used, and the Concord granite for ornamental work. Slabs 20 feet long, for cemetery borders and underpinning, have been obtained from this quarry.

At Wilson hill, 1½ miles from Manchester station, Concord railroad, Hillsborough county, a pinkish-gray, indistinctly-laminated biotite granite is quarried for foundations and underpinnings and trimmings for buildings. The principal market is Manchester. It is assigned geologically to the lake gneiss. The texture is coarse, and has the usual horizontal and vertical jointing of New Hampshire granites. It is of value chiefly because within the limits of the considerable city of Manchester.

At Fitzwilliam, Cheshire county, a massive gray granite is quarried for general building purposes, ornamental work, and paving. The principal markets are New England and the west. Among the structures in which this stone has been used are Saint Paul's church, Worcester, and the trimmings of Murdock block, and the national bank, Winchendon, Massachusetts; soldiers' monument at Granville, New York; Keene (New Hampshire) court-house; court-house at Albany, New York; trimmings of Morse Institute, Natick; court-house at Fitchburg, and Kruff's block, Pearl street, Boston, Massachusetts. The Fitzwilliam granite is of a fine or medium-fine texture, and varies in its ingredients so that the microscope shows specimens from some quarries to be muscovite-biotite granite; from others, biotite granite; and some of the material is laminated so that it may be termed a gneiss. In one of the principal quarries there is a light gray muscovite granite and a dark gray biotite granite. The geological horizon is that of the Montalban Archæan rocks. The position of one of these quarries is mentioned as particularly favorable; it is located on the broad north slope of a hill, drains itself, and a very large surface has been exposed to view. If at all defective, it is in the existence of many thin sheets. The Fitzwilliam granites are generally compact, free, and safe-working stones, taking good polish.

One and one-quarter miles east of the depot of Marlborough, Cheshire county, a gray, massive biotite granite is quarried for building and paving purposes. Among the prominent buildings in the construction of which this stone was used are a church and the Union depot, Worcester, Massachusetts; stone mill at Harrisonville, railroad bridge at Keene, and library building in Marlborough, New Hampshire. The stone lies in sheets which are inclined from 2° to 5°, and vary in thickness from 3 inches to 3 feet. There are natural blocks as large as 30 by 14 by $2\frac{1}{2}$ feet. The stone is good and safe to work, and takes the highest polish. Geological horizon, Montalban.

At Troy, Cheshire county, granite is occasionally quarried for local purposes. It was used in the construction of the bank and court-house in Fitchburg. Some of the quarries there produce excellent material for curbing, being hard and brittle, but free from iron.

At Roxbury, Cheshire county, granite is occasionally quarried for local purposes, and it was used to some extent in the construction of the state-house, in Albany, New York, which was in fact the chief purpose for which the quarries were operated.

VERMONT.

[Compiled mainly from notes of Professor C. H. Hitchcock.]

MARBLES AND LIMESTONES.

The noted marble districts of Vermont are in the vicinity of Rutland and Sutherland Falls, Rutland county; Dorset, Bennington county, and on the islands and near the shores of lake Champlain, in Grand Isle and Franklin counties, known generally as Lake Champlain marble. The marble of Rutland and Bennington counties is used very extensively throughout the United States for general building and monumental purposes, and is among the most widely known marbles in the country. According to the classification adopted in this report, this material varies sufficiently in its composition so that some of it may be properly called a limestone, some of it a magnesian limestone, and some calcareous dolomite. Like nearly all the other material known in the markets as marble which is quarried in this country, it belongs to the Lower Silurian formation. The strata of the rock are usually inclined at various angles, and the courses are of such thickness and the jointing is of such a nature that blocks of any desired size may be obtained. In color it varies from white to a dark bluish, and some of the white is of such quality that it is used for statuary purposes.

The Lake Champlain marble from Swanton, Isle La Motte, and other places in this district varies in its composition so that it is sometimes a magnesian limestone and sometimes a dolomite. It is used chiefly for interior work, mantels, tables, inlaid work, and tiling, and may be seen in many of the most important structures in the country. It is of various mottled and variegated colors. Some of the quarries produce black marble. The variegated appearance of some of this marble is heightened by its highly fossiliferous nature.

GRANITES.

Nearly all of the granites quarried in Vermont are of the Calciferous mica-schist, a formation which Hitchcock states may be as late as Devonian, certainly not earlier than Upper Silurian. They are usually biotite granites of various shades of gray, and have not as extensive a use throughout the country generally as the New England granites situated on the coast—a fact probably due to the less expensive means of transportation of the coast granites. The Saint Johnsbury granite, which, according to Winchell, belongs to the lake group of New Hampshire, is quarried extensively, and is marketed chiefly in the neighboring cities of New York.

SLATES.

The important slate formation of Rutland county, Vermont, is, according to Hitchcock, of Cambrian age. The principal quarries are near Northfield, Castleton, Fairhaven, Poultney, and Powlet, and produce material for roofing, mantels, billiard tables, tiles, school slates, trays, sinks, furniture, and for ornamental and various other purposes. The different colored slates obtained are chiefly a bluish-black, purple, and green. They are used throughout the United States for the purposes before mentioned.

CONNECTICUT.

[Compiled mainly from notes by Harrison W. Lindsley.]

BROWN AND RED SANDSTONE, TRIASSIC FORMATION.

The surface rocks of Connecticut are Archæan rocks, covering most of the area of the state; a small Lower Silurian area, chiefly in the northwest corner of the state, producing limestones which thus far have been quarried only to a limited extent for purposes of construction; and the Triassic rocks of the Connecticut valley, extending, according to Professor J. D. Dana, from New Haven, on Long Island sound, to northern Massachusetts, having a length of 110 miles and an average width of 20 miles. This formation furnishes the celebrated brown sandstone quarried at Portland and at other places in the Connecticut valley. The principal quarries are at Portland and at Middletown, on the east bank of the Connecticut river, near the junction of the Air-Line and the Connecticut Valley railroads, in Middlesex county. These quarries are operated on a very extensive scale, and the most improved methods of quarrying are in use, the work being largely done with steam channeling-machines, as the stone is of such a nature that it is readily cut in this way.

The "Connecticut brownstone", as it is known in the market, is extensively used for all kinds of building and monumental work in the principal cities of the Atlantic border, in Canada, and in Chicago. Most of the fronts on Fifth and Madison avenues, New York city, are built of this stone. Transportation is by boat and by rail. The wharves are situated within 100 yards of the quarries, and railroad tracks are extended into the quarries. The material is very uniform in character and appearance. A considerable quantity of stone from each of the quarries was used in the construction of the Vanderbilt brownstone house on Fifth avenue, New York, and was used indiscriminately in the front of the building. Blocks about 30 by 7 by 7 feet have been moved in the quarry, and there are natural blocks as large as 100 by 50 by 20 feet, so that blocks of any desired size may be obtained. This stone splits in uniform layers from one-sixteenth of an inch in thickness to 15 or 20 feet thick. The texture is medium as to fineness of grain compared with other sandstones, and is very uniform. According to Dana this sandstone is largely a granitic sand-rock made of pulverized granite or gneiss. The following analysis of a specimen was obtained by Mr. F. W. Taylor, chemist of the National Museum:

	Per cent.
Silica	69.94
Iron sesquioxide	2.48
Alumina	13.55
Lime	3.09
Magnesia	trace
Soda	5.43
Potash	3.30
Ignis iron	1.01
Manganic oxide	0.70
	99.50

The Connecticut brownstone should invariably be laid in walls as it lay in the quarry bed, as the signs of stratification are usually distinct, and the material has a tendency to split when set on edge.

There are also extensive brownstone quarries at East Haven, near New Haven, on the Air-Line railroad. The stone at these quarries differs in some respects from that quarried at Portland; it is here a reddish, rather coarse stone, containing much quartz in grains, and is employed chiefly for foundations, underpinnings, and railroad work at New Haven, and by the railroad companies of Connecticut and Massachusetts. It was used in the construction of Saint Paul's church, New Haven, and for the abutments and piers of numerous railroad bridges. The stone is in quite uniform layers 2 or 3 feet in thickness, and blocks 20 by 4 by 3 feet have been obtained. The joints are not frequent and are quite irregular.

Small quarries of the Triassic sandstone are operated at several other points chiefly for local use. Among these points may be mentioned Buckland station, Hartford county, on the Hartford, Providence, and Fishkill railroad, where stone of a very beautiful reddish color, but slightly coarser grained than the Portland stone, is obtained. The material here seems to be in every way suitable to all general building purposes, and can be obtained in blocks of any size ordinarily required. The quarry has also good facilities for transportation by rail.

At Hayden's station, within a few yards of the New York, New Haven, and Hartford railroad, is a quarry of brown sandstone formerly operated to supply stone for the dam at Windsor ferry. It has been operated for local uses for a hundred years. The stone is similar to the Portland stone, but somewhat redder in color, and as there are good facilities for transportation, both by railroad and river, it may be of importance in the future.

At Suffield, Hartford county, there are a number of small brownstone quarries, none of which have been operated except for local or private purposes. Other quarries are operated for local purposes at Newington, Hartford county, Farmington, and Forestville. It will be noticed, however, that the extensive quarrying in Connecticut on this formation is done only at Portland and East Haven.

The principal quarries on the trap dikes of the Triassic age in Connecticut are at East rock and West rock, north of New Haven. The material here is diabase, nearly black in color, fine and uniform in texture, and it is used for cellar stone and street paving in New Haven. This rock is much cut by irregular joints, so that blocks of a size suitable only for cellar work and paving stone can be obtained; however, it serves well for these purposes.

GRANITE AND SYENITE.

Extensive quarries of granite and gneiss are located at various points in the state, especially near Thomaston and Roxbury, in Richfield county; on Long Island sound, in Fairfield county; near Ansonia, Branford, and Stony creek, New Haven county; Middletown and Haddam, Middlesex county; and near Lyme, Niantic, Groton, and Mason's island, New London county. The Connecticut granites and gneisses are usually fine grained and light gray in color, and the appearance is usually so characteristic as to distinguish them from other granites of the Atlantic Coast states.

At Sterling, Windham county, a biotite gneiss, rather coarse in texture, and varying in color from gray to light gray with a pinkish tint, is extensively quarried for general building purposes, monuments, and street work, and is shipped chiefly to Willimantic, Jewett City, Danielsonville, and Baltic, Connecticut, and to Providence and Warwick, Rhode Island. Among the structures in which it has been used are the Furnace block in Willimantic, the Baltic mill, and mills at Warwick, Rhode Island.

Near Thomaston, on the Naugatuck railroad, a light gray biotite-muscovite granite is quarried extensively for general building purposes, and shipped to Waterbury and the towns in the western part of Connecticut generally. Among the buildings in which it was used are the United States building (front), New Haven, and the Episcopal church, Waterbury. The material in the quarry lies in quite irregular sheets, usually inclined about 20°, and has a slightly gneissoid or laminated structure.

At Roxbury, the granite quarried for curbs, foundations, and paving, and employed chiefly in Danbury, Connecticut, and New York city, is similar in structure and composition to the Thomaston granite.

The quarries on the shore of Long Island sound produce a hornblende-biotite gneiss, used extensively for foundations, underpinnings, footings, and piers in New York city and Brooklyn. Transportation is by schooner on Long Island sound. The color of this material is a very dark gray, approaching black.

Near Ansonia a bluish-gray muscovite-biotite gneiss is quarried for general building purposes and used in the vicinity, at New Haven and Bridgeport. Among the structures in which it was used are the copper-mill and clock shops in Ansonia, and Howard Avenue church, New Haven. This gneiss splits very evenly in slabs of almost any thickness. Slabs of 4 inches in thickness can be obtained about 2 feet in width and from 4 to 6 feet long. The rock on the natural surface looks fibrous like a piece of straight-grained wood, and splits vertically in the direction of this grain as well as in the plane of the quarry bed. It can be successfully polished only at right angles to the plane of lamination. A large seam of quartz about 6 feet square in the section crosses on top of this quarry in almost a straight line, having a direction northeast and southwest. This rock is exposed at many points in the vicinity, and probably could be profitably worked at nearly all of the outcrops.

Near Branford the material, though locally called granite, is a biotite gneiss, and has thus far been used for breakwaters and coast engineering works at fort Jefferson and New Haven. A portion of the breakwater in New Haven harbor was constructed of this material It is shipped in barges. This stone is not very uniform in texture and color; even in the same quarry it varies in color from dark gray to a pink.

A biotite granite is quite extensively quarried at Leetes Island station, 6 miles east of Branford, on the Shore Line railroad, in New Haven county. It is used for general and ornamental purposes, chiefly in New York city. Among the structures in which it has been used are the bridges at Springfield and Harlem. It is transported by boats.

The stone quarried at Arnold's station and Maromas station, on the Connecticut Valley railroad, in Middlesex county, is a very dark gray or black hornblende-biotite gneiss, varying from fine to coarse in texture, and used chiefly for curbs, flagging, and steps and street work at Philadelphia, Pennsylvania, Camden, New Jersey, and Springfield, Massachusetts. It is transported by schooners and boats. This rock is considerably marked with fine white veins from one-eighth of an inch to 2 inches wide running irregularly through it. There are occasional quite large veins of quartz, much stained with iron, running through the ledge, but the iron stains are only on the surface. This stone was called blue-stone in the market before the North River blue-stone was extensively used. There is a streak running through portions of the ledge of very much finer and darker colored stone, which splits with a smooth, almost black surface, due to the black-mica scales. Nearly all the mica in this rock is black, and to this fact is due the very dark color of the material.

Material of a similar nature has been quarried at Deep river, at Saybrook, Hadlyme, and Haddam, on the east bank of the Connecticut. In the principal quarries the cleavage is nearly vertical and at right angles to the beds, thus making it easy to obtain blocks of required shape.

At Maromas station the quarry rock is without any jointing or division into sheets, being a solid mass, excepting near the surface. It splits, however, very easily in horizontal planes in any thickness, is very uniform in appearance throughout, and very easily quarried. The quarry is at such a level that it can be drained by the siphon. It is close to the Connecticut river and the Connecticut Valley railway, so that the facilities for transportation are good.

The quarries near Lyme, Niantic, Groton, and Mason's island produce chiefly a gray biotite granite. There is, however, one quarry near Lyme producing a red granite, locally called "red porphyry". The texture is coarse and porphyritic; it is used for general building and ornamental purposes, chiefly at Newport, Rhode Island. Some of the material may be seen in the Chaney Memorial church, Newport, Rhode Island.

The other principal quarry near Lyme produces a plain gray granite, rather coarse in texture, and shows on all dressed surfaces fine parallel lines of alternate dark and gray. These lines prevent its use for the most highly ornamental purposes, as they usually run obliquely across some or all of the finished surfaces. Portions of the material in this quarry are slightly pinkish in color.

The Niantic quarries produce a light gray granite of rather fine and uniform grain, used for general building purposes, monuments, and paving, chiefly in New York city, though it is used in various places in Connecticut and Rhode Island, and has been shipped as far south as Savannah. It is transported by boats. Among the structures in which it has been used are the Norwich court-house, the New York reservoir, and fort Adams, Newport, Rhode Island. The surface rock of this and other granite quarries in the southeastern part of the state is thought to be looser in texture than the rock below and much more easily broken. It is often coarser and less uniform in texture. The usual thickness of this surface rock is from 5 to 15 feet. It is utilized for riprap and similar rough purposes, and may be considered as the lowest grade of the production of these quarries. At the Niantic quarries there are two grades, the finest grain being a perfectly uniform gray in color on a polished surface, and the second having a polished surface covered with spots from one-half to three-quarters of an inch in diameter, quite uniformly spaced from 1 inch to 3 inches apart, and looking much as if a wet finger had been repeatedly applied to the smooth surface. The discoloration in natural joints does not penetrate the stone at all, but discolors the whole surface of the joints as far as it extends.

These quarries are the largest located on Long Island shore between New Haven and the Rhode Island line. They have supplied material for a large number of the ports along the Atlantic coast and for government works at many other places. A small portion of the material at certain sections in the quarries is slightly pinkish in color.

The granite quarried at Groton is a light gray material of a rather fine and uniform grain. It is used for cemetery work, monuments, curbs, trimmings, and breakwaters, chiefly at Providence, New Haven, Hartford, Buffalo, Erie, Milwaukee, Cincinnati, and Chicago. The transportation is partly by boat, but chiefly by rail. Nearly all of the material of the best quality produced by these quarries is used for ornamental work, as it is uniform in color and texture and takes a fine polish. Much of the stone shipped from these quarries is dressed and finished.

At Mason's island, south of the Mystic river, Long Island sound, a gray granite is extensively quarried for riprap and breakwaters. The ledge is very much broken by joints, and blocks of large size are not readily obtained, though the quality and structure of the material and the location of the quarries make it well adapted and convenient for the purposes for which it is used. The material thus far quarried has been chiefly the surface rock. At several places, however, large sheets of what seemed to be much more uniform and better granite have been reached. The rough rock overlying these sheets is from 15 to 30 feet thick.

At Mystic River there is a granite quarry producing a fine quality of gray granite, which may be obtained in blocks of any desired size. As yet, however, it has not been much operated. This quarry is situated on the side of a steep cliff or ledge, very accessible and conveniently located for quarrying, near the Mystic river.

At North Bridgeport, Fairfield county, and Killingly, Windham county, gray and rather coarse-textured hornblende-biotite gneiss is quarried for local use. A material of similar character is quarried at Willimantic for curbing and flagging, chiefly for local use. Fine-grained gray-biotite gneiss is quarried at Bolton, Tolland county, for flagging, and used chiefly in Hartford; it is, however, shipped to some extent to other New England cities.

Dark gray biotite gneiss is quarried for street work at Glastonbury, Hartford county, and used chiefly in Hartford.

At West Norfolk, Litchfield county, a very beautiful light gray, fine-grained gneiss is quarried. It is uniform in texture and color, and has a bright, fresh appearance. It is nearly all distinctly laminated, and is a biotite-muscovite gneiss, though specimens forwarded to the National Museum are properly called "granites".

SERPENTINE AND VERD-ANTIQUE MARBLE.

In the Archæan rocks near New Haven are deposits of serpentine and verd-antique marble, which have not thus far been quarried to any great extent, although if worked they would furnish excellent material for interior decoration and other ornamental purposes.

The serpentine is gray, mottled, yellowish, and greenish in color when rough; when polished it is dove-colored, with lines of yellow and green.

The verd-antique marble is of a grayish color when rough; when polished it is dove-colored, yellow, greenish-yellow, and black and white. The difficulty of dressing and polishing this material seems to have prevented its extensive use thus far.

NEW YORK.

[Compiled mainly from notes by Professors Cook and Smock.]

GRANITE.

Granitic rocks are quarried for local use in a number of localities in Westchester county, and the material is generally fit for rough work only. The gneiss quarried near Hastings by Messrs. Munson & Co., however, is used principally in New York city for foundations and general construction purposes. This is a rather coarse grained material, and is striped by alternate layers of light and dark, varying in thickness. Nearly all varieties, as to color, texture, and composition, occur in this region, though no very valuable exposures have been developed in localities convenient to water transportation.

In Putnam county the granitic rocks are well developed, and have been worked in various localities in cliffs along the Hudson river.

On Grindstone island, one of the Thousand islands, Jefferson county, a beautiful red granite is obtained, which is rather hard to dress, but is susceptible of being very highly polished.

The product of the quarry is at present manufactured into paving blocks and stones for monumental work; the former are used in Chicago, Illinois, and the latter are shipped to Montreal. The quarry is favorably located for transportation by the great lakes and the Saint Lawrence River system of navigation; it is on the west side of Grindstone island, about 5 miles west of Clayton, Jefferson county, and at the dock adjoining the quarry vessels of 400 tons burden can land.

SANDSTONE.

At Malone, Franklin county, the Potsdam sandstone is crossed by the Salmon river, and here some stone is quarried for local demands, but no quarries were reported as worked during the census year.

Three miles south of Potsdam, Saint Lawrence county, the Raquette river cuts across the Potsdam formation, and quarries are worked along the banks of this stream. The outcrop of the sandstone where it is cut across by the river is about 2 miles in width from north to south. The strata dip in a southerly direction at an angle of 45°. The formation shows signs of disturbance, and the layers near the surface are thin and are used for flagging. As the excavation proceeds downward the layers gradually increase in thickness until, in the bottom of the quarry, at a depth of about 40 feet, the layers are from 2 to 3 feet thick. These layers split readily, when first quarried, into any desired thickness. The stone works well when first taken out, but becomes quite hard upon exposure. Much of this stone has a pleasant reddish-brown color, which is very durable, but some of it shows a rusty discoloration upon long exposure. It is quite refractory, and is used for lining cupolas in the furnaces at Potsdam. A large amount of it has been shipped to New York for use in the construction of the new buildings of Columbia college; three churches, the Normal School building, and the town hall at Potsdam, are also built of this stone. The most westerly point where the Potsdam sandstone is worked is at Hammond, in the extreme western part of Saint Lawrence county. The strata here are very nearly horizontal, but the jointing is irregular. The stone is of good quality, and varies in color from gray to red. Thin layers also occur at the top at this point, and heavy layers are found lower. The quarry is conveniently located for transportation, and the stone is used for curbs, flagging, and paving, principally in towns of central New York.

In Washington county the Potsdam sandstone is from 50 to 60 feet thick, generally covered by alluvium, and nowhere extensively quarried. At Fort Ann it is almost pure quartz, and is quarried for use in the steel-works at Troy, and also for the construction of hearths. There are some small calciferous-sandstone quarries in the vicinity of Fort Ann, which furnish excellent paving stone and stone for underpinnings for local use.

In Schenectady county, at a point called Aqueduct, a valuable development of a sandstone stratum in the Hudson River group occurs. It is a very fine-grained, stratified sandstone, in layers separated by thin seams of slate, and the sandstone grades almost imperceptibly into slate. The strata dip slightly to the southwest, and a system of parallel joints, called side seams, runs nearly northeast and southwest, and is cut across at right angles by cross joints. There are main side seams from 30 to 55 feet apart, very regular and filled with mud, and between these there are irregular parallel joints at distances of from 2 to 12 feet apart. In the southward extension of the formation the strata of slate run out and several sandstone layers unite and thus furnish large-sized blocks. The quarry is located on the bank of the Erie canal, by which the stone is transported to market, and the quarrying is done during the season of canal navigation. The stone works well and is used quite largely for buildings in surrounding cities.

BLUE-STONE DISTRICT.

The "flagging" or "blue-stone" of the Hudson River district belongs to several geological formations from the Hamilton upward. The district is confined to comparatively narrow limits west of the Hudson river, and mainly to Albany, Greene, and Ulster counties. It begins with the quarries in Schoharie county, passes to the southeast and enters Albany county near Berne, and from there passes around to the south and southwest, across Greene, Ulster, and Sullivan counties and across the west end of Orange county, to the Delaware river and into Pike county, Pennsylvania. There are no quarries known in any of the formations below the Hamilton down to the Hudson River slate, and the typical blue-stone flagging may all be said to come from the Hamilton formation, which, according to Professor Hall, is succeeded by the Oneonta sandstone, the equivalent of the Portage in the eastern part of the state. The Chemung shales and sandstones have not been identified, and the gray and the red beds of the Catskill mountains probably belong to the Catskill group. It may yet be found that the main blue-stone belt, which extends southwest through Hurley, Ulster county, belongs in part to the Hamilton, while the upper or western beds are of the Oneonta formation. The flat plateau or terrace to the east and southeast may be occupied by the softer Chemung rocks. If this be the case, the quarries of West Saugerties, High Woods, Shandaken, Phœnicia, Boiceville, and Brodhead are all in the Catskill group. The stone from these localities is generally coarser grained than that from the more eastern range, and the gray or the reddish tints predominate over the dark blue-black shades.

The quarry at Eminence, Schoharie county, is probably in the Chemung group. The quarries which are probably in the Hamilton group are the Middleburgh quarry, Schoharie county, the Albany County quarries, those of Greene county and of Quarryville, Saugerties, Kingston, and West Hurley, Ulster county, and those in the southwestern extension of the blue-stone district near Ellenville, Ulster county, and at Pond Eddy and West Brookville, Sullivan county. There is a great number of quarries in this district, and many of them are very small, as little capital is needed to develop a quarry, on account of the small amount of cap-rock to be removed and the little machinery necessary to operate the quarries, as they are worked almost exclusively for flag-stones of small size and small "edge stuff".

In Schoharie county the character of the flag-stone is much the same as in the quarries along the Hudson river. There are in the blue-stone formation always two systems of joints crossing each other nearly at right angles. Those of the principal system, which usually runs nearly north and south, are called "main side joints", and the others "cross joints". In the Eminence quarry the main joints run nearly north and south, and the strata dip slightly to the south or southwest. Several ledges are quarried here at different elevations, and the stone varies in texture, the highest strata being coarse-grained and varying in color from gray to red, and the lower layers are blue-black and fine-grained. The product of these quarries is principally flag-stone, which is used to supply the local demands of surrounding towns. The quarries of the Middleburgh Blue Stone Company are about a dozen small openings near Hunter's Land, and from 5 to 10 miles east and southeast of Middleburgh. The quarries are nearly all in side hills and the strata are very nearly horizontal. Near the surface a hard, thinly-bedded stone is found, which is suitable for common flagging, cross-walks, and rough work. The quality of the stone is found to improve as the quarries are worked to greater depth, heavier beds of finer-grained and more valuable stone being found. This is a newly-developed blue-stone district, and some of the best stone is suitable for trimmings. The material goes principally to Albany, Troy, and other cities to the northeast.

The stone from the Albany County quarries is coarser, harder, and more gray in color than that from the same formation in Greene and Ulster counties. The Reidsville quarries have an average thickness of workable strata of only 4 feet, covered with from 2 to 14 feet of earth and slaty beds. The quarries in the vicinity of Dormansville were formerly worked quite extensively, but for several years past they have been worked but little. The beds in these quarries are thin, and the stone goes principally to Albany for flag-stone. At Stephensville, 6 miles west of Coeymans, a more easterly range of flagging stone occurs, which, however, has not yet been developed.

The blue-stone belt, extending south from Albany into Greene county, crosses New Baltimore and Coxsackie townships, in each of which quarries have been opened, though very little stone has been taken out. At New Baltimore stone is quarried for dock filling at Albany.

The Leeds quarries consist of six or seven different openings, which are worked at intervals by farmers. The product of the quarries, most of which is for small flags, is carted to Catskill, a distance of about 2 miles. The Kiskatom quarries have been worked, but not continuously, for many years. The blue-stone belt is here quite narrow, and in the ledge worked approaches near to the limestone formations that lie between it and the Hudson. The structure of the beds is similar to that of the same formation farther south. The shipping points for these quarries are Catskill, Malden, and Smith's Landing, from 7 to 8 miles distant. The cost of carting the stone amounts to about 25 per cent. of the value at these points. The stones produced are mostly of small size, and are worked into curbs, caps, sills, steps, etc., called "edge stuff". At Palenville a large number of quarries was formerly worked, extending over a large space, but the decline in prices has put a stop to many of them. The quarries are all at the base of the mountains and several hundred feet above the surrounding lowlands, and a good quality of stone and large-sized blocks may be obtained. The strata dip westward into the mountains, and the thickness of cap-rock increases rapidly in that direction. The distance of these quarries from Malden, the shipping point, is 9 miles.

Ulster county has by far the largest number of quarries in the blue-stone district. Quarryville, in the northwestern part of Saugerties township, is a noted quarry district, which has been worked for 40 or more years, and a large amount of stone has been taken from it. The stone is sold at Malden, and is drawn there over a tramway constructed of blocks of stone. There is much less stone quarried here at present than was formerly produced, as the depth of stripping has increased to such an extent that the quarries can be worked with but little profit. The stone is of good quality and is used for turned and general dressed work at the Malden yards. The quarries lie in lines along three parallel ledges which have a general direction from northeast to southwest. There the blue-stone belt makes its nearest approach to the Hudson, the limestone belt, $3\frac{1}{2}$ miles in width, separating the most easterly ledge from the river. The beds of sandstone overlie each other from west to east, and strata of slate and hard sandstone occur between them. The vertical side seams are very regular and run north 40° east, and the joints at right angles to these are irregular and not continuous. The quarries in the easternmost ledge extend about a mile in length, 175 feet in width, and have been worked to an average depth of about 12 feet. A large area has been left on account of the heavy stripping required.

The line of quarries in the middle ledge extends over an area about $1\frac{1}{2}$ miles in length, from 150 to 500 feet in width, and has been quarried to a depth of from 12 to 20 feet. Quite heavy beds occur in some of these quarries, and the joints often allow blocks of very large size to be obtained. In the western ledge the quarries are in a line about

1,000 feet long by 150 wide, and are worked to an average depth of about 12 feet. These quarries are about 5 miles from Malden, being the most distant of all quarries here noted. The total thickness of workable layers in the Quarryville region is from 4 to 20 feet, and the stripping is from 6 to 17 feet in depth. Much of the heavy or thickly-bedded stone is taken to Malden to be worked into edge stuff. In working these quarries little capital is used beyond the value of the necessary tools. Leaseholds are common, and the royalty paid is at the rate of one-half cent per square foot of stone quarried. The larger sizes of blocks have bed dimensions of about 15 by 8 feet, although some 25 by 15 feet have been taken out. The quarries near Saugerties extend in a line from northeast to southwest, about 2 miles in length and half a mile in breadth, and are known as the Fish Creek quarries. A large area has been quarried over and a large amount of stone has been taken out. The quarries have been in operation from thirty-five to forty years, but the product is now small and is carted to Saugerties, which is from 4 to 5 miles distant, and the cost of carting amounts to one-third of the value of the stone at that place. The quarries now worked are in the midst of the old works, many of them previously abandoned. They are now not very productive, and a considerable amount of stripping is necessary. The quarry bed is from 3½ to 8 feet thick, and the stripping or cap-rock from 3½ to 7 feet thick. The stone is fine-grained and is used mainly for edge stone. The Kingston quarries are all in the same belt, and may be separated into several groups, as the Dutch Settlement group, the Hallihan's Hill group, the Sawkill group, the Jockey Hill group, and the Dutch Hill group.

In the Dutch Settlement group the quarry beds have an aggregate thickness of from 5 to 12 feet, and the strata vary from 5 to 16 inches. Generally two or three men work together in a quarry, and some of the quarries are contiguous and admit of a common system of drainage. The amount of capital invested in this region is very small, as the quarrymen do not often own the land on which they quarry, but pay a rent, usually at the rate of half a cent per square foot for the stone taken out. Formerly a large amount of quarrying was done in this locality, but the increasing expense of working the quarries and the low prices for stone have reduced the extent of the industry. The work is now mainly done by men who have their own boys to assist them, and very few men are hired. In some portions of this region the dip of the strata is to the northwest, and in others to the southwest. From the quarries of the Dutch settlement the product is carted to Glasco, Ulster county, a distance of about 6 miles, and is there sold to dealers for flagging and edge stone.

The Hallihan's Hill series of quarries is on the same ledge as the bed of stone extending southwest from the Dutch settlement to the Sawkill creek for a distance of over 2 miles. At the southern end the ledge is quite elevated, but dips to the northwest and descends until it is lost. It is the extreme eastern one of the blue-stone belt, and immediately to the east of it the land descends to the low district extending to the Hudson. The bed worked in this ledge varies in thickness from 4 to 12 feet, and the cap-rock to be removed is from 4 to 30 feet in depth. The entire length of the ledge has been quarried over. The quarries now worked were opened, abandoned, and then reopened; most of them were left on account of the depth of stripping necessary when prices declined several years ago, and are worked now by the men who were unable to leave with their families when wages were low.

The Jockey Hill and Dutch Hill line of quarries is southwest of the Hallihan's Hill quarries and forms one continuous opening, and nearly the whole surface of the ledge has been quarried over. The strata are from 2 to 3 feet thick, and the quarry beds are separated by strata of hard blue-stone which breaks and splits irregularly. The joints are vertical, and the north and south system is very regular and continuous; the east and west system is less regular and not continuous. Excepting for its quarry stone this district is almost valueless; its surface is very uneven and broken, and covered with forest trees. The stone from this district, as well as from the Hallihan's Hill quarries, is carted to Wilbur, a distance of from 7 to 9 miles. The bed dimensions of the largest blocks obtained from these quarries are 20 by 15 feet, but the possible dimensions of blocks from the quarries are claimed to be 60 by 18 feet. Each quarry has from two to ten quarrymen, very few of whom are employed for wages.

The Stony Hollow group is near the Ulster and Delaware railroad, and is the last group on the belt passing from northeast to southwest through Kingston township. The quarries are small, and some of them are on old abandoned sites. The product is taken to Wilbur on wagons, a distance of 6 or 7 miles.

The quarries of Hurley township are in four principal groups. The Bristol Hill quarries are west of Stony Hollow on the southwest extension of the Stony Hollow line, on both sides of the Ulster and Delaware railroad, but the stone is taken by wagons to Wilbur, a distance of 7 or 8 miles. A large space has been quarried over in the thirty or more years in which the quarries have been worked, and the quarries are at present doing quite an extensive business. An excellent quality of stone, applicable to the finest kinds of work for which the North River blue-stone is used, is obtained here. The West Hurley quarries proper are northwest of Bristol hill, in a noted quarry center, where blue-stone has been taken out for forty years. The area worked over is large. The stone found here is remarkable for its evenness of stratification and regularity of jointing. The joint systems are at right angles to each other, the one running northwest being open and continuous, but the one to the northeast is less regular and interrupted in places. Some of the largest quarries of the blue-stone district are in this region. There is generally a lack of capital, and therefore a loss in efficient working. These quarries are on the line of the Ulster and Delaware railroad, but the rates of transportation by railway are so high that the stone is drawn on wagons a distance of 9 miles to the canal at Wilbur.

The Morgan Hill quarries are on the line running southwest from Stony hollow and Bristol hill. They are six in number, all of them quite small, and others in the same range have been abandoned. The locality known as Steenykill marks the southwestern limit of the main Hudson River blue-stone belt, which exhibits the same characteristic features throughout from Quarryville to the Esopus creek, in Marbletown township. Some small openings have been made in the formation just southwest of this creek.

The quarries to the northwest of this belt are, as already stated, in a higher formation. The West Saugerties range of quarries is west of Quarryville and near the foot of the Catskill mountains. Its structure resembles that of the Quarryville ranges, except that the layers are usually thicker. The principal joint system runs north 40° east, and the strata dip slightly toward the southwest. The overlying beds are shale and slate with interstratified beds of rough stone unfit for flagging or edge stuff. The West Saugerties stone has a medium grain and the characteristic color of the North River blue-stone. All the stone is carted to Malden, 8 miles distant, and here the heavier stone is manufactured for various architectural uses. It is quite soft and works easier than much of the North River blue-stone. In the Highwoods quarries the aggregate thickness of the quarry beds is from 4 to 10 feet, and the stripping varies from 4 to 23 feet. Heavy stones are also obtained here, and are cut into sills, caps, and other edge stuff at the yards at Saugerties, 8 miles from the quarries, and at Glasco, from 4 to 6 miles away. At one quarry the layers are from 20 inches to 3 feet in thickness, and a block now exposed is 220 feet long, 26 feet wide, and 1 foot thick. Blocks 25 by 15 feet by 1 foot have been taken from this quarry.

The quarries in the vicinity of Woodstock are on the southern foot of the Catskill mountains, and 1,000 feet above the Hudson river. The strata dip to the northwest, and in some of the quarries the bedding and jointing are somewhat irregular. The layers are usually from 2 to 10 feet thick; the aggregate thickness of the beds is about 20 feet; the stripping is mainly slate, and usually heavy. The product is carted to Saugerties, 11 miles distant, except from the quarries of Messrs. Elting & Maxwell and P. H. Lapo; these two quarries are northwest of Woodstock; the latter is farthest in the mountains, 1 mile northwest of Cooper's lake, and several hundred feet above it. The product of these quarries is carted to Malden, from 16 to 17 miles distant, and is used almost exclusively for cut work.

The Shandaken quarries are in a locality known as Fox hollow, a short distance from the Ulster and Delaware railroad, by which the product is shipped to Rondout, and thence by river to New York city. This stone has a gray color; the layers are from 10 to 12 inches in thickness, and large-sized blocks are easily obtained, but the material is not so much desired on account of its color as the typical blue-stone. There are only two quarries as yet opened on Woodland creek, and it is quite probable that the entire eastern bank, for a considerable distance, is bordered with ledges of sandstone suitable for building and flagging. The rock is of good quality and works freely. Two distinct grades are obtained; the upper part of the bed worked is of a reddish color and rather coarser in texture than the lower portion, which is grayish in color. The bed dips toward the valley, and as it is worked back into the mountain it rises so that the stripping does not increase rapidly. The bed has been worked to a depth of 18 feet and the bottom is not yet reached. The layers are from 2 to 12 inches in thickness, and increase in thickness with the depth of the quarry. Many of the quarries in the vicinity of Phœnicia have been opened quite recently. The amount of stripping in the Phœnicia quarries is about 20 feet, making the working of the quarries rather expensive, but the excellence of the stone and the large and heavy blocks to be obtained make the quarries profitable. The Ulster and Delaware railroad also furnishes cheap transportation.

The quarries near Brodhead are all west of Esopus creek, and from 2½ to 4 miles from the station. Nearly all the stone from these quarries is dressed at Brodhead, and thence shipped to market over the Ulster and Delaware railroad. This stone is of good quality, but there is a lack of capital to open workable beds. The aggregate thickness of the beds is from 4 to 11 feet, and the stripping from 4 to 14 feet, and in some places increasing rapidly.

As has been indicated, the blue-stone formation is traceable to the southwest from the Hudson River quarries through Rochester and Wawarsing, Ulster county; and occurs in Neversink, Fallsburgh, Mamakating, Thompson, Forestburgh, Lumberland, and Highland townships, Sullivan county; and in Deer Park township, Orange county. The Rochester and Wawarsing quarries are all small openings, and generally worked on leases, along the valleys of Vernoog, Beerkill, and Lackanack creeks, all tributaries to Rondout creek. At the quarries on Vernoog creek the beds dip at an angle of 20° to the north, 60° west, and the average inclination of the strata in this region is 20°. The stone is coarser grained in these quarries than in those nearer the Hudson, but is thought to be equally strong and durable. There are many abandoned openings in this region. All these quarries are small, and the workable beds are soon exhausted on account of the steep inclination of the strata. The quarries along Beerkill creek are not now in operation; they were worked quite vigorously for a time to supply Ellenville with stone for sidewalks—a town of about 4,000 inhabitants, which has 14 miles of stone sidewalk.

Along the Delaware river the flagging-stone belt is exposed from near Pond Eddy up the stream nearly 25 miles to Lackawaxen, Pike county, Pennsylvania. The principal quarries on the New York side are in the vicinity of Pond Eddy. From one of these two large flags were furnished, each 25½ by 15½ feet by 7 inches, and their width was limited only by the size of the boats which could go through the locks of the Delaware and Hudson canal.

These quarries on the Delaware river are noted for their excellent quality of stone. The strata are here again nearly horizontal, and from 1 inch to 1 foot in thickness, and the maximum amount of stripping is 10 feet. The product is mainly taken by canal to New York city.

The quarries along the valley from West Brookville, and those along the line of the Monticello railroad, in Mamakating and Forestburgh townships, Sullivan county, are usually small. Their total production has declined greatly within ten years. The West Brookville quarries are on the mountain side, several hundred feet above the canal-level, and all the stone is carted to the canal at West Brookville. Some of this stone has a reddish color, and is said to be stronger than the Ulster County stone; but the market prices are higher for blue-stone, and there is a prejudice against red or gray shades of color. Along the Monticello branch of the Lake Erie and Western railroad there are numbers of small quarries, all of which open into steep side hills, and have a rapidly-increasing amount of stripping.

There is a great number of small openings in this region which have been abandoned. The amount of stripping is always considerable, and the aggregate thickness of the quarry beds is small and the layers are thin. The stone has the color of the Hudson River stone, but it is very hard, and none of it is equal in quality to that obtained in the Hudson River quarries. A new flagging-stone district has been made accessible to the markets by the New York, Ontario, and Western railroad, running across Sullivan and Delaware counties, and stone is being shipped both eastward and westward. The business was insignificant during the census year.

In Delaware county the flagging-stone quarries are along the lines of the New York, Ontario, and Western and the Ulster and Delaware railroads. All these quarries are probably in the Catskill group. The quarries at Westfield flats and near Trout Brook and East Branch are near the New York, Ontario, and Western railroad. The stone is a rather coarse grained sandstone or grit of a grayish to a greenish-gray color, thus differing from the darker and finer-grained blue-stone of the Hamilton formation. Various openings have recently been made in this region along this line of railroad.

At a quarry near Margaretville the depth of stripping is 8 feet, and the blocks, as limited by the natural joints, are very large. The product is carted to Hartville station, on the Ulster and Delaware railroad, and from there transported by rail to Rondout. A quarry has been opened near Halcottsville. The beds here so far as developed are from 1 inch to 4 inches thick and the depth of stripping is 8 feet. The joints are vertical and very regular; the stone is reddish in color and rather coarse grained; blocks 15 by 6 feet have been taken out, and larger sizes might be obtained.

The quarries in the vicinity of Roxbury are also near the line of the Ulster and Delaware railroad. In a quarry about 1 mile from Grand Gorge station, 70 miles from Rondout, the workable beds are 12 feet in thickness and the depth of stripping is about 30 feet. The stone has a grayish color and is coarse grained.

In Otsego county both the Hamilton and the Chemung groups are quarried in a quarry located on the east side of Otsego lake and about 70 feet above it. The jointing is rectangular, the beds are even, and the depth of stripping is 8 feet. The stone is soft, works easily when first quarried, and hardens on exposure. Where used for steps for a number of years it has not worn smooth, and shows considerable durability. At present this quarry supplies only the local demand for foundations and general building purposes.

The quarry at Oneonta supplies the local demand for flagging and cut work.

In Chenango county there was formerly quite an extensive quarry industry at Guilford, but at present only one quarry is in operation. The market for this stone is at Syracuse. Blocks of large bed dimensions may be obtained here, but the layers are rather thin. The quarry at Smithville flats is also remarkable for the large size of the blocks between the joints, and some of the layers are 2 feet in thickness. The aggregate thickness of workable beds is about 12 feet, and the depth of stripping is about 15 feet, but it is mostly loose material and easily removed The stone is shipped principally to New York city for flagging and building purposes; but it has to be drawn on wagons to Greene, 8 miles distant, on the Utica division of the Delaware, Lackawanna, and Western railroad.

In Oneida county the Oneida conglomerate quarried near New Hartford is hard and difficult to dress, and therefore is used only for bridge work and foundations. The quarry at Camden is probably in the Medina sandstone, but the formation has not been well identified. The stone is light gray in color and rather coarse grained; the layers near the surface are thin, and are used for flagging, but they increase in thickness as the quarry is worked downward. The stone is used to supply local demands, and some is shipped to Oswego and neighboring towns.

The quarry near Atwater, Cayuga county, is in a good flag-stone stratum, but its distance from the nearest railway station and the depth of cap-rock to be removed prevent its extensive development.

The Tompkins County quarries are worked chiefly for flagging. The quarry at Ithaca supplies the local demand, and the one at Trumansburg supplies flagging for the town of Geneva and some for Ithaca. The layers in these quarries are rather thin, but large blocks can be obtained. The quarries at Covert, Seneca county, also furnish flagging, which is at present used mainly at the towns of Geneva, Waterloo, and Auburn. The quarries are located but a short distance from railroad and water transportation.

The quarry at Watkins, Schuyler county, is a fine-grained, evenly-bedded blue sandstone. The stone is used along the line of the North Central railroad for general construction purposes, and it seems to be well adapted for heavy bridge construction. No good building stone is found on this line of railroad either north or south of this point for a considerable distance, and the stone from this quarry is used southward on the railroad as far as Williamsport, Pennsylvania.

The Steuben County quarries furnish stone for general building purposes, mainly for local demands. The stone dresses easily, but it is not a safe stone to use, because it is liable to disintegrate. The demand in this county for good stone is supplied from distant quarries, and flagging has been furnished quite largely from Mainsburg, Tioga county, Pennsylvania.

The quarry district in the Medina sandstone extends from Brockport, Monroe county, to Lockport, Niagara county. The stone is very hard, and therefore seldom used for cut work. There is a light gray and also a reddish variety, the latter has a bright and pleasant appearance both in dressed and in rock-faced work, and both varieties are sometimes used together with good effect, but the red is used more than the gray for buildings. Most of the stone buildings in Lockport and in Buffalo are of Medina sandstone. Perhaps the most important feature of this stone is its special applicability for street pavements. It was first introduced for this purpose in Cleveland, Ohio, and it is now used in many cities and towns from New York to Kansas City. The blocks are made of the same size and shape as the granite paving blocks; they do not wear smooth, and are nearly, if not quite, as durable as granite blocks. The stratum of quarry rock is about 30 feet in thickness, and the thickness of the layers varies from 2½ to 18 inches, the thinner ones supplying an excellent material for paving sidewalks.

The remaining quarries in the state of New York are small and supply local demands. The stone is of an inferior quality, except in the Belfast quarry, Allegany county, where it is of good quality, though so far from any route of transportation that it cannot be worked for anything but local use.

MARBLE.

TUCKAHOE MARBLE.—The quarries which furnish this are, according to Newberry, in one of the belts of dolomite of Archæan age which lie to the north of New York city, and cross the country in a north-northeast direction. One of these belts reaches New York island, crossing the Harlem river at Kingsbridge; another crops out on the sound near Rochelle; others strike the river at Hastings, Dobbs Ferry, Sing Sing, and other points, and furnish stones good for construction purposes and of varied colors. The best marbles obtained from these deposits are those of Tuckahoe and Pleasantville. The first is white, rather coarse in texture and regular in quality, and the better grades have been used for some of the finest buildings in the city of New York, notably Saint Patrick's cathedral. The color changes to light gray by exposure.

At the quarry of the Tuckahoe Marble Company the finest grade is nearly a pure white, but this is available only in small quantities, and is used for monumental and ornamental work. In Mr. John F. Masterdon's quarry this same material is quarried more extensively.

In composition the stone from these quarries is a dolomite, containing a small amount of iron and some mica. The buildings constructed of the stone from the Tuckahoe Marble Company's quarry are those of the New York Stock Exchange, New York city, and the Mutual Life Insurance Company at Boston. Those constructed of the material from Mr. Masterdon's quarry are the New York Life Insurance building, New York city, the city hall, Brooklyn, New York, and the hotel Vendôme, Boston.

At Pleasantville, a few miles north of the Tuckahoe quarries, a coarse, crystalline white marble occurs; formerly this was quite extensively quarried for building purposes. The front of the Union Dime Savings Bank building in New York city is built of this stone. Its structure being quite coarse, it is not well adapted for carved work. It has also been found to break easily, especially when used for long columns; and it would not be a safe stone on this account for all kinds of work. The stone is remarkable for its crystalline appearance, the crystals being usually large and conspicuous, and, from this peculiar appearance, it has received the name of "snow-flake" marble. This quarry has recently been furnishing about 25 tons of stone per day for making soda water.

At Dover Plains and South Dover are three other marble quarries, the stone from which also shows a coarse structure and is easily broken.

A quarry of bluish-gray limestone was opened in November, 1880, at Clinton Point, about 5 miles south of Poughkeepsie. The material that has been extracted has been used for bridge abutments at Newburgh.

At Greenport, Columbia county, Mr. F. W. Jones' quarry is worked on a stratum from 60 to 70 feet in thickness. Blocks of any desired dimensions may be obtained. The stone is employed for general architectural and ornamental uses, principally at Hudson and Troy, New York. The Presbyterian church at Hudson is constructed of it. It is a nearly pure limestone, containing some protoxide of iron and a little magnesia. The quarry of the Kingsbury Blue Stone Company at Sandy Hill, Washington county, is located on a branch of the Champlain canal and near the railroad of the Delaware and Hudson Canal Company, and has superior facilities for transporting the material to market both by canal and by railway. The quarry proper covers an area of 40 acres. A face half a mile in length and 30 feet in height is opened. The stone is very nearly a pure limestone, containing a very small amount of iron, a little magnesia, and a little siliceous matter. It was used in the construction of most of the locks upon the Champlain canal and the city dam at Cohoes, and it is now being used for the construction of the Harlem bridge for the West Side and Yonkers Elevated railway.

The quarry of Mr. Prince Wing, near Saratoga, has been worked for many years, stone for burning lime having been taken out before 1800. The lime produced from it is very white and of excellent quality. In composition it is almost a pure limestone, containing very little magnesia and some graphite. It is used for general building purposes and for flagging, mainly at Saratoga and Ballston, New York.

The quarries at Glens Falls are worked on both sides of the Hudson river, which breaks through the formation at this point. The same formation crops out a short distance east of this place, is crossed by the river, dips under the overlying formation, and disappears just above the falls. On the south side of the river there are three distinct strata of limestone; the upper one, about 12 feet thick, being overlaid by about 15 feet of rough limestone and some slate. It is fine-grained and makes a good material for cut work. Below this is a stratum of about 15 feet of the slaty-structured stone, and then a stratum 2 feet in thickness of a coarse crystalline limestone. Below this occurs the valuable black-marble bed, about 12 feet in thickness. From this a large amount of tiling is manufactured. The stone is taken out in large blocks, and is either sawed and rubbed in the mills at the quarry or is shipped in the rough, mainly to the neighboring cities and to New York. The tiling and material for ornamental purposes go to all the principal cities in the United States. The stone is shipped both on the Champlain canal and the Delaware and Hudson Canal Company railroad. It is a limestone in composition, containing a little magnesia, some iron, and some graphite. None of the products of the lower stratum are allowed to go to waste, though a very large proportion of the material is not suitable for architectural or ornamental work. A large amount of the marble of the lower bed on both sides of the river is burned in the extensive kilns of the Glens Falls Company, and produces the so-called "Jointa" lime of remarkable purity. The stone is quarried by blasting, and, therefore, much of it is shattered so as to be fit only for burning. The slaty-mixed limestone of some of the layers and of the stripping was formerly used for flux in the iron furnace at Fort Edward, New York.

On the north side of the river, where the quarry of the Glens Falls Company is located, the two upper strata above mentioned do not occur. The formation has here been worked to an average depth of about 30 feet and 60 feet in width for a distance of half a mile eastward from Glens Falls.

The next point to the north of Glens Falls where the Trenton limestone is quarried is at the quarry of Mr. Frank Clark, near Crown Point, Essex county. In general appearance and composition this stone resembles that of Glens Falls, but its texture is finer and more brittle. It is used for curbs, trimmings, and various kinds of cut work, principally at fort Henry, Plattsburgh, Saratoga, and Schuylerville. The rock is considerably fractured, and large blocks suitable for sawing cannot be readily obtained.

Of the marble and limestone deposits on the west shore of lake Champlain only two localities have been extensively developed, one at Willsborough, Essex county, and the other at Plattsburgh, Clinton county. The quarry of the Lake Champlain Quarry Company is located on the extreme northeast portion of Willsborough point; it is well equipped and favorably located, the blocks being swung by derricks directly from their beds to the decks of the boats used for transporting the material to market. The stone is, for the most part, a fine-grained, compact, blue limestone, containing fossil remains; the different layers differ slightly in color and texture. Formerly a large amount of this stone was shipped, but during a few years past the demand has been much lighter. It was used in the foundations of the piers of the East River bridge, and in the foundations of the new capitol at Albany. There are several layers worked which are separated by thin seams of clay; large-sized blocks can be obtained, and the stone is worked into all kinds of cut work and can be sawed and rubbed. Some of the layers furnish a fine black marble, which is susceptible of being highly polished, and it is used for various kinds of ornamental work. The rock comes to the surface and no stripping is necessary. The formation dips east of north under the lake. A porphyritic dike crosses the formation from east to west; it is from 12 to 14 feet wide and exceedingly well marked, extending from the shore of the lake until lost beneath the soil beyond the quarry.

The quarry of the Burlington Manufacturing Company is located near lake Champlain and not far from Plattsburgh. Large blocks are channeled out and shipped by boat to Burlington, Vermont, where they are sawed, and from the slabs all kinds of ornamental work are produced. Two varieties of limestone occur at this point, and are known in the trade as French-gray and Lepanto marbles. The latter is beautifully variegated with red and gray, and is largely made up of fossil remains, which give a beautiful appearance to a polished surface. The variegated marble is quite extensively used for inside decoration in public buildings, often in connection with white marble. It is shipped, for mantels, tiling, table-tops, and general decorative work, to all parts of the United States. Another marble quarry has recently been opened by this company at fort Henry, Essex county. This marble is composed of a ground mass in which are patches of serpentine, numerous crystals of pyrrhotite about one-eighth of an inch in diameter, and some graphite scales.

The quarry of the Gouverneur Marble and Whitney Granite Company is situated one mile west of Gouverneur, Lewis county. The limestone is crystalline and lies immediately on the granite; in fact, in some places the granite overlies the limestone. The surface is glaciated and rubbed smooth. It is usually called "Whitney granite", on account of its close resemblance to several kinds of gray granite when polished or finished with a patent hammer; but it is properly a marble, being, however, too coarse-grained to be finely carved. There is reason to believe that it will withstand the action of the weather, as head-stones in this immediate vicinity have been standing from 40 to 70 years. In the Riverside cemetery at Gouverneur there are about one hundred of these old head-stones; they present a good, clean, uniform surface, are very free from moss or any discoloration, and the corners and arrises are sharp and perfect. This marble is easy to work and takes a very fine gloss, and, being dark colored when polished and white when chiseled, any scroll-work or tracing makes a nice contrast. Much of it is finished with a patent hammer, some partly patent-hammered and partly polished, or polished and margined.

On account of the thickness of layers in the quarry, dies can be furnished 7 feet high that will stand on their natural bed and be of good uniform color. All dies 18 inches square or over are quarried to stand on their natural bed. Smaller sizes are quarried the other way.

The entire limestone formation is marketable stone, and there is no cap-rock to be removed. The upper portion, which is coarsely crystalline, is used for building purposes. Farther down the grain is finer and the color darker, and most of this is shipped directly to Cleveland, Ohio, and to New York city, where it is sawed and manufactured.

In this locality there are several quarries of the same stone now being opened. An excellent quality of granite is also found here, but as yet has not been worked. Soap-stone is also found in workable quantities, and asbestus appears. A large variety of serpentine is found in this locality, though as yet none has been put into the market.

A quarry at the head of Three-Mile bay, Jefferson county, is favorably located for water transportation. The rock is a rather hard, compact limestone, but works quite well for fine cut work. Two varieties, blue and gray, are used. Several quarries have been opened in the same formation at Chaumont, a few miles from the Three-Mile-Bay quarry, and on the Rome and Watertown railway.

A quarry at Lowville, Lewis county, in the cliff of Trenton limestone caused by Mill creek cutting across the formation at this point, has a face of nearly 90 feet, which is almost the entire thickness of the blue limestone in this section. It furnishes an excellent building stone, for local demand mainly, and also stone for flagging and curbing.

A quarry in a gorge through which the Sugar river passes, at Talcottville, Lewis county, can be worked with the least possible amount of labor and expense. The stream has cut through the ledge and left cliffs of solid stone 30 or more feet in height in an exposure of a quarter of a mile or more. All of this is valuable stone. The top layers are used for lime and the lower ones for building stone. The layers are from 3 to 15 inches thick, and furnish an excellent working stone, making good cut work. Between the layers of stone are thin layers of slate. Marine fossils are found in abundance. Formerly large amounts of stone were sent from this quarry to the towns along the Utica and Black River railroad, but at present the building stones taken out are used in the county. The jointing of the formation at this point is remarkably regular, and the layers of the bed are free and easily separated. No other quarries of any importance are opened in this vicinity.

At Canajoharie, Montgomery county, an extensive ledge of Trenton limestone occurs south of the Mohawk river. Quite a variety of stone is obtained in the different layers in the quarry worked at this point. The topmost layer is a hard, rough, somewhat calciferous sand-rock, and below this is a gray rock, gray limestone, etc. The layers vary in thickness from 2 feet downward. Only the gray limestone is dressed, and the sand-rock is used quite largely for foundations; a number of the houses in the town of Canajoharie are built of it. The stone from this quarry is also shipped to Utica and Little Falls; at the former place it was used in the construction of the steam cotton-mills and the Mohawk River Valley mills. Farther down the Mohawk river, at Tribes Hill, the Trenton group is partly cut through, and valuable building stones are obtained on each side of the stream. The quarries here produced in former years much of the stone used in the construction of bridges on the New York Central and Hudson River railroad, and much of that used in building the locks of the Erie canal. The locations of these quarries are convenient for transportation, those on the north of the river being on the line of the New York Central railroad, and those on the south on the canal banks. The stone is strong, compact, and durable, and is little affected by atmospheric action, though some of the strata which occur here are not valuable for building stone. At the top occurs a shell limestone; below this a stratum of gray limestone about 4 feet in thickness, then a dark blue limestone 7 feet in thickness, then a stratum, about 4 feet in thickness, of rough, hard, flinty sandstone, somewhat calciferous, and below this is the stratum which furnishes the best stone. This last has been worked to a depth of 28 feet, and the bottom has not yet been reached.

About 1 mile north of Amsterdam, Montgomery county, there are two distinct strata of stone quarried, differing in color and quality, that of the upper stratum being quite largely burned for lime, and also used for cut work; the lower stratum is more brittle. The layers are from 4 inches to 2½ feet in thickness; the weathered portion of the top is burned. Most of the product of these quarries is used to supply local demands, though some of it has been shipped for use in important structures, including the New York Central Railroad bridge at Albany, the Cohoes dam, and the state capitol.

At Sharon Springs, Schoharie county, is a dark-colored, firm limestone, in beds varying in thickness from a few inches to 2½ feet. The thin beds are used in the vicinity for paving sidewalks. The stone, though quite hard, dresses easily, and is used for general architectural purposes, though mainly to supply the local demand. This quarry has been worked at intervals for many years past, but during the last eight or nine years it has been worked but little, though the stone is of superior quality, and might form the basis of an extensive industry with sufficiently low rates of transportation.

Near Cobleskill the Corniferous formation occurs in strata of cherty limestone, and gray and blue limestone, separated by layers of chert nodules. The stone dresses quite well, and is used for buildings and monumental work.

Just south of Howe's cave there is a high cliff of limestone of the Lower Helderberg formation, in which the quarry of the Howe's Cave Association is located. The total height of the escarpment above the valley bottom is about 150 feet. The vertical section of the quarry is as follows:

	Feet.
Gray stone, used for heavy work	15
Gray and black stone mixed, used for ballast	12
Blue limestone—building stone	10
Shaly beds, used for ballast	10
Blue limestone—building stone	6

The heavy gray limestone is taken out in large blocks and is used chiefly for the construction of bridge abutments. It is not susceptible of being polished and is not well adapted to fine work. The blue limestone dresses well, and the material readily finds market along the line of the Albany and Susquehanna railroad. A considerable quarry industry has been built up at this point, owing to the excellence of the stone, especially for heavy masonry, and to the convenience in working the quarry due to the slight amount of cap-rock to be removed, the height of quarry face, and natural drainage. There is also an advantage gained from the fact that the material which, for one cause or another, is not suitable for building stone is broken up and used for railroad ballast.

The Onondaga limestone occurs in beds from 1 foot to 2½ feet in thickness. One mile north of the village of Springfield Center, Otsego county, on the west side of the outlet of Summit lake, the quarry of Messrs. McCabe & Brothers is located. The top of the limestone is polished and grooved by glacial action, and is covered by from 15 to 30 feet of glacial drift. This covering of clayey and calcareous drift has protected the stone against atmospheric influences, and no discoloration has taken place. The rock has a bluish color, which on exposure becomes somewhat lighter. The massive character of the stone makes it suitable for heavy work, and it also seems to possess the properties of strength and durability; however, no examples are known where the stone has been exposed for a very long time to test its power of endurance. Several buildings have been constructed of it, including the Otsego County jail, and the hotel Fenimore, at Cooperstown.

In Onondaga county the Onondaga limestone was formerly quite extensively quarried, during the period of the rapid development of the country. The quarries at Onondaga are within the Indian reservation, and furnish an excellent quality of stone; but the amount of cap-rock to be removed is considerable, being from 16 to 18 feet, and the lack of facilities for transportation prevents an extensive quarry industry. The stone is used for buildings and monuments chiefly at Binghamton and at Syracuse; in the latter place the university building, the court-house, and Saint Mary's church are built of this stone.

The quarries at Fair Mount and Manlius were first opened to obtain stone for locks on the Erie canal. In this vicinity there were formerly also a greater number of quarries than at present, and the demand for the stone is still gradually diminishing. The beds are not so heavy as those at Onondaga; they are here from 8 to 12 inches thick, and at Onondaga some layers are 4 feet in thickness. Fine exposures of the Tully limestone also occur in some localities, but it is not found in places where facilities for transportation are afforded, and has therefore not been at all developed.

The quarries at Auburn, Cayuga county, supply the local demand for general construction purposes, and some of the gray limestone from the quarry of Mr. John Bennett has been used for monuments. Some quarries are also worked in the vicinity of Auburn for stone used in macadamizing roads, and some for lime. The rock is nearly a pure limestone, containing a little magnesia and iron.

At Union Springs the Seneca blue limestone is quarried principally for railroad work along the line of the Delaware, Lackawanna, and Western railroad. The stone is suitable for bridge construction and other heavy masonry in which undressed stone may be used, the beds being even, some of them 20 inches in thickness, and the blocks being readily broken out in rectangular shapes. This limestone contains little magnesia, some graphite, and some protoxide of iron.

A favorable development of the Onondaga limestone occurs at Waterloo, Seneca county, on the Erie canal. The quarries at this point were opened when the canal was built, and have been worked more or less ever since. The stripping is from 5 to 8 feet, and the limestone has been quarried out to a depth of from 18 to 22 feet. The stone is used chiefly at Rochester for general construction purposes. At Rochester the Niagara limestone occurs in broken strata and is quarried for rough foundations. The stone is easily accessible, being covered with only 2 feet of loose material, and conveniently supplies the local demand for foundation stone.

At Le Roy, Genesee county, the Onondaga limestone is quarried for the Elmira market, chiefly for foundations and for bridge work on the Erie and State Line railroad. The stone is too hard to dress, and is used only for rough masonry. Some stone has also been quarried in this vicinity for blast-furnace flux.

At Lockport, Niagara county, the Niagara limestone has been quite extensively quarried for many years for general construction purposes, and the stone has been shipped to New York, Buffalo, and Rochester. In some years the value of the product sold has reached $400,000, but the demand for this stone has diminished in the last few years. The quarry is favorably located for transportation both by canal and by railroad.

The corniferous limestone crops out quite extensively in the vicinity of Buffalo and within the city limits. The quarries at Williamsville, about 10 miles northeast of Buffalo, are worked for the Buffalo market, producing material for ordinary purposes of construction, and some stone suitable for sawing and polishing, which is manufactured for ornamental purposes, principally table-tops and mantels. The Buffalo quarries supply most of the stone for rough masonry, such as cellar walls, foundations, cribs, piers, and general railroad work in the vicinity of Buffalo. It is not adapted to cut work.

A number of quarries which do not appear in the tables are worked at intervals in this vicinity. The deepest of the quarries have been excavated about 30 feet in depth, and several acres in area have been taken out. A considerable amount of lime is manufactured in the quarries of the corniferous limestone in Erie county. The rock is nearly pure limestone, containing small quantities of magnesia and iron, and very little siliceous matter.

NEW JERSEY.

[Compiled mainly from notes by Professors Cook and Smock.]

ARCHÆAN GRANITE, GNEISS, AND MARBLE.

The gneisses make up the great mass of the Archæan outcrop. The areas of granite and of crystalline limestone are comparatively small, and are confined to the highlands in the northern part of the state, in Sussex, Warren, Morris, Hunterdon, Passaic, and Bergen counties. The Morris canal, the Delaware, Lackawanna, and Western, the Central New York, the Susquehanna and Western, the New York and Greenwood Lake, the Belvidere Delaware, and the Sussex railroads all traverse the district. The New York, Lake Erie, and Western and the new Lehigh and Hudson railroads also run close to outcrops of these Archæan rocks. The facilities for easy transportation to large cities and towns are good.

The beds of gneiss are in many places very regular, and the stone is generally free from pyrite, magnetite, or other injurious constituents; but care is necessary to avoid these minerals, as they are found widely distributed. Granite is not common, except in small masses, and the outcrops are too limited for quarrying.

LOCALITIES WHERE GRANITE QUARRIES HAVE BEEN OPENED.

1. Near Franklin Furnace, Sussex county. *Geology of New Jersey*, p. 503.
2. Port Murray, Warren county. *Geology of New Jersey*, p. 503.
3. Dover, Morris county. *Geology of New Jersey*, p. 502.
4. Bloomingdale, Passaic county. *An. Rept.*, 1873, pp. 99, 100.
5. Near Charlotteburg (granite), Passaic county. *An. Rept.*, 1873, p. 100.

MARBLES.

1. Warren Marble quarry, Warren county. *An. Rept.*, 1872, p. 26.
2. Marble mountain, Warren county. *An. Rept.*, p. 28.
3. Rose Crystal Marble quarry, Warren county. *An. Repts.*, 1872, p. 27; 1881, p. 42.

A white limestone has been quarried near Stanhope, in Sussex county, but without much success, as the mass appears to be traversed by seams.

REFERENCES TO GENERAL DESCRIPTIONS OF GNEISS LIMESTONE.—*Geology of New Jersey*, 1868, pp. 64, 312, 316, 319, 321, 502; *An. Rept.* for 1873, p. 101; *ibid.*, for 1881, pp. 41, 42; *ibid.*, for 1879, p. 104 (Mendham limestone).

The only locality in New Jersey where gneiss has been quarried uninterruptedly for any considerable period is at Dover, Morris county, on the Delaware, Lackawanna, and Western railroad. The material is quarried for bridge construction and general work for the railroad company's use exclusively. Quarries in the other gneissic-rock localities in the state have all been abandoned after short periods of working. The convenient location at the side of the railroad track, the very light stripping, the facility with which the stone can be quarried, and its excellence as durable and solid stone for heavy work make this quarry a profitable one. The direction of the outcrop is northeast, and it is cut by the new High Bridge railroad a few rods from this quarry.

The New Jersey Central Railroad Company proposes to open a quarry near the railroad in the same hill. With the two lines of railroad and the Morris canal, all crossing the ledges, the transportation facilities are unsurpassed. The great amount of stone which can be obtained in the clearing of ground for agricultural purposes in this neighborhood and in northern New Jersey generally has retarded the development of quarries in the gneissic rocks of this part of the state. As the country becomes more cleared and the land more valuable, these sources of supply are gradually restricted and other quarries similar to the Dover quarry will be developed. For ordinary foundation work and for cellar walls, bridges, wharves, and work of that class, the supply is inexhaustible, and stone can be furnished at comparatively low rates The use of the gneissic rocks of New Jersey is increasing, as they are excellently adapted from their strength and durability to many purposes.

POTSDAM SANDSTONE AND GREEN POND MOUNTAIN CONGLOMERATE.

The sandstone considered of Potsdam age occurs in narrow outcrops bordering at intervals the gneisses. For localities see *Geology of New Jersey*, pp. 71–79. A little less has been quarried at (1) Franklin Furnace, Sussex county; (2) Danville, Warren county; (3) Oxford Furnace, Warren county; and (4) in the Pohatcong valley, near Washington, Warren county.

The sandstone of the Green Pond mountain belt (of Potsdam horizon) has been quarried on Kanouse mountain (near) 1, Newfoundland, Passaic county; (near) 2, McCainsville, Morris county.

REFERENCES ADDITIONAL TO ABOVE.—*Geology of New Jersey*, pp. 503, 504; *An. Rept.*, 1872, pp. 28, 29; *ibid.*, 1881, p. 42.

The Green Pond mountain conglomerate has been used with good effect at Morristown and at Boonton, but the bowlders of the country around the towns have furnished an adequate supply. The same stone can be obtained at many places in Morris and Passaic counties. It can be had in blocks of any size capable of easy handling. The stone is very hard and solid, and free from all minerals other than quartz; and the sharp, angular edges and numberless glacier-polished bowlders which have been exposed to the weather for ages attest its ability to resist atmospheric agencies; but it is not easy to dress on account of its excessive hardness. The quarries in this formation were not in operation during 1880.

MAGNESIAN LIMESTONE.

This rock is the predominating limestone of the state, and is found in Hunterdon, Warren, Sussex, Morris, and Somerset counties. For the localities see *Geology of New Jersey*, pp. 9–130; also map. It has been opened at many points for stone to be used in lime manufacture. For building purposes the localities in which this stone is found are numerous, particularly in Sussex and Warren counties; and it is in general use in these counties, and in parts of the adjoining counties of Hunterdon, Somerset, and Passaic, for building foundations, and for buildings of all kinds. For heavy bridge work it is used largely. The railroad and canal companies use a great deal of it in heavy construction. (See *Geology of New Jersey*, pp. 513, 514 and 392–396; *An. Rept.* for 1873, pp. 100, 101; *ibid.*, 1881, p. 41; also schedule of Newton limestone.) For analyses see above references and *An. Repts.*, 1875, p. 36; 1876, p. 55; 1878, p. 104.

HUDSON RIVER SLATE.

This rock yields the roofing slates. The principal quarries are: (1) La Fayette, Sussex county; (2) Newton, Sussex county; (3) Delaware Water Gap, Warren county.

REFERENCES.—*Geology of New Jersey*, pp. 135–145 and 518–520; *An. Rept.* for 1872, pp. 29, 30. The flagging stone of Flag-stone hill, Wantage township, Sussex county, belongs to this geological horizon. *Geology of New Jersey*, 1868, p. 522: Flag-stone; *An. Rept.*, 1881, pp. 64–66.

The only quarries of roofing slate in New Jersey that were operated to any considerable extent in 1880 are those near La Fayette, Sussex county. They are within a mile of the Sussex railroad, and but little farther from the new line of the New York, Susquehanna, and Western railroad. These quarries dip to the northwest. The geological horizon is that of the Hudson River slate. The reputation of the La Fayette slate is good; the color is usually a blue-black.

ONEIDA CONGLOMERATE AND MEDINA SANDSTONE.

These rocks constitute the mass of the summit and western slope of the Kittatinny or Blue mountain, stretching from the Delaware Water Gap to the New York state line. They have not been opened by any regular quarries, although the outcrops are many and the stone of the conglomerate formation is solid and durable, and can be had in quite regular beds. The sandstone is, in most places, too slaty and shaly in structure to make a good building material. The only quarry or opening worthy the name is in Sussex county, and in Montague township, where the red stone is got out in thin beds of large size; but it is not near transportation. (*Geology of New Jersey*, 1868, pp. 146, 149, 513.)

LOWER HELDERBERG LIMESTONE GROUP.

The rocks of this group are found in place in a narrow belt in the valley of the Delaware from near Port Jervis to the Nalpack bend, and are confined to Sussex county alone. They are quarried extensively for lime manufacture, but not for building, except a little which goes to Port Jervis and the adjacent country. The quarries are in Montague township, Sussex county.

UPPER HELDERBERG GROUP—ONONDAGA AND CORNIFEROUS LIMESTONES.

The above-mentioned belt in Sussex county is bordered on the west and northwest by the very narrow belt of Oriskany sandstone and Cauda-galli grit (both unfit for building material), and these latter are followed by the Onondaga and Corniferous limestones in a very narrow outcrop bordering the alluvial plain of the Delaware river.

They have yielded considerable stone for this part of the Delaware valley, which is used for bridge piers, abutments, dwellings, etc., but there are no large and regularly-worked quarries. The outcrops are many, and no excavation is generally necessary to meet the occasional demands of the valley.

REFERENCES.—*Geology of New Jersey*, 1868, pp. 165, 166, 514.

TRIASSIC AGE—SANDSTONE, FREESTONE, AND BROWNSTONE.

The most noted quarries in the state and some of the largest in the country are opened in the sandstones of the Triassic age. The formation occupies a broad belt of the state, running from the New York line southwest to the Delaware river. Its boundaries are shown by the geological maps of the state. For general descriptions of its rocks, see *Geology of New Jersey*, 1868, pp. 206–225; also *An. Rept.* for 1879, pp. 18–35.

The Little Falls, Paterson, Belleville, and Newark quarries are the most celebrated of any on the eastern side of the state. In the central part of the belt there are quarries in Washington valley (north of Plainfield), at Martinsville and Princeton.

Along the Delaware river there are large quarries at Greensburg, 4 miles above Trenton, and farther up the river valley at Stockton and Prallsville. The localities where quarries have been opened are given in the *Annual Report of the New Jersey Geological Survey* for 1879, pp. 21, 25. There are other places where stone has been quarried, but the above list includes those which have been worked for sale of stone.

The principal building stone in Newark, Paterson, Orange, Elizabeth, and New Brunswick comes from the Belleville and Newark quarries. They furnish a large quantity of very superior building stone to New York city. The new Mills building in that city is one of their monuments. Trinity church, New York, represents Little Falls. In beauty of shade, solidity, and durability the selected stones from the Little Falls, Belleville, and Newark quarries are unsurpassed. It is not superfluous to add that the stone of these quarries is the best of the New Jersey sandstones or freestones. It is not so micaceous as many other sandstones, and has not their laminated structure; hence for ornamental work it is well adapted. The absence of bedding lines admits of less care in laying it up. Some horizons are more argillaceous, and so-called "clay-holes" are observed in them.

The Belleville quarries are at North Belleville, and on the right, or west, bank of the Passaic river. They are located on a nearly north and south line, and are about 100 yards distant from the river front, which affords wharfage room for vessels of moderate size, as the tide comes up to this point. The railroad line (Newark and Paterson branch of the New York, Lake Erie, and Western railroad) runs nearly parallel with the river and about a quarter of a mile west of the quarries. There are three different openings. The following are some of the principal buildings in which this material has been used: Fort La Fayette, New York harbor; Stevens' house, Fifth avenue and Fifty-seventh street; Ruppert's house, Fifth avenue and Ninety-third street; building corner of Madison avenue and Twenty-eighth street; the Mills building, on Broad street, and A. T. Stewart's buildings, New York city.

There is considerable variation of the strata in the different parts of the quarry. In the southernmost of these quarries the glacial drift is 20 feet thick; then there is a thickness of 30 feet of red, fine-grained sandstone, most of which is of inferior quality, and the best of it is only fit for foundations, cellar walls, etc. Under this thickness comes next a coarse-grained, thickly-bedded, reddish-gray sandstone; beneath the latter is a fine-grained red sandstone, which can be rubbed and polished. The reddish-gray stone is equally durable, and looks well, but it cannot be rubbed. The former brings $1, the latter $1 50 per cubic foot. Explosives are used mostly for throwing down the top stone. Canisters or conical charges of black powder are always employed in working off blocks of the best and most valuable stone. There are disadvantages of considerable stripping. Working in the direction of the dip, water must be pumped out, as all of the quarries are below tide-level in the deepest points, one of them being 35 feet below the Passaic River level (tide).

Near Avondale station, Belleville, is a quarry of this material which was opened about the time of the Revolution. The principal markets now are Newark, New York, and Brooklyn. The ledge here extends S. 5° W., the strata being vertical. At the west end of the quarry there is a fine-grained chocolate-colored stone at the top, under several feet of stripping. The light-colored stone is a coarse, granular mixture of quartz and feldspar. The shade of color is very pleasing and the stone is solid, occurring in thick beds. It was used in the construction of the Presbyterian church, Fifth avenue and Fifty-fifth street, New York city, and of various bank buildings in Newark.

In one of these quarries the total area of the opening is at least 5 acres, being about 500 feet square. The vertical section on the northwest includes 60 feet of stripping, of which one bed 3 feet thick can be used for cutting into stone for foundations and cellar walls. Then there are 20 feet of the thick and solid beds of grayish, coarse-grained stone at top, and fine red stone used for rubbing at the bottom; underneath the latter there is an excavation 14 feet into a shaly rock. These varieties are sometimes designated "No. 1" and "No. 2" stone, respectively. On the south side of the quarry there are only 20 feet of stripping, and then comes solid stone. A fault traverses this quarry in a north and south direction, displacing the beds to the extent of 4 or 5 feet. Its plane dips 65° to 70° west. This fault also appears in one of the neighboring quarries.

On the south side of Bloomfield avenue, Newark, is located one of the principal quarries. The opening is at least 400 feet long from north to south, and the quarry progresses west and northwest in the line of the dip. The stripping consists of earth and shaly rock, and varies in thickness from 10 to 30 feet. The dip is very uniformly in a west-northwest direction and at a slight angle. The joints show no apparent system. On the west the vertical section is approximately as follows, beginning at the top:

	Feet.
1. Glacial drift	12
2. Shaly rock	15
3. Shaly beds	1 to 4
4. Dark-colored red sandstone	6
5. Callous	1
6. Light-colored sandstone, thick beds	8 to 15
7. Callous	3 to 4
8. Dark-colored harder sandstone	4 to 6

In the glacial drift the material is mostly red shale. Nos. 4, 6, and 8 are workable horizons. At the south end of the quarry the stripping is only 10 feet thick. Very little powder is used. Stone is wedged off and split up after the top or stripping has been removed. One engine works both derricks, and the pumping is done by a small engine. The material from this quarry has been used for the construction of the Collegiate Reformed church, Fifth avenue and Forty-eighth street; the Saint Thomas Protestant Episcopal church, Fifth avenue; the Jewish synagogue; Presbyterian church, Lexington avenue; Reformed Episcopal church, Madison avenue; Trinity Church school, Church street—all in New York city; Saint Peter's Episcopal church, Albany, New York; La Fayette College buildings, Easton, Pennsylvania; Yale College buildings, New Haven, Connecticut; Princeton College buildings, Princeton, and Kirkpatrick's chapel, Rutger's college, New Brunswick, New Jersey, and many other buildings, especially in Newark.

The Newark quarries are all conveniently located for transportation. There is natural drainage, as the quarries are on a ridge or the highest ground in Newark, which is 100 feet above mean tide-level. The thickness of workable strata, the pleasing shades of color, and the fine texture and evenness of grain are circumstances very favorable to these quarries, but the value of the land for building purposes is high.

In the quarry between Fifth and Sixth avenues the strata quarried are remarkable for their thickness and solidity, and the joints are wide apart. One system of joints runs northeast and southwest, and is clean and open. The glacial-drift covering is about 30 feet thick, but varies to 10 feet in thickness in places. The quarry is nearly square, having sides about 200 feet in length, and the stone worked has a total thickness of 30 feet. At the bottom a shaly rock is found. Very large and solid blocks can be quarried here, and some of the more solid rocks show no signs of stratification.

The following are some of the principal buildings in the construction of which this stone was used: The college dormitory and the Marquand chapel, Princeton, New Jersey; Trinity chapel, Houston street; Saint Jerome's church spire, and the trimmings of buildings on the corner of Thirty-second street and Broadway, New York city.

At the corner of Bloomfield and Prospect avenues is an old quarry formerly worked very actively, but it is about to be closed, as land here is considered too valuable for quarry purposes. The quarry has a length of 700 feet and is 300 feet wide and 60 feet deep at the deepest point. The glacial-drift covering is on an average 15 feet thick. On the north side there are two workable horizons each 12 feet thick and separated by shaly beds 3 feet in thickness. The location is northeast of that of the Newark Quarry Company, and crosses Bloomfield avenue about 150 yards away.

A short distance west of this quarry, and on the same excavation, a new quarry was opened in 1880. The excavation measures 50 by 50 feet and is 40 feet deep. The beds are covered to a depth of from 5 to 8 feet by glacial drift. The ledge here opened is shaly at top, and there is first a thickness of from 10 to 15 feet of red sandstone. Beneath this there is a drab-colored sandstone 12 feet thick. Its shade of color and fineness of grain recommend it, but the extent of the supply is still unknown. The dip of the ledge is to the northwest.

The principal quarry at Orange mountain, in Essex county, produces stone for ordinary building purposes, used in Orange and vicinity. Among the buildings in which it may be seen are the Central Presbyterian church, the addition to Grace Protestant Episcopal church, South Orange Presbyterian church, and the residence of Davis Collamer, at Orange, and that of Kenyon Cox, at Millburn. The quarry is in the eastern face of Orange or Watchung mountain, and about 250 feet higher than Orange. An excellent Telford road within 250 yards of the quarry leads to Orange and Newark. There are in all 14 feet of workable beds, one of which is 6 feet in thickness. There is considerable thickness of stripping, which consists of reddish shaly beds. This stone presents a pleasing appearance when dressed, either ax-hammered or bush-hammered, and is readily dressed. Like all the stone of Essex county, it hardens on exposure. The working advances in the direction of the dip; hence there is no advantage of gravity in getting blocks from the beds. There is a fault running north and south through the quarry, but the dislocation does not appear to be great. The plane of the fault dips about 85° to the east. The rock surfaces are coated with yellowish earth, and in places the rock is crumbling, so that there is no workable or marketable stone for a distance of from 1 foot to 3 feet from the fault plane.

There is a quarry at West Orange, Essex county, which produces a rather fine grained brownstone, used for buildings and trimmings, chiefly in New York and Orange. This quarry is in the valley between the first and the second Watchung mountain ranges and near the summit of the second range. It occupies the same relative position as the well-known Little Falls quarry. The stripping is not heavy, so that the aggregate thickness of workable beds is about 40 feet, but this does not include all, as there is said to be good stone at the bottom. The stone is heavy-bedded, and a set of regular and true joints extends through the ledge which facilitates the work of quarrying. The stone when quarried is easily dressed, and can be carved into any desired forms. It hardens by exposure. At present there is the disadvantage of having to move the stone by team a distance of from 2 to 4 miles before reaching railroad or canal. Among the most important buildings in the construction of which the stone from this quarry was used are the Presbyterian church at Caldwell, chapel of Grace Protestant Episcopal church at Orange, Reformed church at East Orange, Niles' mansion, Bloomfield, and a house at the quarry. Much of the stone was used in the construction of college buildings at Garden City, Long Island. During 1880 nearly all the material quarried, including a common rough stone, was marketed, the rough stone being used chiefly for walls at Garden City.

The gray feldspathic sandstone of the Palisade mountain is found in a crumbling condition on the east face of the Palisades and near the river, but not there suitable for building. At Englewood and Tenafly, in Bergen county, it is found so abundant in loose masses that this source has furnished stone for many elegant country houses and public structures; but no quarry in the rock *in situ* has as yet been opened.

At Paterson (in the western suburbs) a light colored buff stone has been quarried to some extent. The pleasing shade of color and its ease in working give it a local use.

The principal quarry near Paterson is in the eastern face of First mountain. The average stripping has been 15 feet thick, largely a red shale and sandstone with trap-rock débris fallen from cliffs above. The working has reached the trap-rock wall, and now must be carried laterally or the trap-rock must be undermined. The rock face presents a vertical section, the divisions of which are approximately as follows:

	Feet.
1. Trap-rock	80
2. Red-shale rock	8
3. Red sandstone of varying thickness	15
4. Sandstone and shale irregularly alternating	10
5. Sandstone in two thick beds with shale intervening in places	20
6. Shale	1½
7. Grayish sandstone of the best quality for building purposes	15

The stone most used comes from Nos. 5 and 7 of this section. The quarry has advantages in location, giving a great thickness of strata above all drainage, and being situated, as it were, on the bank of the Morris canal. There are also three railroad stations within one mile. The principal markets are Paterson and Hackensack. Some is shipped to Newark and to Jersey City. The character of this material as to durability may be observed in the Passaic County jail building, and in many other buildings in Paterson and Hackensack. The principal drawback is the heavy stripping in the trap cliff; this might be thrown down and the stone utilized for roads. Professor Smock, of the New Jersey geological survey, thinks the stone under the trap-rock will probably be found more solid and in thick workable beds. (*a*)

In Washington valley, and at Martinsville, in Somerset county, there are quarries in the lighter-colored stones which look well in buildings. At the principal quarry at Martinsville the stripping at the north end is 21 feet thick, and consists mostly of red-shale earth at the top and red sandstone below. Some of the beds in the stripping furnish stone suitable for foundations. At the opposite end of the quarry the stripping has ranged from 10 to 30 feet. The total thickness of the courses now worked is about 20 feet, 11 feet of which is a light-colored freestone. At the bottom of the quarry a greenish shale sets in. The dip of the strata is 10° north-northeast. Most of the stones taken out are from 1 foot to 2 feet in thickness, but blocks 3 feet thick and 12 feet square may be obtained. The stone is readily sawed and dressed; gang-saws cut about 1 inch deep per hour in it. The light-colored stone is sawed into shape for caps, window-sills, lintels, water-tables, etc. The principal markets for the stone from this quarry are Boundbrook, Somerville, Plainfield, Brooklyn, and neighboring places. Among the buildings in the construction of which it was used are those in Prospect park, Brooklyn, and a hotel in Martinsville. In old buildings where this stone has been used it proves to be durable.

At New Brunswick and along the Raritan River valley the stone is too shaly and does not weather well. The quarries are not now worked.

The Delaware River quarries supply a large quantity of stone to Trenton, Lambertville, Bordentown, Burlington, Philadelphia, and Camden. This stone varies somewhat in the different quarries. It is conglomeratic in the Prallsville quarries and in some of the beds at Greensburg. The best stone is of a reddish-gray shade, and contains a little feldspar associated with the quartz. The stone is easily dressed, and is used for both ornamental and common building work. Much of the Stockton-Prallsville stone has been used in the construction of heavy bridge work on the lines of the Pennsylvania Railroad company. The stone on this side of the state appears to be a little more open and porous than that of the Little Falls and Belleville quarries, and it favors the growth of a green fungus (?) in dark and shaded outside localities.

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a *Geology of New Jersey*, 1868, p. 506.

There are four important quarries at Greensburg, and the stones from all of them are known in the market as "Trenton brownstone" or as freestone. The quarries are about four miles from Trenton, on the bank of the feeder of the Delaware and Raritan canal, and near the line of the Belvidere Delaware railroad; the Delaware and Boundbrook railroad crosses the Delaware river within a mile of the quarries. The general direction of the dip is north-northwest to an angle of about 10°. Some of the stripping consists of a friable and coarse-grained stone made up of a mixture of quartz and feldspar, with some red-shale rock in places. The workable beds are from 12 to 15 feet in total thickness. These beds are usually separated by from 3 to 4 feet of red-shale beds. The total thickness of merchantable stone is in some places 35 feet. The proximity of these quarries to both canal and railroad, their easy drainage, comparatively light stripping, and the thick beds of workable stone, are very considerable advantages. Its durability and the ease with which it is dressed create a large demand for this stone; the sale of the dirt and rotten rock of the stripping at a compensation sufficient to pay for removing it is another considerable advantage. The Trenton brownstone or freestone is most largely used in Trenton, and nearly all of the stone buildings are of this material; it is quite largely used in Philadelphia also, and a little is used in the towns along the Delaware river from Lambertville to Philadelphia. The following are some of the principal buildings in the construction of which the Trenton brownstone was used: House of Correction at Holmesburg, Pennsylvania; Catholic church, third and Reed streets; the Episcopal church, Nineteenth and Wallace streets; Presbyterian church, Twenty-first and Walnut streets; Presbyterian church, Twenty-second and Bainbridge streets; school-house, Sixth and Coates streets, all at Philadelphia, Pennsylvania; the library building at Princeton, New Jersey; Saint Mary's church at Warren and Bank streets; and the residences of Hon. A. G. Ritchie, Rev. R. S. Manning, S. Prior, and others, at Trenton, New Jersey. For the composition of these stones see *Geology of New Jersey*, 1868, pp. 515, 516.

FLAGGING STONE.

At two localities, Woodsville, Mercer county, and Milford, Hunterdon county, flagging stone is obtained. There are several distinct openings near Milford. The quarries at Milford are all within two miles of the Milford Railroad depot, and are in the dark blue fine-grained sandstone of the Triassic formation near its junction with the gneissic rocks of the Archæan age. A full description of these localities may be found in the *Geology of New Jersey*, 1868, pp. 521, 522. The quarries are at present worked only for local markets along the Delaware river from Easton to Lambertville. The beds are generally quite thin, and most of the stone splits nicely, giving a smooth surface suitable for floors or sidewalks. The maximum thickness of flag-stone produced here is 4 inches; thicker layers are used for building purposes. The dip of the beds is 20° N., 40° W. A fine dividing plane or joint traverses the stone in a direction N. 75° E.; another runs N. 15° W. Impressions of stems, fragments of coal, and some supposed foot-prints have been found in this locality. The following is an analysis of this flag-stone made for the New Jersey geological survey:

	Per cent.
Sand and silicic acid	79.25
Protoxide of iron	3.78
Alumina	7.49
Lime	1.86
Magnesia	Trace
Potash	0.50
Soda	0.62
Sulphuric acid	1.39
Carbonic acid	1.46
Water	2.76
Moisture	0.40
Total	99.51

The principal quarry at Woodville is in a dark-colored, fine-grained shale of the Triassic age. The surface layers are shale; the beds below are a fine, bluish, slate-like rock, which, however, is properly classified with the sandstones. The dip of the strata is 20° N., 4° W., very irregularly bedded in layers varying in thickness from very thin flagging to those 16 inches thick. The excavation in the quarry is 40 feet deep at the deepest point. Stripping is easy and drainage natural, but the stone has to compete with the Hudson River blue-stone at Trenton and on the railroad lines; as better prices are obtained in the immediate neighborhood than at Trenton, the local demands regulate working. The fineness of grain and smooth surface of this stone make it desirable for flagging; although a slate-like rock, the cleavage is not of such a nature as to permit it to be used as roofing material. Flag-stone of inferior quality is obtained at Princeton also. Martinsville quarry affords some stone suitable for flagging. In all of these places the stone is chiefly a fine-grained, slate-like rock, and generally of slate color. One of the quarries at Princeton produces what is called by Professor Smock a "blue, indurated, argillaceous sandstone", although, according to the classification adopted in this report, it is put with the slates. It is used for ordinary building purposes in Princeton.

Another quarry produces a grayish sandstone used to a limited extent for building purposes at various places along the Delaware and Raritan canal, and was used to some extent in the construction of the Princeton College buildings.

TRAP-ROCKS.

The trap-rocks included in the sandstones of the Triassic in New Jersey are quarried extensively, their principal use being for paving. The stone splits readily into blocks of specification sizes for street paving, and is hard, wearing well. For such use the oblong-shaped blocks are found to be quite as good as granite, and their employment is increasing in New York and in cities of the state. The quarries for paving blocks are confined mostly to the east bluff of the Palisade Mountain range, or Bergen hill, and to Goat hill, near Lambertville. in Hunterdon county. For building, the trap-rock has been used in Jersey City and in Orange, but not to any great extent, although for large structures it is well adapted and looks finely. Trap-rock is also used largely for ballasting railroad beds and for Telford roads.

REFERENCES.—*Sandstone.*—(Analysis.) See *Geology of New Jersey*, 1868, pp. 215, 218. Trap-rock: *An. Rept. N. J.*, 1873, pp. 113, 114; *ibid.*, 1879, pp. 25, 26; *ibid.*, 1881, pp. 60, 63.

The principal quarry in the Triassic trap, or diabase, is at Bergen hill, Hudson county. It is used for paving blocks chiefly in New York, Jersey City, Hoboken, and Newark. The trap-rock quarries at this place are confined to the eastern brow of the hill and to the summit of the range. They extend at intervals from Montgomery street, Jersey City, to the Bergen County line, a distance of 7 miles. These quarries are very small; they are opened on the brow of the hill where streets are to be cut through, or on knobs such as mount Pleasant, near the track of the Pennsylvania railroad, which is to be taken down to a much lower level. Others are so located as to get stone most easily and of quality suitable for use. The excavations are not sunk into the rock, but are simply extended into the ledge as it projects from the hill. There is but little stripping, cap-rock, or waste of any kind; nearly all of the rock is used. All the quarries are worked on leases, and a common practice is for a gang of three or four men to work together. The only capital is the value of tools and powder, averaging probably less than $100 to each quarry. The specification paving blocks are cut 8 by 10 inches (or by 12) by 4 inches; the square blocks are 5 or 6 by 7 inches. The former are cut with some regard to dimensions, but the square blocks are cut with much variation, some having nearly twice the cubical contents of others. There is much variation in the stones of different localities, and some cuts much more readily than others, and with less waste. The spalls are used for Telford-road making. Black powder is employed to break off large masses, which are broken up by hand-sledges, and the blocks are split out by hammers. The blocks are carted direct from the quarries to streets to be paved in New York or Jersey City. The specification block is growing in favor, and the use of trap-rock as a paving stone is increasing very rapidly. Against the square blocks there seems to be a serious objection—that its surface grows smooth very soon and is slippery; but against the oblong blocks the objection does not exist.

The location of these quarries is above all water, with natural drainage, with no stripping to be removed, and they are often worked for the double purpose of removing the stone in the grading of streets and for paving stone. As a building stone this trap-rock has been used with good results in Saint Patrick's church in Jersey City, and in the Hudson County court-house, besides other edifices both public and private. It is also used in retaining-walls.

The late Dr. George W. Hawes said of this Triassic diabase or trap:

From a specimen of the normal rock from Jersey City the feldspar was separated and was analyzed by Dr. Howe, and proved to be complex, a circumstance not indicated by the microscopic examination. The process of separation by means of the specific gravity necessitated the presence of what may be called "middlings", which were not sufficiently dwelt upon, and which may be supposed to have modified somewhat the composition of the parts. One part was a little more siliceous than labradorite, and the other analysis gave the formula of andesite. The second feldspar may be assumed to be a little more acid than the analysis.

The complexity of the feldspathic element being demonstrated in this case, we may, if we choose, by a calculation, indicate the percentage of the feldspar in the rock, if the composition of the pyroxene is known. The pyroxene of West rock has been analyzed, and if this rock is selected as typical we obtain:

	Per cent.
Anorthite	15.52
Albite	22.16
Potash feldspar	2.32
Pyroxene	54.47
Titanic iron	2.68
Magnetite	1.76
Apatite	0.32
Total	99.23

Thus the percentage of total feldspar is shown, but it is not intended in any degree to suggest that anorthite, albite, and potash-feldspar are present in these or any proportions, but a calculation is only possible when the extreme species are considered; and, these molecular relations being known, in the words of the article "it becomes easy to see how extremely diversified the feldspathic elements may be in rocks of this nature. The molecules may arrange themselves in very diversified ways, while the rocks remain identical in composition".

This method of calculating the amount of feldspar has been very often used. West rock, according to the calculation, includes just 40 per cent. of feldspar, which contains the elements that might form three species or be combined in one. In the Jersey City rock the feldspathic molecules have combined to form labradorite and andesite. In a little dike which intersects West rock, forming a bit of its western face, and identical in composition with all the rocks of this remarkably uniform system, anorthite has formed in small amount, which does not necessitate a more basic rock, since a simple arrangement of the remaining feldspathic molecules into other species could compensate for this.

It is known that Jersey City trap consists of pyroxene, two feldspars of intermediate composition, titanic iron, magnetite, and some minutely microscopic ingredients; and the occurrence of anorthite in rocks of like composition that may be supposed to have cooled under different conditions indicates that constancy of composition as regards the species of feldspar is not to be expected.

LATER FORMATIONS.

BROWN SANDSTONE AND CONGLOMERATE.—This is the only building stone found in the southern half of the state. It is a cemented sand or gravel, and the cementing material is iron oxide. It is not confined to any particular geological horizon, but occurs from the lower beds of the Cretaceous age to the latest drift, although more common in the outcrop of the red-sand bed and the drift gravel of the southeastern part of the state. In the absence of any other stone it is useful and is largely used for foundations and cellar walls. The quarries are generally small pits or shallow openings, and the stones occur in beds of varying thickness, lying upon earthy strata or beds, and covered by sand, or sand and gravel or earthy materials. In a few instances buildings have been constructed of this stone.

REFERENCES.—*Geology of New Jersey*, 1868, pp. 516, 517, and *An. Rept.*, 1881, pp. 66, 68.

At Egg Harbor city, Atlantic county, a quarry of this stone is located on rocks of Cretaceous age. A description of this quarry and the material produced by it will illustrate what is done in southern New Jersey in these quarries of brown sandstone.

The stone from the Egg Harbor quarry is durable, as it hardens on exposure, but it is not adapted to nice work, and hence its use is limited to the construction of wine vaults at Egg Harbor city, foundations, cellar walls, and occasionally bridge abutments and a few buildings; one is a Protestant Episcopal church at Eatontown, Monmouth county, built of stone from the vicinity; another is the West Jersey academy at Bridgeton, built of stone quarried near the town. Some of this material was used in the construction of the large dam at May's Landing. Among the more important of the numerous quarries in this stone are the following: near Eatontown, Monmouth county; Stonehill, Atlantic township, Monmouth county; Arney's mount, Burlington county; near Wareton, Ocean county; Bridgeton, Cumberland county; Egg Harbor city, Atlantic county; May's Landing, Atlantic county.

PENNSYLVANIA.

[Compiled mainly from notes of members of the Second Geological Survey, etc.]

BUILDING-STONE RESOURCES.

The ranges of the Appalachian mountains passing in a general direction northeast and southwest through the central and eastern parts of the state are the most marked feature in the geographical structure; and, speaking very generally, the exposures of the different geological formations, especially in the mountain regions of the state, are in the form of bands, of greater or less width, having the same direction as the mountains.

The oldest rocks in the state are the Archæan, in the southeastern corner; and going west and northwest newer rocks appear in consecutive order, with the following exceptions:

There is a belt of Mesozoic red sandstone passing through the southwestern corner of the state, lying unconformably on and bounded by rocks of Archæan and Lower Silurian age. This is the latest formation found within the limits of the state. It is described very fully in Vol. II, *First Geological Survey of Pennsylvania*, by Professor Henry D. Rogers.

The next important exception is the anthracite-coal fields of eastern Pennsylvania. These are comparatively narrow belts, the exposures of which are bounded by sub-Carboniferous and Devonian rocks. In the reports of the geological survey of Pennsylvania the preservation of these isolated Carboniferous strata is ascribed to the fact that there is a marked depression of the surface in this section of the state, placing the rocks much lower than those of the same age in other mountain regions.

There are small, separate areas of the Lower Silurian limestone, sometimes called Siluro-Cambrian, by Lesley, in the second Pennsylvania survey, and called by Rogers the Auroral limestone.

Among the most important in their resources of building stone, beginning at the southeast, are the Archæan rocks before mentioned, which furnish gneisses in the neighborhood of Philadelphia and Chester county; serpentines in Chester county, and slates, for roofing purposes, in York county.

The Mesozoic or Triassic belt before mentioned furnishes a brown sandstone at various localities, which material is of the same age and bears a general resemblance to the brownstone of the Connecticut valley, and there is a belt of this age in Nova Scotia furnishing sandstone of superior quality for building purposes, but it does not bear as much resemblance to the Connecticut stone as does the material of the Triassic formation quarried in Pennsylvania.

There are dikes of trap-rock cutting this Mesozoic belt at various points. A microscopic examination shows it to be a diabase, and it furnishes a very hard and practically indestructible building material, but from its hardness it is difficult to work and is dull and somber in appearance. There are quarries in these dikes at Collins station, near Falmouth, in Lancaster county, and near York Haven, in York county. Surface bowlders of the material are taken up for purposes of construction on and near Cemetery ridge, Gettysburg, Adams county. The trap at this place lies a short distance south of the present southern boundary of the Mesozoic sandstone, but there is little doubt that it is contemporary with the trap dikes which cut the Mesozoic sandstone at various places. The most important quarries at present are at Hummelstown, and the material is also quarried at Yardleyville, Lumberton, and Newtown, Bucks county, to a slight extent near Reading, in Berks county, and at York Haven, in York county.

The Lower Silurian or Auroral limestone before mentioned, which covers quite a large area in Cumberland or Lebanon valley (the Shenandoah valley of Virginia), furnishes by far the largest part of the limestone quarried in the state. The isolated bodies of this limestone in Montgomery, Chester, Lancaster, and York counties, lying southeast of the main body of the strata, furnish, in Montgomery county, the "Pennsylvania marble"; but in the other counties mentioned they furnish a limestone similar to that to be found almost everywhere in the Cumberland valley.

Strata of Hudson River age, lying immediately upon the Lower Silurian limestone, in Northampton and Lehigh counties, furnish roofing slates which are extensively quarried, the trade in which is rapidly increasing year by year.

Northwestward of the Lower Silurian limestones there is quite an extended area of Devonian strata, and on these there are ledges of Catskill sandstone in Pike county and vicinity that are much quarried for flags. The material is of the same structure and character as the North River blue-stone so extensively quarried in Ulster county, New York, for flags, and is scarcely distinguishable from it: it is marketed with the North River blue-stone and bears the same name.

The strata in this region are usually thin and evenly bedded shales and sandstones, hard, fine, and compact in texture, and particularly well adapted to paving purposes. In Wyoming county, in the vicinity of Meshoppen, there are quarries located on Devonian strata of the Chemung horizon, and the material is a very superior, fine-grained, compact, light gray or bluish sandstone, well adapted to the better class of construction, which is rapidly coming into use in New York and other eastern cities. Although the courses here are usually sufficiently thick to furnish material suitable for massive construction, much of it is thinly-bedded and is extensively quarried for sidewalk paving.

There are flag quarries also in Susquehanna and Tioga counties, and numerous other quarries are distributed over the country covered by these rocks, but the localities mentioned are the principal ones thus far where they have been quarried for purposes of construction.

There are numerous quarries of sub-Carboniferous flag-stone, probably of Chemung age, and certainly belonging to the Venango Oil group, along the high divide overlooking lake Erie, in Erie county.

There is one important quarry of umbral or mountain limestone (a division of the sub-Carboniferous in Pennsylvania), near Connellsville, Fayette county, quarried for street paving, and marketed thus far chiefly in Pittsburgh.

The Carboniferous area in the western portion of the state furnishes but little excepting coarse sandstone and conglomerates, which have been extensively used for local construction, but are usually not of such a quality as to justify their being shipped to distant points. There are, however, a few quarries producing material of such quality that they are used to some extent for building purposes in neighboring towns and cities; among these may be mentioned a quarry at Gallitzen, on the Pennsylvania railroad west of Altoona, and the quarries at Baden, Homewood, and Beaver Falls, in Beaver county. In Washington and Greene counties there are ledges of Coal-Measure sandstone sufficiently durable and of good quality for ordinary uses, though they have been as yet but little used.

ARCHÆAN ROCKS.

The southern gneissic district described in the geological reports of Pennsylvania, as ranging from the Delaware at Trenton to the Susquehanna, south of the state line, and lying south of the limestone valley of Montgomery and Chester counties, is the district in which are located nearly all the quarries of gneiss in the state; and those furnishing most of the material are in the vicinity of Philadelphia. This rock is here extensively used for foundations, walls, docks, paving blocks, curbs, and rubble work. It is for the most part a hornblende gneiss; in some of the quarries it is a muscovite gneiss, and there is a quarry at Frankfort, in the Twenty-third ward, Philadelphia, producing material which may properly be called a biotite granite.

There are quarries of hornblende gneiss at Rittenhousetown, Twenty-first ward, Germantown, Twenty-second ward, and Jenkinstown, Montgomery county. This material is gray in color, varying from light to dark and from fine to coarse in texture. It usually lies in sheets sometimes horizontal, sometimes vertical, though they are found inclined at every angle. It usually splits very regularly in the direction of the lamination, and is conveniently wrought into regular blocks for the purposes for which it is used. Some varieties of the gneiss are subject to decay from the decomposition of the feldspar, by means of which the rock is disintegrated.

Near Chester, Delaware county, the gneiss is very extensively quarried for the same purposes for which it is quarried within the limits of Philadelphia. The ingredients of which it is composed vary within certain limits, so that, according to the system of nomenclature used in this report, some of it is called a biotite gneiss, some biotite-muscovite gneiss, and some muscovite-biotite gneiss. The proximity of the quarries to the Delaware river affords ready means of transportation to Philadelphia and other cities and towns bordering on that river. The following list includes some of the important buildings in which this stone has been used, chiefly for foundations: The Cooper hospital, Camden, New Jersey; church in Chester, Pennsylvania; Catholic church, Third and Reed streets, and Presbyterian church, Nineteenth and Green streets, Philadelphia; Saint Charles Bartholemew church, near Philadelphia; railroad-station buildings, Overbrook; fort Delaware, built largely of this rock; various light-houses along the Delaware river; and the following structures in Philadelphia: Chestnut Street bridge (partly); Market Street Bridge abutments and piers; Junction Railroad bridge; Manayunk bridge; Penrose Ferry bridge; foundations of Market Street gas-works; foundations of Girard college; Fairmount water-works; Blockley alms-house; the old Naval Asylum and the Arsenal buildings. Also Swarthmore college, Delaware county.

In many private residences in Philadelphia and vicinity the walls are built of rough blocks of this stone firmly cemented together and presenting a very pleasing appearance.

As before stated the principal quarries in the Mesozoic trap are at Collins station, Lancaster county, and some in a dike on the opposite side of the Susquehanna river near York Haven, York county. The following description of the York Haven trap will give a general idea of these dikes wherever exposed. The face of this particular quarry is about 70 feet in height, but the material extends to an unknown depth. It lies in huge natural blocks sometimes weighing hundreds of tons, and having curved outlines giving them a sort of oval shape. Smaller blocks of various shapes are wedged in between the larger ones, and sometimes regular parallel sheets are seen lying together, usually near the top of the mass. The stone is reduced to proper shape by drilling rows of holes about three inches in depth and using plug and feather. It splits well in two directions. Stone from this quarry is used only by the Northern Central railroad in the construction of bridges, culverts, etc., and its indestructible nature and the fact that it may be quarried in regular massive blocks of any desired size make it a very desirable material to be used for these purposes.

At the Kellar quarry, Collins station, the stone is more extensively quarried than at any other place in the state, and is used for curbing, steps, base courses, cemetery work, caps, sills, columns, etc. The stone is used in the foundation of the new Harrisburg post-office, the superstructure of which is of the Richmond, Virginia, and Manchester, New Hampshire, granites; and the soldiers' monument at Harrisburg is a rectangular obelisk wholly built of this material.

There is much information concerning the geographical limits, geology, and character of material of these trap dikes in Report C C C, *Second Geological Survey of Pennsylvania.*

The material of the trap bowlders quarried near Gettysburg, and before referred to, is a diabase exactly similar to the stone in these dikes wherever they appear; but in this immediate vicinity there is an unusually large number of surface bowlders, and they have thus far supplied all the stone quarried here, there having been no necessity to operate on the dikes in place. The bowlders are particularly numerous and of large size in the vicinity of Vincent's Spur, Round Top, and Little Round Top, prominences of Cemetery ridge, along which the army of the Potomac was posted during the battle of Gettysburg. The places mentioned are all in close contiguity; and Devil's Den, where there is also a fine exposure of these trap-rocks, lies also at the base of Round Top. The bowlders are also to be found at Culp's hill, the northern extremity of Cemetery ridge. The stone is obtained in regular blocks by plug and feather, in the same manner as at Collins station and York Haven, and is used to a considerable extent for steps, caps, curbs, bases, and cemetery work in general. The stone is used in the Gettysburg national cemetery as head-stones. It may be seen in use in nearly all the towns within a radius of 50 or 60 miles of Gettysburg, and is known as Gettysburg granite.

SERPENTINE AND SOAP-STONE.

Serpentine is becoming more and more popular as a building material. The Chester County stone has attracted much attention in many quarters. Quite a number of important buildings have been constructed of it in Philadelphia, Washington, and Chicago. The stone is apparently very durable, and buildings in the neighborhood of West Chester, which have been erected over one hundred years, are fresh and maintain their attractive color unchanged. The stone is easily worked, and it is claimed that it can be furnished at a smaller cost than any other stone at the quarry.

Professor Henry D. Rogers, in Vol. I, *Geological Survey of Pennsylvania*, describes a number of belts and outcrops of serpentine in the southeastern corner of Pennsylvania south of the limestone valley of Montgomery and Chester counties. The first, or the most northwesterly, serpentine and steatite range is near the Schuylkill river in the southern edge of Montgomery county, and is the most eastern zone of the magnesian rocks in southern Pennsylvania. It is a long, straight, narrow line of outcrop of steatite or serpentine crossing the Wissahickon creek and the Schuylkill river. The steatite in this belt predominates, serpentine being usually dispersed through it in lumps. The steatite, where sufficiently free from the serpentine, was formerly quarried for the lining of stoves, fire-places, and furnaces; the principal market being the city of Philadelphia. It is also sawed into slabs of various thicknesses and used for mantels, stoves, sinks, etc. The débris is sometimes ground into a flour and used for foundery facings, lubricating purposes, roofing material, in paint manufacture, and for various other purposes.

Toward the end of the last century, before the introduction of the Montgomery County marble, this easily-quarried material was used for street-door steps in Philadelphia, but its unequal hardness, owing to the dispersion of imperfectly-crystallized lumps of serpentine, caused it to wear unevenly and to soon present a rough appearance; and Professor Rogers notices the fact that in some old and much-worn door-sills of this rock the knots of the serpentine mineral project above the steatite like hob-nails in a plank. The fifth serpentine tract, or that of the West Chester barrens, is the one which has been quarried most for building purposes. The rock here is of a grayish-green color, massive, medium fine and uniform in texture, and has been extensively used for buildings, principally as ashlar in walls. The principal markets are Philadelphia, Baltimore, New York, and Washington, and it has been shipped as far west as Chicago.

Among the principal constructions of this stone are the Girls' Normal School building, Seventeenth and Spring Garden streets, Academy of Natural Sciences, Philadelphia; Pennsylvania University buildings, West Philadelphia; the court-house, Wilmington, Delaware, and 20 large churches, a number of school buildings, and several hundred private residences in Philadelphia, and more particularly in West Philadelphia. A portion of the material is sawed at the quarry. Several old farm-houses in the neighborhood built of this stone more than a century ago are reported, two having been erected in 1730; and the color of the stone is as perfect as when first quarried. A number of columns 6 feet long and 12 inches in diameter were furnished from this quarry for the university of Pennsylvania. This is about the longest that can be obtained, but it is not difficult to find good sound pieces 4 feet long and 6 or 8 inches thick. The broken and jointed character of the rock renders it impossible to obtain large blocks, hence its chief use thus far has been as ashlar in the walls of buildings. This stone can be readily carved, but cannot be sawed into very thin slabs. Although it has only been introduced to the public in the past ten years, it has been very extensively used by architects and builders, especially in Philadelphia. The quality of the stone both as to color and texture is more uniform in every respect than it was when the quarries were first worked, and the supply appears to be practically inexhaustible.

Near Rising Sun, Maryland, in the southern edge of Chester county, Pennsylvania, there is a serpentine tract upon which is located a quarry, formerly extensively worked, but which was idle during 1880. There are also one or two other quarries on this tract in the same locality; and there is a quarry of serpentine near Media, Delaware county, which, however, was not operated during 1880. Some of the stone for the building of the Pennsylvania university, West Philadelphia, was obtained at the Media quarry, and some at the quarries near Rising Sun, Maryland.

LIMESTONE.

Lower Silurian.—At the Bushkill quarries, Easton, Northampton county, the lowermost portion of the great Lower Silurian limestone of Pennsylvania, known as the Calciferous, is quarried for ordinary building purposes, and has quite an extensive local use for base courses and curbs, and is also burned for lime. An analysis of the stone shows it to be highly magnesian; in fact it may properly be called a dolomite. Graphite and protoxide of iron are found in specimens of the stone. The limestone in and around Easton is in comparatively even beds, and good stone of proper shape for building purposes can readily be obtained, though the stratum inclines sometimes at high angles. The base of the court-house and many other buildings in Easton are of this limestone, chiefly from the Bushkill quarries.

Montgomery County marble.—The Montgomery County marble, so extensively used in Philadelphia, is quarried from an isolated belt of the great Magnesian or Auroral limestone of Lower Silurian age. Professor H. D. Rogers, in the *Report of the First Geological Survey of Pennsylvania*, describes the geographical limits and geology of this limestone belt substantially as follows: It is the bed of a long, narrow valley in Chester and Montgomery counties; the ridges bounding the valley consist of the primal slates and primal white sandstone. The whole is a narrow, synclinal basin, with strata closely folded together, those of both sides of the trough dipping with much regularity to the south-southeast at an angle ranging between 60° and 70°. All the strata here are greatly altered by diffused igneous action. The belt of limestone itself, which forms the great valley, extends through the western half of Montgomery county, southwestward through Chester county, and Sadsbury and Bart townships, in Lancaster county. The general geological structure of this populous and rich limestone belt, is extremely simple. Measured from one extremity to the other, the limestone, coincident very nearly with the bed of the valley, has a total length of about 58 miles; its eastern end being just north of Abington, in Montgomery county, and its western end is at the source of Big Beaver creek, in Lancaster county. In form it resembles very much a long, slender fish. The general structure of this first main belt of the Auroral limestone is that of a long and slender basin or a synclinal trough, the southern side of which is much steeper than the northern. The strata of the southern side of the valley dip perpendicularly, often a little overturned into a steep south dip, but sometimes incline steeply in the normal direction or northward. It is only toward the western extremity, where the whole trough grows shallow as it rises up and thins away, that the north dip ceases to be steep. The strata of the north side of the valley, or from the synclinal axis northward, dip at an average inclination of about 45° southward, or more strictly, south 20° east; this inclination, however, is not absolutely constant. Throughout this limestone basin the southern steeply-upturned outcrop exhibits a far higher degree of metamorphism by heat than the northern, and this alteration appears greater where the strata approach most nearly a vertical position, and is greater still where they are inverted; that is to say, between Wissahickon and Brandywine creeks. It is chiefly within these limits that the elsewhere bluish and yellowish limestone is in a condition of crystalline and granular marble, white shaded or mottled from the dispersing and segregating action of a high temperature upon its changeable ingredients. All the marble quarries hitherto opened are included in this steeply-upturned or overturned outcrop, the best of this lying within half a mile of the southern edge of the formation, or of some sharp, inverted anticlinal like that of the Conoquenessing ridge. Throughout the northern half of the basin, especially where the limestone observes its usually very regular southward dip of seldom more than 45°, the rock is in the condition of a subcrystalline and earthy or purely sedimentary magnesian limestone, and its bedding is for the most part very uniform and rather thick. Its color is a pale greenish-blue, except in neighborhoods like that on the Schuylkill, below Norristown, where a partial metamorphosis has approached the northern border, and it is then very frequently a pale straw color and a pale bluish-white; but the slate in which the very same beds exist, where they rise perpendicularly or with inversion to their southern outcrop, after passing the synclinal turn in the center of the basin, is very different from all this, and in striking contrast with the faintly crystalline and earthy limestone which is here a distinctly-crystallized and often granular marble. Its color is changed to a brilliant white or to a mottling of purely white and dark blue from the presence of segregated or half-developed graphite, and the dispersed ferruginous matter is here in a state of minute, solitary crystals of sulphuret of iron disseminated through the body of the stone. Viewed edgewise a fresh exposure of the most altered limestone, such as is visible on the Schuylkill river, near Conshohocken, has the aspect of a blue and mottled marble streaked with films of talc and shivered by innumerable cleavage joints; but viewed facewise the layers and fragments have an aspect of a talcose or micaceous slate, so copious is the covering of talc and mica upon their surface.

The belt of marble in Montgomery county is about three-quarters of a mile wide, and it is in this county that the principal quarries on this belt are now operated. Marble Hall, in this county, is the easternmost point at which good marble is quarried, and the best of the material lies between this point and the Schuylkill river nearly to the Chester County line.

A mile from Spring Mill station on the Germantown and Norristown railroad the marble is quarried for buildings, cemetery work, and furnace flux, and shipped to Philadelphia, Lancaster, and other places in Pennsylvania, and to Washington, District of Columbia. The stone here varies in texture from coarse to fine, is semi-crystalline, light blue in color, with signs of irregular stratification, unevenly bedded, and in medium to thick layers. Blocks of 500 cubic feet might be moved in this quarry. Steam-drills are used in quarrying, and powder, and to some extent dynamite, in blasting. The production here during 1880 is said to have been less than the average.

Near Bridgeport, Montgomery county, the marble is quarried for ordinary building purposes, and shipped chiefly to Philadelphia and throughout Pennsylvania. It is here of a light blue, fine, semi-crystalline texture, with signs of irregular stratification, evenly bedded, and in medium to thick courses. It was used in the construction of the following buildings in Philadelphia: Girard college, United States custom-house, Merchants' exchange, and the passenger depot of the Pennsylvania railroad, at Broad and Filbert streets.

Near King of Prussia station, on the Chester Valley railroad, in Montgomery county, marble is quarried for ordinary building purposes, and shipped to Philadelphia, Baltimore, and throughout Pennsylvania. It is blue, has a fine, semi-crystalline texture, signs of irregular stratification, is rather unevenly bedded, and in thick courses. Plate V represents the polished surface of a specimen of this marble. It was used in the construction of Girard college, the new city building at Broad and Market streets, the old post-office and numerous churches in Philadelphia, and the court-house at Norristown.

At Henderson station, Montgomery county, similar marble is quarried for ordinary building purposes, and shipped to the cities of Philadelphia, Baltimore, and Washington. This marble was used in the construction of the Law Library building in Philadelphia.

At East and West Conshohocken, in Montgomery county, on opposite sides of the Schuylkill river, the ledge is quarried, the product being commonly known as limestone. It is gray, with a rather coarse, semi-crystalline texture, irregularly stratified, and comparatively even bedded in layers of varying thickness up to 2 feet; it is but little jointed, and its difference in texture and structure from the material in the marble quarries of this district is apparently due to less disturbance of the strata. The principal use of the stone at present is for foundations and bridge abutments. The stone-work of the Philadelphia and Reading Railroad bridge at the falls of the Schuylkill and that of the Girard Avenue and the Callowhill bridges, Philadelphia, is of this material. The following are some of the buildings the foundations of which were built of stone from the West Conshohocken quarries: The new city buildings, Broad and Market streets; Masonic temple, Broad and Filbert streets; Main Exhibition building, Memorial hall, Machinery hall, and Horticultural hall, in Fairmount park; Philadelphia Saving Fund building; Provident Life and Trust Company building, and the Union Insurance Company building; new grain elevator of the Philadelphia and Reading Railroad Company; South Street bridge; E. H. Fitler & Co.'s new buildings at Bridesburg; bridges on line of Philadelphia and Reading railroad, and on the connecting link of the Boundbrook line to New York.

Beside the limestone or marble of the Lower Silurian or Siluro-Cambrian belt of Montgomery county, there are quarries at various other points in Pennsylvania on this formation where the stone is quarried for ordinary building purposes, chiefly to supply local demands. There are quarries of this kind at Easton, as before mentioned, at Tuckerton and Reading, in Berks county, and in Lebanon county; near Harrisburg, Dauphin county; Leaman Place, Lancaster county; York, York county; and at Bridgeport, Shiremanstown, and Carlisle, Cumberland county.

There are also numerous other points where the material is quarried principally for lime, and where but little of the product is used for building purposes. At Tuckerton the stone is gray in color, massive, and the courses are even and thick. The stone is a calcareous dolomite. It lies in courses varying from about a foot at the top to 2 feet or more in thickness at the bottom of the quarry, and the total depth of stone quarried is about 50 feet, the inconvenience of drainage being the cause for not going deeper. The joints are from 3 to 20 feet apart. This quarry is operated by the Philadelphia and Reading railroad, chiefly to obtain stone for bridge construction and other railroad work. The inclination of the strata at this quarry is about 4° or 5°, and, contrary to the condition of the rock at other places near Reading, it is not much broken by joints, and hence is in a more favorable condition to be used for building purposes. Portions of the ledge of limestone not far distant from the Tuckerton quarry are upturned at a high angle, very much jointed and broken, and are quarried extensively for lime burning and furnace flux. The material the point where the Tuckerton quarry is located is a limestone, but is not of sufficient purity to be well adapted either for furnace flux or for lime burning, but the regularity of the strata and the substantial and durable character of the stone recommend it for building purposes. (*a*)

At Reading, a few miles south of the Tuckerton quarry, this limestone is worked only to a depth to which natural drainage is obtained—10 or 15 feet. Stone similar in character to that quarried extends downward to an unknown depth. In some sections of the quarries the ledge is a solid mass, and in others the division of the layers varies from 4 inches to 1 foot in thickness. The inclination of the strata is 45°. The stone is of a bluish color, with indistinct signs of stratification, fine in texture, and a qualitative analysis shows that it contains graphite, protoxide of iron, much lime, and considerable magnesia. It is scientifically a calcareous dolomite. This stone is well adapted to the purposes for which it is used in Reading and vicinity, such as cellar walls, foundations, curbstones, and for macadamizing streets and roads.

The Annville (Lebanon county) quarries of this formation produce limestone which is used for building, and for lime and furnace flux; the building stone and furnace flux are used chiefly at Lebanon, and considerable lime is sent to Wilmington, Delaware. The stone here is a blue-black color, irregularly stratified, fine and semi-crystalline in texture. The stone at this point contains less magnesia than that at most places in Pennsylvania where limestone of the same age is exposed. The magnesia is nearly always a prominent feature in the rock of this age in Pennsylvania, and the *Second Geological Survey* entitles it the magnesian limestone formation.

Four and a half miles southeast of Harrisburg, on the east side of the Susquehanna river, there is a quarry of this rock, producing material for building purposes, for lime, and for furnace flux. The stone here is a dark gray in color, fine, compact texture, is irregularly stratified, lies in even courses varying in thickness from a few inches to 2 feet or more, and is a magnesian limestone.

At Leaman Place station, Lancaster county, this limestone is quarried for building purposes, and is used chiefly in Philadelphia, Lancaster, Harrisburg, and on the line of the Pennsylvania railroad.

The abutments of the Conestoga bridge at Lancaster and those of the State Street bridge at Harrisburg are built of this stone. It is here dark gray in color, indistinctly stratified, and fine in texture; is a calcareous dolomite, containing graphite, some protoxide of iron, and sulphides of copper and iron. The courses are even and from 3 inches to 3 feet in thickness.

At Lancaster the stone is quarried for local use, chiefly for cellar walls and foundations. It is here blue-black in color, fine in texture, and with signs of indistinct stratification; contains a high percentage of magnesia, and is a dolomite. It contains graphite, protoxide of iron, little lime, and much magnesia. It lies in even beds, from a few inches to 2 or 3 feet in thickness, and the joints are usually from 3 to 20 or 30 feet apart. The walls of the Lancaster County prison are built of this stone. The height of the face of the quarries is about 20 feet. The strata are tilted up at an angle of about 45°, and a material of quality similar to that quarried might be obtained to an unknown depth, as is true at other quarries of the vicinity. The quarrymen find it convenient to go no deeper than the point at which natural drainage may be obtained. The rock in these quarries is not of a character to answer well for furnace flux, though the same ledge is quarried for that purpose a short distance away.

It may be observed here that throughout eastern Pennsylvania, where this Lower Silurian limestone outcrops in places where the rock was found in even, massive, thick, and little-jointed courses so as to be readily obtained in proper shape for building purposes, the material seems to contain too great a proportion of ingredients other than lime to answer well for furnace flux or lime burning; and, on the other hand, where the strata are much tilted and broken by joints so as not to be susceptible of being readily wrought into shape for building purposes, its composition is such as to make it well adapted to use for furnace flux and lime. In the Lancaster quarries, although the layers have an even surface, the stone breaks with an irregular fracture and is rather difficult to shape for other than the ruder purposes for which it is now used. Several old one-story houses constructed of this material are still standing in Lancaster, some of which were built a century ago. The only way in which the weather seems to affect this stone is to fade it to a lighter color, and this is due probably to the evaporation of the water, which process also has the effect of hardening it. This stone underlies a large area of Lancaster county and is extensively used by farmers, their barns and residences being often constructed of it. (*b*)

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a Report M M, p. 304, *Second Geological Survey of Pennsylvania.*

b For analysis see Report M M, p. 304. *Second Geological Survey of Pennsylvania:* Siluro-Cambrian Limestone.

Near York, York county, the Lower Silurian limestone is quarried for the ruder building purposes, such as cellar walls, foundations, and bridge abutments, and to some extent for paving blocks. Nearly all the streets of York are macadamized with this stone, it being about the only material used for the purpose in the town and vicinity. There are, however, two varieties here, one used for building purposes and the other for burning and as a fertilizer. The variety which is used for building purposes is blue-black in color, fine, compact, and uniform in texture, with no signs of stratification, and contains a high enough percentage of magnesia to be called a calcareous dolomite. It contains graphite, which is doubtless a principal part of the coloring matter, little iron, much lime, and little magnesia. The courses are even, from 15 inches to 2½ feet in thickness, and almost horizontal, there being but little dip. The material is quarried with comparative ease in regular blocks for building purposes, and is used almost exclusively for cellar walls, foundations, bridge abutments, etc., the local demand being greater at present than the production.

The height of the face of the quarry is 20 feet, the material being quarried only to the depth at which the natural drainage is obtained. There is no exposure showing the actual thickness of the ledge. The stone which is burned for a fertilizer is white in color, fine and crystalline in texture, containing less magnesia than the variety used for building purposes; it also differs from it in the absence of graphite or other coloring matter, and contains a greater proportion of the carbonate of lime. The courses are uneven and irregular, being much jointed, and the natural blocks vary much in size and shape. The height of the face of the quarry is about 15 feet. It is noticeable that the dip of the strata in these quarries is from 15° to 20°, which constitutes another marked point of difference between the white and the blue-black limestone quarried near York. In some places there are divisions into layers varying from 1 foot to 6 feet in thickness, but often the ledge is simply a broken and much-jointed mass. There is always more or less metamorphism in portions of the ledge producing the white limestone, the material in some places being a kind of marble of a white and bluish mottled color. The rock when burned makes a superior quality of white lime, and would be a durable building stone, but rather too expensive, owing to its hardness and the difficulty of obtaining rectangular blocks. It has no regular cleavage and cannot be split into prismatic blocks. There has been apparently enough metamorphic action to partially destroy the stratification, but not enough to entirely convert the material into a crystalline marble. Nearly every farmer in the vicinity of York has an opening in his limestone and uses it for building purposes and for fertilizing fields. The stripping in the vicinity of York is usually a red clay of the Mesozoic or New Red Sandstone formation. (*a*)

At Bridgeport, on the opposite side of the Susquehanna at Harrisburg, this limestone is extensively quarried for foundations, furnace flux, railroad ballast, and fertilizers. It is here dark drab in color, fine, hard, compact, and in texture rather brittle; it is a dolomite containing graphite and some protoxide of iron. Analyses of specimens from 115 layers of the rock in these quarries are given in Report M M of the *Second Geological Survey of Pennsylvania*, which seem to show that alternate strata of limestone and dolomite make up the mass; that the dolomite layers carry the most insoluble materials, and that as a rule each layer is nearly homogeneous. Magnesia is present in greater or less quantities in all the layers. It is even and rather distinctly stratified; the bedding is moderately uneven, and varies from a few inches to 10 feet in thickness; the joints are from 6 to 20 or 30 feet apart; the strata dip at an angle of 30° or 35°, and the depth of the face of the quarries at present opened varies from 15 to 40 feet, the variation being due to prominences and depressions in the outcrop of the ledge. The railroad track running into the quarry is on the level at which the material is quarried. The bed of the Susquehanna river at Harrisburg is of this material. The upturned edges of the strata over which the waters pass may be seen from the bridges in the vicinity, as the river is shallow and the water quite clear. The limestone here is of such composition and character as not to be very soluble in water, so that it does not wear away rapidly under the action of the river, although the current is quite rapid. The abutments of the bridges are mainly constructed of this limestone. It is found most convenient not to quarry the material in these quarries below the level of the railroad track, on account of the great expense and difficulty which would be incurred in loading the cars, though the material below this level is deemed quite as good for all the purposes for which the stone is used. Several houses in Harrisburg are of this stone, notably the residences of Hon. Simon Cameron and Senator J. D. Cameron. Several miles to the westward of the Bridgeport quarries, at Shiremanstown, this limestone is quarried for building purposes and as a fertilizer. It is here blue-black in color, fine, compact, even, and distinctly stratified; the proportion of carbonate of magnesia varies so much that some of the material may be called a calcareous dolomite and some a limestone, strictly speaking. The specimen of dolomite analyzed for this report contained some graphite, some iron, a high percentage of lime, and considerable magnesia; while in another specimen from the same quarry the graphite and iron were wanting, and there was still a greater proportion of lime and less magnesia. The stone is evenly bedded, and the courses vary in thickness from a few inches to 2½ feet. The bed of these quarries is worked only to the depth to which natural drainage is obtained. The dip is about 30°, and stone of a similar quality to that quarried can be obtained to an unknown depth.

In the discussion by Professor Lesley on the analyses of specimens from 115 layers of the rock in these quarries (Bridgeport), which were referred to above, he states that alternate strata of limestone and dolomite

a See Report of *First Geological Survey of Pennsylvania*, Vol. II, p. 667, for some description of the Mesozoic rocks in Pennsylvania.

make up the mass; adding, however, that none of the layers contain a sufficiently high percentage of the carbonate of magnesia to form a true lithological dolomite. The dolomite layers are found to carry the most silicates and other insoluble materials, and as a rule each layer is nearly homogeneous. Magnesia is present in greater or less quantity in all the layers. These 115 layers belong to the lower middle part of the great Magnesian formation, and the chemical analyses show them to belong to two well-marked lithological species, one a limestone carrying 2 or 3 per cent. of magnesia carbonates and 1 or 2 per cent. of insoluble material; the other a dolomitic limestone charged with from 25 to 35 per cent. of magnesia carbonate and an average of over 7 per cent. of insoluble matter, rising in some cases to 10 and 15 per cent., or even more. The largest percentage of the insoluble silicate of alumina is almost invariably found in the higher magnesian layers. From these conclusions of Professor Lesley, and from the conduct of the limestone in the bed of the river and in old buildings constructed of it, this stone is entitled to rank very high as to durability; a comparatively high percentage of insoluble matter may have something to do with enabling it to resist water-wear and other weather exposure. As a matter of course, a soluble or otherwise easily-destructible cementing matter will disintegrate a rock, even though its chief constituents be indestructible fragments so cemented together. The specific gravity of the specimens analyzed range from 2.68 to 2.85.

In Cumberland county about one farmer out of every ten quarries this stone in a small way for local building purposes, and for plaster, fertilizers, etc. The same may be said of Franklin county, and in fact of the whole region of Pennsylvania where the formation outcrops. It would be difficult to give an intelligent estimate of the amount of the material which is quarried in this way outside of the more important quarries, though the figures, if arrived at, would be very considerable.

Progressing still farther down the Cumberland valley, we find that at Carlisle stone is quarried for caps, sills, and bases, and all ordinary building purposes; also for plaster and for fertilizers. The stone is here blue-black in color, fine in texture, and indistinctly stratified; it is evenly bedded, lying in layers from a few inches to several feet in thickness, and in some places very much and at others but little jointed. It is here a calcareous dolomite containing a little iron. In the vicinity of Carlisle much of the rock is gathered from the surface of the fields, where it is an obstruction to farming operations, and nearly all that is needed for local use is obtained from the surface blocks. Dickinson College building, which has stood for nearly a century, and several churches and private residences in Carlisle and vicinity are built of this stone; and the only way in which it seems to have been affected by the weather is that in the older buildings it has faded to a lighter color.

At Chambersburg, Franklin county, in the Cumberland valley, this stone is very similar in every way to that quarried near Carlisle; it is blue-black in color, fine and compact in texture, and the stratification is indistinct and sometimes not observable. The specimen analyzed for this report proved to be calcareous dolomite containing some graphite. The ledge at these quarries is generally worked to the depth of about 20 feet, which is as deep as it can be worked without resorting to artificial drainage. The stone is evenly bedded, the courses being from 2 to 4 feet in thickness usually, and are readily taken out by plug and feather in convenient shape for building purposes. Many farm-houses and barns in the surrounding country are built of this stone; some of them have been standing for a century, and show no evidence of being affected by the elements excepting to fade to a lighter color. Numerous small quarries in this ledge are being operated throughout Franklin county to obtain material for plaster and for fertilizers, and the amount thus quarried each year is very considerable. It is also extensively quarried, throughout the regions of Pennsylvania where it is exposed, for macadamizing streets of the cities and towns and the roadways through the country; it is admirably adapted to this purpose. Another characteristic of this stone, which has been before mentioned in connection with the quarries at particular localities, is its great durability and resistance to atmospheric conditions, with the one exception of its fading to a light color. In Chambersburg old buildings constructed of this stone are sometimes painted so as to imitate very nearly the original color, which is a dark blue or blue-black.

Near Columbia, Lancaster county, the Lower Silurian limestone is quarried extensively at the Kauffman quarry, chiefly for railroad ballast and lime-burning. It is gray in color, massive, fine, and semi-crystalline in texture; it is a calcareous dolomite, containing a little protoxide of iron; and, although having considerable magnesia in its composition, it is very extensively used for furnace flux. The total height of the face of the quarry is 85 feet, and the courses are from 2 to 10 feet in thickness. The strata are inclined at various angles, there being considerable irregularity. There are two different ledges of the limestone in this quarry, disposed non-conformably to each other, though the character of the materials is about the same. The material is not so brittle as the limestone of the Trenton age quarried for ballast at Orbisonia and Morell, in Huntingdon county, and therefore requires more labor in breaking up. There is a marked difference between the stone in the Kauffman quarry and that quarried immediately across the Susquehanna at Wrightsville, in York county. The latter is white and otherwise apparently much altered by metamorphic action, and differs from the Montgomery County marbles in being less crystalline.

At Wrightsville, in the quarry of Kerr, Weitzel & Co., the limestone is of a white and light gray color and fine, compact texture; it is a calcareous dolomite, the proportion of magnesia being considerable.

The following is an analysis of samples of four different varieties of this limestone, made by the state chemist of Maryland in Baltimore, in 1857, with a view to introducing it extensively as a fertilizer in the country bordering the Susquehanna river and upper Chesapeake bay, to which place there is ready access by canal:

	1.	2.	3.	4.
Total	100.0	100.0	100.0	100.0
Carbonate of lime	97.1	80.8	95.4	85.0
Magnesia	2.6	14.7	3.1	4.5
Sand, iron, and carbon	0.3	4.5	1.5	10.5

The limestone from quarry No. 1 is of uncommon purity, and its lime is especially adapted to application on white-oak soils. The limestone from quarry No. 2 is a weak magnesian limestone; its lime is well adapted to application on soils which are moderately deficient in both lime and magnesia. These are in particular the volcanic soils of some counties in Maryland. The stratum in this quarry is 70 feet in thickness, and is tilted up to an angle of about 45°; and, though the inclination is different at different places, there is no considerable irregularity. The material at the point where quarried has been so much changed, apparently by metamorphic action, that it has very much the appearance of what are commonly called marbles, excepting that crystallization is not so apparent. The color is sometimes white, sometimes bluish. There is no regular division into layers, the stone being simply a much-jointed mass; and it would not be practicable to obtain large, regular blocks for building purposes. The railroad depot at Columbia is built of small, irregular blocks of this material, firmly cemented together in the style commonly known as rock-faced work. It presents a very pleasing appearance, and stone for this style of construction can be obtained in inexhaustible quantities here. The stone which is now quarried is the No. 1 given in the analysis, and is chiefly burned for a fertilizer and for building lime on the eastern and western shores of Maryland, to which, as before mentioned, there is ready access from the quarry by water, although some of it is now shipped by rail.

A specimen of the Lower Silurian limestone forwarded by E. V. D'Invilliers, of the Second geological survey of Pennsylvania, from near Yellow House, in Berks county, is a bluish-gray, fine, compact, indistinctly-stratified magnesian limestone containing a little iron.

The great Magnesian limestone formation which extends across Pennsylvania from the Delaware river to the Maryland state line, along the north foot of the South mountains, sinks northward and rises again to the surface in the valleys and coves among the mountains of middle Pennsylvania, viz, in McConnellsburg cove, Kishicoquillis valley, Morrison's cove, Nittany valley, Spruce Creek valley, etc.

A specimen from Spruce creek, Huntingdon county, is a blue-black, fine magnesian limestone, compact in texture, and breaks with a conchoidal fracture. It contains graphite.

Some description of the limestone in this region may be found in Vol. I, p. 500, of the *First Geological Survey of Pennsylvania*. This great limestone formation in Pennsylvania was called by Rogers the "Auroral" limestone, and it is termed by the *Second Geological Survey of Pennsylvania* the Siluro-Cambrian, and quite as often the magnesian limestone, from the universal presence of magnesia in greater or less quantities. The same authority also has local names for it in different parts of the state, as the York limestone, in York county; the Lancaster limestone, in Lancaster county, and the valley limestone in Chester county. For analysis of the Siluro-Cambrian limestone see Report M M, p. 304, *Second Geological Survey of Pennsylvania*.

DEVONIAN.—The only Devonian limestone quarried extensively in Pennsylvania is the Corniferous, of which there are massive beds exposed in the mountain regions in the central part of the state, and which are chiefly used for furnace flux and railroad and turnpike ballast.

Among the principal quarries on this formation are those of the Warrior ridge, at Huntingdon, where the stone is quarried for ballast by the Pennsylvania railroad. It is here a dark drab, fine, compact, and brittle material, non-fossiliferous, and contains graphite, some iron, and little magnesia. According to the system of nomenclature observed in this report it is a true limestone. The total thickness of the ledge is about 100 feet, disposed in layers varying from 8 inches to 3 feet. There are two layers of shale, each about 4 feet in thickness, one about 25 feet from the ledge, the other 5 feet lower, with limestone between. Numerous seams of calcite run through the stone. It is used only as ballast at present. It is said to furnish but a poor, mean lime when burned, and is not suitable for furnace flux.

For a description of this ledge of Corniferous limestone in the Juniata valley see Report F, *Second Geological Survey of Pennsylvania*. It contains few or no fossils, and in this respect differs radically from the highly fossiliferous Corniferous limestones of Ohio and other parts of the west.

Farther to the south, along the Warrior ridge at Cove station, in Huntingdon county, on the Broad Top railroad, the Shirley quarry is extensively worked for furnace flux, which at present is chiefly used by the Kemble Coal and Iron Company at Riddlesburg, Pennsylvania, to which place it is transported by rail. The ledge at this place is at least 200 feet in thickness, and possibly much thicker; it dips at an angle of 60°, giving the strata a very fine position for quarry operations. One particular division of the strata deserves special notice; it is about 15 feet in thickness, divided into layers from 2 to 4 feet in thickness; is uniform in character throughout, and, according to an analysis made for the Cambria Iron Company of Cambria county, contains 98.55 per cent. carbonate of lime. It is drab in color, massive, and coarsely crystalline in texture, containing a very little iron and magnesia, and is susceptible of a good polish. It is locally known as the "fossil" limestone as distinguished from the rest of the ledge, which is non-fossiliferous. The fossils are chiefly three or four different species of brachiopods, found on the surfaces of the layers, but not within the stone, as when fractured it shows a uniform, highly-crystalline texture, as is also true at other quarries of this ledge.

The non-fossiliferous part of the ledge, according to the analysis for the Cambria Iron Works, contains 94 per cent. of carbonate of lime; is very hard, compact, and brittle, breaking with conchoidal fracture, and would not in its natural condition be well adapted for purposes of construction, excepting for ballast on railroads and turnpikes. Only that portion of this ledge, 65 feet in thickness, which extends above the level of the stream is quarried. The rapid dip of the strata carries it beneath the surface an unknown distance.

Still farther south on the Warrior ridge, at Hyndman, at the junction of the Broad Top and Baltimore and Ohio railroads, this Corniferous ledge is quarried for furnace flux for use in Pittsburgh, to which place it is transported by rail. The stone is here a dark drab, massive, magnesian limestone, containing a little protoxide of iron and magnesia. It is fine, hard, and brittle in texture, and breaks with a conchoidal fracture. The face of the quarry is 200 feet in depth, and the strata are tilted to a vertical position.

Although the strata in all the mountain regions of Pennsylvania are usually tilted at a variety of angles, it is unusual to find strata of limestone perfectly perpendicular. The layers vary in thickness from 1 foot to 2 feet in that portion of the ledge quarried. A width of about 50 feet of the strata is quarried at present, the quarry progressing into the hill, and the uptilted layers of limestone on each side forming perpendicular walls.

A considerable part of the whole ledge is made up of layers of shaly, thinly-bedded limestone. Seams of calcite are frequent. It exists in inexhaustible quantities here, and the amount quarried for furnace flux, lime-burning, and fertilizers is increasing rapidly, as new quarries on the ledge are being started.

Warrior ridge, upon which the Corniferous quarries at Huntingdon, Cove station, and Hyndman are located, is an outcrop of the Oriskany sandstone formation, which crosses the Juniata river a little above Huntingdon, and ranges northeast and southwest for many miles parallel to and facing Tussey mountain, from which it is separated by the valley of the Lower Helderburg limestone and Clinton red shale (fossil iron ore). Its crest and escarpments are cut into remarkable "pulpit rocks". The dip is usually gentle to the southeast, but there are local anticlinal rolls, with very steep or vertical northwest dips. The return of the outcrop east, south, and southwest, around the head of Standing Stone valley, brings the Oriskany and the limestones above and below it back to the Juniata at the glass-sand quarries below Huntingdon, in Jack's narrows.

SUB-CARBONIFEROUS.—The only extensive limestone quarry producing stone for purposes of construction on other than Lower Silurian rocks in Pennsylvania is on the umbral or mountain limestone, a division of the sub-Carboniferous in Pennsylvania.

This quarry is located 3 miles southeast of Connellsville, on the Baltimore and Ohio railroad, in a gap made by the Youghiogheny river in the Chestnut Ridge mountains, through which the railroad passes. The ledge on which this quarry is situated is one of the strata forming the anticlinal axis of Chestnut ridge. There is considerable dip of the strata to the northwest away from the crest of the mountain, the general direction of which is north-northeast and south-southwest. The joints in this quarry are about 15 feet apart, the ledge not being so much broken as is the case with nearly all the mountain ridges of Pennsylvania. The total thickness quarried is about 80 feet, with the bottom not reached, and the material is disposed in courses from 10 to 14 feet in thickness. Professor Stevenson, in Report K K of the *Second Geological Survey of Pennsylvania*, describes it as very compact, blue, breaking with a conchoidal fracture, and in general appearance bearing a close resemblance to quartzite. The analyses of specimens made for this report show it to be properly a limestone, containing some silica, protoxide of iron, considerable lime, and very little magnesia. Professor Stevenson describes the stone as essentially a sandstone, with cementing material of calcium carbonate, but analysis shows that it contains a sufficient proportion of carbonate of lime to be properly a limestone. It is a bluish-drab in color, fine and subcrystalline in texture, and evenly bedded.

In Pittsburgh, where there is much heavy traffic over the streets, it has given good satisfaction as a paving material; it is very hard and compact, resisting wear exceedingly well, and it is readily shaped with the hammer into rectangular blocks of a proper size for paving.

This ledge has been thought to correspond with the Maxwell limestone of southern and eastern Ohio; in Pennsylvania it is variously called the siliceous, umbral, or mountain limestone, and lies on the Pocono or Vespertine sandstone, at or near the horizon of the Waverly series of Ohio, the formation producing the fine, compact sandstone so much quarried at Amherst, Berea, Brownhelm, Waverly, and other points on the sub-Carboniferous outcrops extending through the central part of Ohio from its northern to its southern limits.

During the census year 52,000 paving blocks from this quarry were used in Pittsburgh.

CARBONIFEROUS.—The Carboniferous limestones of Pennsylvania are but little used for purposes of construction. At Van Port, Beaver county, on the Ohio river, there are quarries on the ferriferous limestone, (*a*) and the material is used chiefly for lime and furnace flux, though it has been employed to a slight extent for walls and foundations. The stone is a massive magnesian limestone, fine and fossiliferous in texture, containing a little protoxide of iron. The total thickness of the ledge is about 11 feet, divided into three principal layers, of which the upper is 4 feet in thickness, the middle 3 feet, and the lower 4 feet. Thin shaly layers usually cover the top, and sometimes intervene between the principal layers. The middle layer resists the action of the elements and is susceptible of fine dressing. Although the color of this limestone is a bluish-gray where the face of the ledge is exposed, it weathers with a peculiarly-wrinkled, russet-colored appearance. It is highly valued as a furnace flux. and is used chiefly at Allegheny, Pennsylvania, Wheeling, West Virginia, and Mingo Junction and Steubenville, Ohio.

TRIASSIC.—At various places near the South mountain, in Pennsylvania and Maryland, the Triassic (Mesozoic) formation consists of a calcareous conglomerate, made up chiefly of fragments of the magnesian limestone upon which it rests, and which bounds it on the northwest, cemented with a red clayey material, very calcareous from infiltration, and in Maryland called Potomac marble. When polished, the stone presents a very singular but pleasing appearance from the numerous fragments of which the mass is composed. A chemical analysis shows its ingredients to be about the same as those of the limestone, from which it is chiefly made up. A specimen from near Fairfield, Adams county, forwarded by A. E. Lehman, of the Pennsylvania geological survey, proved to be a dolomite, containing considerable reddish residue, clay-cementing material, and a little iron, which gives the clay its reddish color. It is here burned for lime. Its local name is "calico rock", from its peculiarly diversified appearance.

SANDSTONES.

TRIASSIC.—The geographical limits of the belt of Triassic age passing through southeastern Pennsylvania are described in the geological reports of that state as commencing at the west bank of the Hudson river in a broad belt extending from the bay of New York to the base of the first ledges of the Highlands, and as bounded on the northwest by this chain and its continuation; southwestward it traverses New Jersey, Pennsylvania, Maryland, and, in a more interrupted manner, Virginia and part of North Carolina, so that its total length is not less than 500 miles, with a width in New Jersey of 20 miles between the Hudson and the Highlands. After crossing into Pennsylvania its breadth expands to nearly 30 miles, retaining this until it approaches the Schuylkill, when it contracts and maintains its course through Berks, Lancaster, Lehigh, Dauphin, York, and Adams counties, a breadth of about 10 miles between the Schuylkill and the Susquehanna rivers, and of 15 miles between the latter river and the Maryland state line. The south margin of the formation crosses the Delaware about 1½ miles above the town of Trenton, and the north border crosses the Delaware at Durham, near Trenton. The geology of this formation is very simple, and is made up chiefly of red sandstones and shales alternately, the arrangement being in many places layers of sandstone of various thickness, with red shale intervening. The lowest portion of the formation is a conglomerate, chiefly made up of fragments of the primal rocks and limestones upon which it rests; then comes a considerable thickness of the red shales and sandstones, surmounted by the calcareous conglomerate, or "calico rock", just noticed. The sandstones in the middle part of this formation is the portion which produces nearly all the building stone at present quarried from the formation.

One of the principal quarries in Pennsylvania, on rocks of this age, is at Hummelstown, Dauphin county, a few miles east of Harrisburg. The material here is a brown, massive sandstone of a uniform and medium texture, and is quarried for caps, sills, trimmings, bases, steps, and other building purposes. It has been much used in Philadelphia, Harrisburg, Williamsport, Pottsville, Reading, Lancaster, York, Richmond, Baltimore, Washington, and other cities of the east. The ledge is 85 feet in thickness in this quarry, dipping perhaps 40° to the northward, and outcrops in places, the stripping setting in and increasing as progress is made into the hill. It may be observed here that the dip of this Triassic sandstone in Pennsylvania is almost universally in a northerly direction, and remains steadily between about 15° and 40°. But there are remarkable exceptions to this rule, as shown on the sheets of the topographical map of the Durham hills and Reading mountains (by Berlin and D'Invilliers), published in the atlas to Prime's Report D D D, *Second Geological Survey of Pennsylvania*. A considerable tract east of Reading is covered with south dips varying from 40° to 75°. There are south dips alternating with north dips along the Schuylkill below Reading, and Professor Frazer reports local anticlinals in York county.

The quarry is located on the south side of a hill. The stripping is not great, from the fact that the ledge is inclined at such an angle (40°) that it may be followed downward without the necessity of taking off much cover. The face of the quarry is at present about 100 feet, which is greater than the real thickness of the ledge, a fact due to its inclination. The rock is evenly bedded, and in courses varying in thickness from 3 to 10 feet. Blocks of as

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a Under the Kittanning coal group, in the Lower Productive Coal Measures.

large a size as are desirable may be taken out. The jointing is rather regular, and the joints are from 4 to 40 feet apart. The topmost courses are of a reddish-brown color, resembling very much that of the Connecticut brownstone of the same formation, but the great body of the material is of a uniform, characteristic bluish-brown color, by which it is readily distinguished. Plate W represents a dressed surface of the Hummelstown brownstone. Among the buildings in which this stone has been chiefly used for trimmings are: In Washington, District of Columbia, the Bureau of Engraving and Printing and the residences of Hon. James G. Blaine, Senators Sherman and Cameron, and Colonel Jerome Bonaparte; in Philadelphia, the Academy of Fine Arts (basement), old Trinity church, Academy of Sciences (basement), and Philadelphia library. A slab from this quarry was forwarded to the National Museum which has every indication of having been formed by being sun-baked when in a soft, plastic state, the cracks being filled by material swept over them by the waves. In the quarries at Goldsboro', York county, the surfaces of some of the layers contain what resemble worm tracks or borings, and the stone is of a medium-fine texture, some of it conglomeratic, small siliceous pebbles being present; it is a reddish-brown in color, and has been quarried for caps, sills, steps, base courses, and trimmings generally, and is used in York, Harrisburg, Danville, Williamsport, and other cities in this part of Pennsylvania. Some of the trimmings in the Pennsylvania Capitol building are of this stone. It was not quarried during the census year. The total thickness of the ledge quarried is about 25 feet, in courses varying from 1 foot to 10 feet in thickness, with layers of red shale intervening between many of the courses of stone. The portions of the ledge nearest the surface are not so compact and durable as those below; this is, however, a characteristic of nearly all sandstone quarries. The distance from the railroad station is about 2½ miles.

Along the line of the Philadelphia and Reading railroad, in the vicinity of Mohn's store, several miles south of Reading, Berks county, the Triassic sandstone, here a reddish-brown, massive stone of uniform medium-fine texture, not differing greatly in appearance from that quarried at Goldsboro', York county, is quarried from surface rocks, which are scattered thickly over the ground, and is used for steps, caps, sills, fronts, base courses, and other trimmings, chiefly in Reading, where several churches are built of it. The ledge of sandstone is found in place, but the stone is not quarried, as there is a supply of the surface rocks fully seasoned by the weather, furnishing a reliable and durable material, while some of the layers of the Triassic sandstone in place show themselves, when first quarried, to be susceptible to the action of dampness and frost, and need some care in seasoning. Many of the farm buildings through the area covered by this formation in Pennsylvania are constructed of the sandstone from it. The color is always some shade of brown, or reddish-brown, from the intimate dissemination of iron oxide through the cementing matter.

Within the limits of Norristown, Montgomery county, and the immediate vicinity of the city, the Triassic sandstone is quarried in a small way for local purposes, such as cellars, foundations, and ashlar for walls and fronts. The quarry just west of Bridgeport, across the Schuylkill from Norristown, ships a small amount of stone to Philadelphia. The location here is not far from the southern edge of the formation, and the stone quarried is from its lower strata, with a coarse, almost conglomeratic, texture and somewhat lighter color than the rock quarried higher in the strata. The total thickness of the ledge quarried here is about 14 feet, disposed in regular layers varying in thickness from 9 inches to 2 feet, some of which are separated by thin partings of the reddish clay. It is considerably jointed and broken. It is probable that layers of the stone lie below the bottom of the quarries at present opened in this vicinity. The stone presents a rougher appearance than that obtained from the same formation in most of the other localities where it is quarried, and it is of a lighter color, sometimes having only a tinge of brown. The color is not uniform throughout the quarries, and the buildings constructed of it in Norristown have a variegated appearance on this account, though there is not enough of variation to make the walls of the buildings present violent contrasts of color. This stone in the walls of buildings constructed of it over half a century ago still remains firm and durable, but its grade is not such as to make it important for other than local uses.

At Lumberton, Yardleyville, Center Bridge, and other places in Bucks county, near the Delaware river, the Triassic sandstone is quite extensively quarried for cellars, foundations, bridge abutments, and ashlar, and is shipped chiefly to Philadelphia by rail and boat; it is also shipped to Camden, Norristown, and neighboring places. The material here is of medium texture, with indistinct signs of stratification, and usually of a light brown color. The quarries are on the lower portions of the strata. The bedding is fine and the courses are thick and regularly jointed, being usually from 8 to 20 feet apart. Among the buildings constructed of this material are the Bucks County court-house, at Doylestown; the insane asylum, Norristown; approaches to the South Street and Callowhill Street bridges; the Catholic churches at Lehigh avenue and Diamond street, and the wing of the Episcopal hospital, Philadelphia.

At Newton, in Bucks county, a small amount of stone is quarried, the material being similar and used for the same purposes as that at Lumberton and Yardleyville.

The stripping in all of these red-sandstone quarries is a red clay, and varies in depth from nothing to 12 or 15 feet, excepting in the Hummelstown quarries, where the stripping is sometimes greater. As the ledge always has considerable dip, it outcrops in places and the stripping increases more or less rapidly according to the topography of the ground.

Lower Silurian.—Outside of the Triassic border to the north and west, middle Pennsylvania is a country of parallel sandstone mountains and shale and limestone valleys, of which the principal sandstone formations are the Oneida and Medina (No. IV), the Oriskany (No. VII), the Catskill (No. IX), the Pocono (Vespertine, No. X), and the Pottsville (Seral, No. XII); but in none of these except the Catskill have quarries of building stone been opened for commercial purposes, although the sandstones and conglomerates have been locally used for building purposes.

The South mountains, which rise immediately from the north border of the Trias belt, are made up of Laurentian gneiss overlaid by Potsdam sandstone between the Delaware and Schuylkill rivers, and of Potsdam sandstone and Huronian porphyries between the Susquehanna river and the Maryland line.

The Welsh mountain, on the south edge of the Trias belt, in Chester and Lancaster counties, is Potsdam sandstone overlying (Laurentian?) gneiss. This Potsdam sandstone formation extends westward underground beneath the limestone plain of Lancaster and appears on the Susquehanna river above Columbia.

Both above and below the Potsdam sandstone (quartzite) proper lie schists or slates which belong to the same formation and ought to bear the same name. The upper slates are calcareous and underlie the great Magnesian limestone (Lower Silurian) formation of the Cumberland valley.

There is a quarry of Potsdam sandstone at Columbia, Lancaster county, in beds immediately underlying the Siluro-Cambrian limestone. It is used only for cellars, foundations, furnace stacks, and work of that class in Columbia, Harrisburg, and vicinity. The height of the face of the quarry is about 110 feet, in layers varying from 3 to 20 or 30 feet in thickness. The strata are perpendicular and are sandwiched between strata of magnesian limestone. The horizontal measurement across the face of the quarry is from 1,200 to 1,300 feet. These two formations apparently form an anticlinal axis from which the top has been eroded. The stone is invulnerable to the attacks of the weather, is dry, and will absorb but little moisture; it has no regular cleavage and is somewhat difficult to get into proper shape for any but the ruder uses. It stands a high degree of heat. The material is fine-grained, calcareous, massive, compact, gray in color, having somewhat the appearance of an argillaceous schist, and breaks with a very irregular fracture.

In Northampton county, near Bethlehem, there is a fine, massive, gray, hard, and rather quartzitic sandstone of the Potsdam formation, lying in thick layers and irregularly jointed, quarried for local purposes.

Upper Silurian.—Rocks of Upper Silurian age are but very little quarried in Pennsylvania for building purposes.

Two miles north from Danville, on the line of the Bloomsburg division of the Delaware, Lackawanna, and Western railroad, and on the north branch of the Susquehanna river, in Montour county, rocks of the Clinton subdivision of this formation are quarried for building purposes and for heavy foundations. It is a dark gray sandstone, massive, fine in texture, evenly bedded, and lies in medium to thick courses. This stone was used in the construction of the Danville insane asylum.

Near Mapleton, Huntingdon county, at the west entrance of Jack's narrows, a deep gap in Jack's mountain, letting the Juniata river and the Pennsylvania railroad pass through, the face of the mountain is covered with surface rock of Medina sandstone to a depth of 50, perhaps 100, feet or more in places, making the mountain appear from some points like a huge stone heap. The stone is a light gray in color, of medium texture, irregular in stratification, very hard, and only less brittle than the limestone much quarried in the mountain region of this part of the state for railroad ballast. The stone here is used for railroad ballast and bridge abutments on the Pennsylvania railroad. It is very durable, resisting the elements well; blocks large enough to produce stone for bridge abutments do not occur often enough to furnish a convenient supply. Considerable selecting is necessary when blocks of this kind are desired, but the blocks are flat-bedded and large enough to be used for foundation and cellar work and for ashlar. The only labor necessary at this quarry is the breaking of the stone and sending them down the chute to the cars below. For description of Medina sandstone in Juniata valley see Report F, *Second Geological Survey of Pennsylvania.*

At the upper end of Jack's narrows the Oriskany sandstone is quarried extensively for glass-sand; it is too friable at this point to answer for building purposes. The strata stand vertical or with a very steep westerly dip.

Devonian.—At Weissport, in Carbon county, there is a fine, thin, and evenly-bedded carbonaceous sandstone of the Marcellus Shale age quarried to a limited extent for flagging and other uses at Weissport, Mauch Chunk, and Bethlehem; it is dark gray, approaching black in color, due probably to the carbonaceous matter in it. The depth of the material quarried is about 12 feet, out of which about 5 feet are suitable for flagging, the workable material being disposed in beds a foot or two thick through the mass. The flags are from half an inch to 8 inches in thickness; dip of the strata, 20°.

The Marcellus shale in this vicinity is reported to contain sufficient carbonaceous matter to occasionally amount to a thin streak of bituminous coal; and this is a characteristic feature of the formation in many counties of the state. In Perry county it contains numerous thin streaks of coal.

Next in order, progressing to the northward, in eastern Pennsylvania are the Catskill beds, which contain the flag-stone quarries of the Delaware River valley, above Port Jervis, in Pike county. The rocks here quarried have been by the *Pennsylvania Geological Survey* named "Delaware flags". They are quarried chiefly for sidewalk paving and other flagging, and for curbs and trimmings. It is dark grayish, usually massive, but sometimes indistinctly stratified, fine, compact, and hard in texture. It lies usually in even parallel layers from 1 inch to 12 inches and upward in thickness. It is marketed in Philadelphia, Newark, New York, New England, and Washington, and is known as the New York blue-stone, going into the market with stone from Ulster county, New York, from which material it is scarcely distinguishable.

The surface of the country in this section is very hilly and rugged. The strata are nearly horizontal, and the roughness of surface has been produced by erosion simply.

The flags are quarried along the face of the steep cliffs, on both sides of the river, at a number of convenient points where the fallen débris is not too thick. On starting a new place the quarrymen usually have to remove about 6 feet of worthless rock, getting about 4 feet of flags, increasing from 1 inch to 12 inches in thickness from the top downward. Below this the layers continue to increase in thickness, and are considered too thick for flagging. Machinery has not been used except as an experiment. Some of the Pike County flag-stone is quarried at higher elevations and is of a somewhat lighter color than that which is quarried lower. The method of transportation to Philadelphia, where much of the stone is used, is by canal to Rondout on the Hudson, thence round by water, but to points in New York, New England, and New Jersey usually by rail, so as to avoid transfer.

The Catskill sandstone is quarried in the mountains near Scranton, chiefly for local use in bridge abutments, cellars, and foundations. It is here of a buff color, medium hard in texture, indistinctly stratified, and lying in even parallel seams from 3 to 20 inches in thickness; the joints are usually from 12 to 15 feet apart. The quarry is located in a mass of stone exposed on the northwest side of the mountain west of Scranton. There is no stripping; the dip of the strata northwestward is about 25°; the thickness of the beds quarried 30 feet. The blocks readily break into rectangular shapes with proper management. As nothing but cobble pavement, and but little of that, has thus far been used in Scranton and neighboring towns, there has been no demand that would justify a trial of the experiment of shaping this stone into paving blocks. It is stated in the geological reports that the lithological characteristics of this ledge are those of the Pocono sandstone, but that there are some stratigraphical relations that indicate it to be Catskill.

In the mountains a few miles east of Wilkesbarre, in Luzerne county, the Catskill red sandstone is quarried for sidewalk-paving, caps, sills, and ashlar. The stone here is quartzitic in appearance, of medium texture as to firmness, and lying in even parallel courses of thin to medium thickness, with beds inclined at various angles according to locality; the joints range from 20 to 40 feet apart. It is shipped by rail to Wilkesbarre, Allentown, Bethlehem, Easton, and neighboring towns. This formation is the principal one exposed on the side and crest of the mountain which borders the Wyoming valley on the east. The soil on the mountain is sterile and scant from the slow weathering of the rock. There is but a scanty growth of cedar, hemlock, pine, and scrub-brush, the crests of some of the ledges being entirely bald. The thickness of the workable stone in the quarries now opened is from 8 to 10 feet, in courses from 1½ inches to 2 feet in thickness, the thin layers lying usually near the top, but sometimes intervening between thicker layers. Nearly all of the sidewalks in Wilkesbarre are paved with this stone. In the locality where the quarrying is done at Laurel run the dip of the strata is into the mountain. The stripping increases very rapidly, and the quarrymen keep around the skirt to avoid deep stripping.

The Chemung beds of Wyoming county rank very high in the production of building stone. The material is quarried for all building purposes, and chiefly for caps, sills, bases, monuments, and trimmings. It is used in New York, Philadelphia, Boston, and Washington. The stone is fine, compact, massive, dark bluish-gray in color, lies in even parallel layers from a few inches to 6 feet or more in thickness, the courses at the top being usually thin, and increasing in thickness downward; the thicker beds are quarried extensively for flagging. The surface of the country is very broken and hilly, the hills being usually steep and rocky, showing the resistance of the stone to decomposition. Beds of good stone for flagging and general building purposes are found here and there at all elevations, flaggings of the same quality, texture, and general appearance being found at the foot and at the summit of the same hill; from 6 to 20 feet of good stone may be found at one place. The abruptness of the hills usually causes the stripping to increase rapidly; the strata are nearly horizontal, the broken character of the country being caused by erosion. This stone does not scale or crumble. The expense of dressing the stone is comparatively high, but it is thought to fully repay for its costliness by the handsome and substantial character of the work constructed of it. The quarries at Black Walnut, Skinner's Eddy, and Nicholson, all in Wyoming county, are of the same formation, and the material is the same as to quality. Gang and rip saws, rubbing-beds, and turning-lathes are used in dressing the stone. This stone has been used in the construction of the Produce Exchange building, the residence of Mr. W. J. Hutchinson, on Fifty-eighth street, and that of Mr. Addison Hutton, Fifth street, New York city; the residence of Mr. A. J. Dull, at Harrisburg, and the carved work for the interior decoration of St. Mark's Episcopal church at Mauch Chunk, Pennsylvania. Other quarries in this vicinity produce flagging exclusively from the thinner layers. The surface layers are usually not solid, but have a sort of laminated structure, and can readily be split into thin plates; such flags prove to be inferior, on account of the separation of these plates by the water and frost. Considerable of the stone from these layers is shipped, but sells at a lower price. The lower courses are solid, quite substantial, and durable. For the past few years the amount of flagging shipped from this locality each year has been more than double that of the preceding year.

In beds at apparently the same horizon as those quarried at and near Meshoppen, stones similar in character are quarried for flagging, steps, water-tables, caps, sills, and monument bases, at Nicholson, about 20 miles east of Meshoppen, and are shipped to Scranton and vicinity and Easton, Pennsylvania, and to Hoboken and Morristown, New Jersey. Twelve feet in thickness of the ledge is quarried, but the bottom has not been reached. The courses are very even, and parallel and horizontal, varying in thickness from 1 inch to 3 feet, the thinnest layers at the top, though thin layers often intervene between the thicker ones. The section of country in which the quarry is situated is hilly and broken, caused by erosion, apparently, as the strata are all horizontal. The hills are made up mostly of stone, generally lying in thin layers. Where the quarries are located at the base of these steep hills the stripping increases rapidly.

At Brandt, in Susquehanna county, on the Delaware and Hudson Canal Company's railroad, the Chemung beds are quarried for flags, curbing, crossings, caps, sills, and other trimmings, which are shipped to Elmira and Binghamton, New York, and to Scranton, Pennsylvania, and vicinity. The stone is massive, fine and hard in texture, dark gray in color, and lying in even parallel courses from 2 to 8 inches in thickness; the joints are 10 feet and more apart. Where quarried there are about 25 feet in stripping of cap or worthless rock, under which is a bed of good flagging 12 feet in thickness, lying horizontally; flags at the top are about 2 inches thick, and they increase very regularly in thickness downward, the bottom flag being 12 inches thick; beneath the flagging is a bed of brittle, crumbling slate. The surface of the country here is very rough and broken, and beds of the flagging occur at almost every elevation.

At Mainsburg, Tioga county, the Upper Chemung beds are quarried for paving flags, which are shipped to the neighboring towns in the south-central part of New York. The stone is dark gray, sometimes massive, and sometimes distinctly stratified, lying in even, thin, and horizontal courses. The bed of the quarry is about 8 feet in thickness, covered by a solid stratum of hard, dark-colored shale, which is removed by drilling and blasting. The courses are from 1 inch to 8 inches in thickness, most of them being less than 4 inches. The 3- and 4-inch courses make very desirable material for sidewalk flagging, the thinner courses being adapted only to use in pavements which are not required to sustain much wear nor heavy shocks. The natural blocks are usually nearly square and quite evenly and smoothly bedded. The bed will at the present rate soon be exhausted in the hill where it is now quarried, but it is probable that in some of the surrounding hills beds of equally good quality exist. An ordinary paving material is quarried in the Red Catskill formation near Wilkesbarre and Osceola, Tioga county.

Sandstone of Chemung age is quarried at Farrandville, Clinton county, for ordinary building purposes, and is used chiefly at Danville, Montour county, Pennsylvania. It is buff in color, massive, and of medium texture, lying in even courses of varying thickness. The front and tower of the Bloomsburg jail, the Memorial church at the same place, and the Danville National Bank building are constructed of this stone.

At Queen's run, in Clinton county, Devonian rocks of Catskill age are quarried for foundations and bridges, and are used chiefly at Lock Haven, to which place they are transported by water. The stone is fine in texture, indistinctly stratified, dark gray and brown in color, and lying in even courses of medium thickness. The use to which this stone is most applicable is curbing; it is used in the rough for cellar walls and bridge abutments, sometimes rough-pointed for these purposes. Some of the courses make an ordinary material for sidewalk pavement. The stone has been quarried at various localities in the vicinity along the bank of the river. The strata of quarry rock are found at different horizons; they are usually but a few feet in thickness, and the dip soon carries them under, so that they are not quarried extensively at any one locality.

The Oriskany sandstone has been extensively quarried for bridge abutments and wall stone near McVeytown, and is used for bridge abutments and wall stone at Harrisburg, Pennsylvania, and along the line of the Pennsylvania railroad, chiefly on the middle division. It is gray in color, coarse in texture, its stratification is even and parallel, lying in even, regular courses of varying thickness. Up to the present time only the surface rocks have been quarried at this place; they are scattered over the sides and top of a low anticlinal ridge of Oriskany sandstone lying just east of McVeytown and parallel to Jack's mountain, which rises a couple of miles to the west. It is estimated that $1,000,000 have been expended on this ridge in quarrying and preparing this stone, chiefly for bridge abutments on the Pennsylvania railroad. It is rather rough in texture, but very hard and durable. The sandstone usually has a ripple-marked surface, but the natural blocks are usually rectangular in shape and nearly as regular as if sawed. The much-weathered rocks on the crest of the ridge exhibit casts of a brachiopod (probably the *Spirifer arenosus*) in abundance. There is yet a large supply of the stone in the shape of surface rocks, and, because less expensive, they will probably all be removed before the rock in place is touched.

The sides of the mountain near Altoona, Blair county, are thickly strewn with surface rocks of different formations, chiefly Catskill, Pocono, Pottsville conglomerate, and Mahoning sandstone, which furnish nearly all the building stone for cellars, foundations, terrace walls, and other ordinary building purposes, and is used in the town of Altoona and vicinity. These surface rocks are gray in color, and, though varying much in color and texture, are usually very hard and durable; on breaking up they exhibit many cracks and fissures, due to the effects of fire passing over the mountains. The material is too rough and hard to dress well, and is only suitable for the ruder building purposes.

At Lebœuf, Erie county, the third oil-sand, locally so called, which is of Devonian age, produces a sandstone used at Erie for foundations, bridges, flagging, sills, and other trimmings. It is gray in color, fine in texture, distinctly stratified, and evenly bedded, the courses being of medium thickness. This formation produces the best building stone quarried in Erie county. When seen in the stone-yards, fresh from the quarry, it can hardly be distinguished by its general appearance from some of the stone quarried at Berea, Ohio. By some geologists the third oil-sand was for a long time supposed to be the equivalent of the Berea grit in Ohio. but it is now pretty generally admitted that the Corry sandstone, several hundred feet above the third oil-sand and above the whole Venango oil group, is the equivalent of the Berea grit. The Corry sandstone in Pennsylvania does not possess the valuable characteristics of its equivalent, the Berea grit, in northern Ohio. There are a number of quarries worked to a limited extent in the third oil-sand in Erie county. The rock of this formation has been quarried in different localities at different times for local and temporary demands, but there are few permanently-worked quarries in the county. The rock contains petroleum and soluble sulphates in such large quantities that it is not a desirable material to be used in fine buildings. Builders say it "sweats and spoils everything below it". It is, however, a good material for bridge-building and other like purposes. The stratum in the quarries is about 11 feet in thickness, the courses varying from 8 inches to 3½ feet thick. A section of the quarry is as follows:

Drift deposit	6 feet.
Blue shale	6 feet.
Coarse conglomerate	1 foot 6 inches.
Quarry rock, sometimes containing pebbles, especially between the beds	7 feet.
Quarry rock, clear, fine-grained sandstone, beneath which shale appears	4 feet.

The stone is quarried chiefly on the left bank of French creek. The stripping constantly increases as the excavation is carried farther into the bank. The outcrop of the quarry rock is about half a mile in length, and a large amount of the stone may yet be quarried with a little increase of stripping.

At Jackson station a quarry is opened in the third oil-sand formation, and experiments are being made with the rock with the expectation of successfully marbleizing it for mantels in the same manner as the Euclid (Ohio) stone.

Devonian rocks of Portage age are quarried a few miles east of Erie for foundations in that city. The stone is gray in color, fine in texture, indistinctly stratified, and evenly bedded in layers of medium thickness. The principal quarry is in a stratum of fine-grained sandstone from 20 to 30 feet in thickness; in some places there are two or three courses from 6 to 12 inches thick, and in some places the stratum is solid. The rock contains petroleum and other soluble impurities which make it unfit for use in all buildings exposed to the atmosphere. Other quarries of the same rock are quarried near the lake shore, the quality of the rock being about the same in all the quarries on this formation near Erie. A blue, impure sandstone in the Chemung flags is quarried occasionally to a limited extent at different localities in the vicinity of Erie.

SUB-CARBONIFEROUS.—Rocks of the sub-Carboniferous formation in Pennsylvania have thus far been quarried but little for purposes of construction. It will be noticed that there is but one limestone quarry of importance located on rocks of this age in Pennsylvania, and the following description will give an idea of the extent to which the sub-Carboniferous sandstones are quarried in the state:

Three miles north of Scranton, in Lackawanna county, in the side of the mountain a short distance westward of that city, and close to a quarry in the Catskill sandstone before mentioned, there is a quarry located on rock, probably, though not certainly, of Pocono sandstone of sub-Carboniferous age. The stone is much softer than that in the quarry of Catskill sandstone, and produces the best cutting stone in the vicinity; it is used for base courses, caps, sills, and other trimmings at Scranton, and was used in the construction of the Megargill and Cornell bank in that city. There are 26 feet of workable stone in this quarry, the thickness of the layers being from 3 inches to 2 feet, with the thinnest at the top, although thin layers occasionally intervene between the thicker ones. The dip of the strata is about 25°.

Two miles northwest of Altoona, in Blair county, on the Pennsylvania railroad, sandstone, probably of Pocono age, is quarried for cellar walls and foundations in Altoona. The material is gray, of medium texture, evenly and distinctly stratified, evenly bedded, and in courses varying from 1 foot to 4 feet in thickness. The stratum is much jointed, being usually not farther apart than from 5 to 10 feet. The total thickness of the ledge is about 15 feet. The stratum inclines about 45°, and dips into the hill in such a way as to increase the stripping very rapidly, so that it is not practicable to follow the ledge far into the hill.

Four miles southeast of Uniontown, at the west foot of the Chestnut ridge, the Pocono sandstone is quarried for lining steel furnaces, cupolas, and converting-furnaces. It is used chiefly at Pittsburgh and at Braddock's Field, Pennsylvania, and Saint Louis, Missouri. It has been used in the construction of cellars and foundations. It might be used for ordinary building purposes, but is rather hard to dress; and there is such a demand for it as firestone that the latter will probably continue to be the principal purpose for which it will be used. It is light gray in color, of medium-fine texture, irregularly stratified, evenly bedded, in courses varying in thickness from 2 or 3 inches to 8 inches. Only about 15 feet of the stratum is quarried, and the courses below are probably thicker. The Pocono sandstone in this locality is found also on the top of the synclinal arch of Chestnut ridge, the inclination of the strata being such as to bring it near the surface at nearly every point on the west side of the mountain. It is quarried about a mile up the side of the mountain, at Turkey's Nest, on the National road, as it has been quarried at the summit of the mountain above, where the stone is said to be superior to that at the other points mentioned, but transportation is so costly from the summit that the quarry there is not operated at present.

At Venango, in Franklin county, the Chenango sandstone, a subdivision of the sub-Carboniferous rocks in Pennsylvania, and known in Warren, McKean, and neighboring counties by the name "sub-Olean", or "flat pebble rock", is quarried for sidewalk paving and general building purposes, and used in Franklin and Oil City. It is gray in color, fine and uniform in texture, evenly and distinctly stratified, evenly bedded, and lying in courses from 1 inch to 30 inches thick. This formation, like the Corry sandstone, was supposed for a time to be the equivalent of the Berea grit in Ohio. In this locality some portions of it somewhat resemble the Amherst "buff" stone in appearance, and other portions have very much the appearance of the Amherst "blue"; and the material is more nearly equal to the famous Ohio stones mentioned than is that of any other quarry in northwestern Pennsylvania. The thicker courses, from 4 to 6 inches in thickness, are used largely for sidewalk paving, and large blocks from the heavier courses can be split into thin slabs by means of wedges. These quarries are located in the right bank of the Allegheny river.

On the opposite side, about one mile back from the river, is a quarry which has been worked quite extensively in the past for paving stone. The layers vary in thickness from 1 inch to 6 inches, and the stone is very micaceous and tough. The stratum of quarry rock in all these quarries is about 15 feet in thickness. The amount of stripping rapidly increases as work is carried farther into the banks.

The Chenango sandstone is also quarried at Titusville, Crawford county, for local use in bridges and foundations. It is here gray in color, massive, coarse in texture, evenly bedded, and in thick layers. The rock from this stratum is used more than any other for building purposes in Crawford county. It is usually colored with peroxide of iron, nodules of which frequently occur from a quarter of an inch to 2 inches in diameter; the color is not uniform, though seldom disagreeable to the eye. The texture differs but little from that of the stone obtained from the conglomerate measures above, except that it is usually more uniform. The rock in most localities very much resembles the Waverly conglomerate of Ohio, and if the following correlation can be sustained the two formations are identical:

CARBONIFEROUS CONGLOMERATE.

Crawford County, Pennsylvania.		Ohio.
Chenango group:		Cuyahoga shale:
Shales	1 = 1.	Shales.
Chenango sandstone	2 = 2.	Waverly conglomerate.
Meadville group	3 = 3.	Shales.
Sharpsville flags	4 = 4.	Buena Vista stone.
Orangeville blue slate	5 = 5.	Berea shale.
Corry sandstone	6.	Berea grit.

But so far as the economic value of these different formations is concerned their identification is of little consequence. The highly valuable deposit of Berea grit in northern Ohio becomes an almost worthless rock within 100 miles east of where it has its maximum development. The Chenango sandstone is usually an ordinary coarse-grained rock, but near Franklin, Venango county, Pennsylvania, it is a uniform, fine-grained sandstone, and is perhaps the most valuable sandstone deposit in western Pennsylvania.

The Sharon conglomerate, existing over an extensive territory and locally known by various names, as "second mountain-sand", and "Ohio," "Garland," and "Olean conglomerate", is in some localities a mere mass of quartz pebbles loosely cemented together, and in texture varies from this to a fine-grained blue-black stone. It is quarried near Greenville, Mercer county.

Carboniferous.—As before stated, the Carboniferous rocks in western Pennsylvania and the isolated tracts of the same area in the anthracite regions of the northeastern part of the state, have thus far produced scarcely anything but sandstones for building purposes, and the general statement may be made that they were quarried only for local use. These sandstones intervene between the different beds of coal in the Coal-Measure formations, and are often of coarse and conglomeratic texture, though occasionally fine and compact. The anthracite region gets its supply of building stone mostly from the Chemung, Catskill, and other Devonian rocks quarried at Meshoppen and Nicholson, Wyoming county, and at various places in the mountains extending through the region, and the Carboniferous sandstones are but little drawn upon.

At Shickshinny, Luzerne county, on the Bloomsburg division of the Delaware, Lackawanna, and Western railroad, there is a quarry of sandstone of Carboniferous age quarried chiefly for bridge-building and other railroad work on the line of railroad above mentioned. It is a dark gray sandstone of medium texture, evenly and distinctly stratified, evenly bedded, the layers at the top being 2 inches thick, and at a depth of 100 feet 4 to 6 feet thick. The top stone is used for sidewalks at Wilkesbarre and other towns along the banks of the Susquehanna river, and at Danville, Scranton, and Lancaster. The jail at Danville is built of this stone, and also the side walls of the Bloomsburg jail.

Progressing northward and westward from the anthracite region we come to the Carboniferous rocks in Tioga county. At Antrim, in that county, they are quarried for bridge work and general building purposes, and are used chiefly at Corning, New York. An Episcopal church at Antrim, and a court-house at Wellsboro' are built of this stone. It is light gray, massive, and coarse in texture, evenly bedded, and in thick courses. Much of the material obtained here is almost a purely white sandstone; it is a strong and durable rock, and holds its color well. It presents the best appearance when used in connection with a dark-colored stone, as is well shown in one of the county buildings at Wellsboro', the white sandstone structure being trimmed with white Medina sandstone. It works rather hard under the chisel, and its use is thereby greatly limited. There are indications, however, that if the excavation were carried farther into the bank a softer material would be obtained where it has not been so thoroughly drained; or, in the language of the quarrymen, "where it still contains the sap."

Near Somerset, in Somerset county, there is a flag-stone quarried and used locally for sidewalk paving. It is gray in color, of medium texture, irregularly stratified, very evenly bedded in thin layers, and but little jointed. The total thickness of the ledge is not exposed; it is quarried to a depth of 6 feet only, coming out in blocks varying in thickness from 2 or 3 to 10 inches, the average being from 4 to 6 inches. The general shape of natural blocks is exceedingly regular, presenting, however, an apparently ripple-marked surface. The flags are very hard and would be difficult to dress to a smooth surface, but they resist foot-wear exceedingly well.

At Johnstown, in Cambria county, the Mahoning sandstone, at the top of the Lower Productive Coal Measures, is quarried for general building purposes and used locally. It is dark gray, massive, medium, but uniform texture. The stratum of quarry rock is about 20 feet in thickness, the courses varying in thickness from 8 to 32 inches; there being one 32-inch course near the middle of the stratum. This is the firmest and most uniform in texture, and the most durable material for steps, for which purpose it is largely used. There are thin beds of ferruginous, shaly material between some of the layers. Sometimes this ferruginous material amounts to a thin layer of rich, compact iron ore. The stone itself is ferruginous, and when freshly quarried presents a compact, bluish appearance, flecked through with minute spots of peroxide of iron; and when exposed for a time it changes to a rough reddish-brown color to a depth of 5 or 6 inches. There is a layer about 4 feet in thickness about the center of the ledge. It is so ferruginous as to render it inapplicable to building purposes.

The Homewood sandstone (which is the uppermost of the three subdivisions of the Pottsville conglomerate formation, No. XII, underlying the Coal Measures) of the Pennsylvania geological reports is quarried for bridge construction at Iowa station, Jefferson county, on the Allegheny Valley railroad, and used on the low-grade division of that road. It is a gray, massive, coarse stone, evenly bedded, and in thick courses. Ordinary stone for foundations, bridge abutments, and work of that class can be obtained almost everywhere along this line of railroad from Driftwood to Red Bank: the best perhaps is found in the immediate vicinity of Brookville. It has been used in this town extensively, but only detached blocks have been quarried. The railroad company does not always obtain stone in the same locality, but moves from place to place according to convenience.

At Freeport, Armstrong county, the Mahoning sandstone is quarried for bases and steps, and used along the line of the Pennsylvania railroad from Allegheny to Tyrone. It is gray and light brown in color, irregularly stratified, coarse texture, unevenly bedded, and in courses of medium thickness. This stratum has a much better development farther north, in Clarion county, and it has been quite extensively quarried near Catfish in that county, and near Logansport, Armstrong county. The stone for the construction of the court-house at Kittanning and that for the construction of the new jail at the same place were obtained near Catfish. The texture of the stone differs but little in these two localities, but the color of the Catfish stone is lighter and more uniform than that of the Logansport stone. At these localities the material is quite free from mica.

About 2 miles north of Penn Junction on the Allegheny Valley railroad the full thickness—20 feet—of the stratum is exposed: here the upper and lower portions are quite micaceous, and the middle portion contains very little mica. At the Freeport quarry mica scales are found in abundance from the top to the bottom of the stratum; here the color of some portions of the rock is brown and other portions light bluish or nearly white. The darker portions have the reputation of being quite durable, but the lighter portions are not so. The stone from Catfish and Logansport wears away rapidly when used for steps and door-sills, but lasts quite well when merely subjected to atmospheric action. It is easily broken by concussion, but is capable of withstanding considerable pressure.

A quarry near Cowanshannock, a few miles north of Kittanning, has been worked quite extensively from time to time. From this and the Catfish quarries stone has been largely shipped to Allegheny and Pittsburgh.

Mahoning sandstone is quarried at Lucesco, the junction of the Allegheny Valley and West Pennsylvania railroads, on the Allegheny river, in Westmoreland county, and used chiefly for cellar walls and foundations for manufacturing establishments at Pittsburgh. It is employed to some extent for caps, sills, and other trimmings; it is gray, irregularly stratified, and of medium texture, evenly bedded and in thick courses, though much broken at the outcrop. The total thickness of the ledge of the quarry is 60 feet, with indications that it will be found thicker as the quarry progresses in the hill. The hill is so steep at this point that the stripping must increase rapidly unless the ledge sets in more heavily to compensate. The material of the upper 40 feet of the ledge is rather coarse in texture, with considerable iron in it; that of the lower 20 feet is of a bluish color, close, compact, much finer and more uniform in texture, and proves to be superior to the upper for building purposes. Only the outcrop has as yet been touched, and the ledge presents a broken appearance; but layers 10 feet in thickness are occasionally seen, indicating that as the quarry progresses in the hill the base will not be broken. The Mahoning sandstone is quarried at Derry station, Westmoreland county, on the Pennsylvania railroad, for ordinary building purposes; it is coarse in texture, with signs of stratification distinct, reddish-gray in color; it is used at Greensburgh and other places in Westmoreland county, and at McVeytown. The supply is obtained from large surface bowlders found along the west side of Chestnut Ridge mountain; in this part of the state large surface bowlders of the Mahoning sandstone are found and broken up to obtain material for ordinary building purposes. The stone splits readily into regular blocks, and is variegated in color by alternate different shades of a reddish color parallel with the stratification.

Near Derry station, on the Pennsylvania railroad, another ledge of sandstone belonging to the Upper Productive Coal Measures is quarried chiefly for the construction of coke-ovens by the Loyalhanna Coal and Coke Company. The stone is gray, massive, uniform, medium in texture, and unevenly bedded in courses varying in thickness from 2 or 3 inches to 3 feet. The total thickness of the ledge quarried is about 19 feet. Large, irregular, detached masses from 6 to 8 feet thick, heterogeneous in composition and useless for building purposes, are frequently found embedded in the other stones; these are locally called "nigger-heads". The blocks break up with rather irregular fracture, and the stone is not esteemed for any other purpose than the rough work required in the building of coke-ovens, and as these ovens are lined with fire-brick the stone is not subjected to any great degree of heat. The quarry is situated at the foot and on the west side of the anticlinal axis known as Chestnut ridge; and there is considerable dip of the strata toward the northwest, away from the crest of the mountain.

At Greensburgh the sandstone of the Upper Productive Coal-Measure series is quarried to a limited extent for cellar and foundation stone used locally. It is gray, irregularly stratified, of medium texture, and unevenly bedded. The total thickness of the ledge quarried thus far is 15 feet, though in sinking a well close by the whole thickness of the ledge was found to be 37 feet. The layers as observed in the quarry vary from 3 inches to 2 feet in thickness, and a thin vein of coal lies beneath the ledge of stone.

In Webster, near the Monongahela river, in Westmoreland county, a sandstone of the Upper Productive Coal Measures is quarried for paving and used in Pittsburgh. It is gray in color, fine in texture, evenly and distinctly stratified, evenly bedded, and in courses varying from 3 to 16 inches.

At Scottdale, Westmoreland county, on the Southwest Pennsylvania railroad, the sandstone of the Upper Productive Coal-Measure series is quarried for the construction of coke-ovens and house foundations locally. It is of a brownish color, regularly stratified, and evenly bedded in courses varying in thickness from 2 to 8 inches. The total thickness of the ledge of the quarry is 4½ feet, which thickness seems to continue regularly throughout. From the hardness of this stone and the ease with which it may be taken out for flagging, it seems better adapted to this purpose than to any other.

At Layton station, Fayette county, on the Baltimore and Ohio railroad, there is a sandstone (between the Upper and Lower Productive Coal Measures) of the Lower Barren Measures quarried and crushed into sand for the manufacture of glass; it has, however, occasionally been used for building purposes. The abutments of the suspension bridge across the Youghiogheny river at Connellsville, and those of the Saint Clair Street bridge at Pittsburgh, were constructed of this stone. It is light gray in color, of coarse texture, irregularly stratified, evenly bedded, and lies in two courses of 10 feet each in thickness, making the total thickness of the ledge 20 feet. The stone increases somewhat in hardness from top to bottom. This material seems very well adapted to all ordinary building purposes, but it serves so well for glass-sand that so far it has been found more profitable to quarry it for that purpose.

Three miles southeast of Connellsville, Fayette county, on the Baltimore and Ohio railroad, is a sandstone of the Lower Productive Coal Measures also quarried for glass-sand. It very much resembles the material at Layton station, and is of such quality that it might be used for local building purposes. It is easily dressed, and exposures of the ledge which have not been disturbed artificially seem to indicate that the stone is durable. There is no regular division here into layers, the rock being usually found in one mass. The quarry is located on the side of the mountain, and the dip of the stratum is about 15 degrees at the point where quarried.

In Connellsville, in the same county, the sandstone of the Barren Measures is quarried for ordinary building purposes and used locally. It is gray, coarse in texture, indistinctly stratified, and evenly bedded in courses varying in thickness from 2 to 3 inches at the top to 12 feet at the bottom of the ledge, the total thickness being about 40 feet. The material of the uppermost 30 feet is of a light brown color, and appears to have a little clay in its composition; it cracks under the effect of water-soaking and freezing, is soft when first quarried, but hardens considerably on exposure. The stone breaks or splits rather easily in almost any direction; wears away rapidly under foot-wear, but seems very well adapted for use in caps, sills, and other trimmings. The color of the lower 8 feet of the ledge is bluish, and the material is variable in texture, full of nodules of iron, and holds a good many fossil coal-plants.

Three miles southeast of Uniontown, on the side of the Chestnut Ridge mountain, surface rocks of Mahoning sandstone are found and broken up for ordinary building purposes, used chiefly at Uniontown. The material is gray, coarse in texture, with signs of irregular stratification. The blocks are sometimes as large as 30 by 20 feet and 12 feet in thickness. When the large rocks are first broken the material is comparatively soft and easily worked; but it becomes hard on exposure to the air, and small fragments that have been long exposed to the atmosphere are extremely hard. This stone seen in houses in Uniontown built fifty or sixty years ago exhibits every evidence of durability.

Near Waynesburgh, Greene county, sandstone of the Upper Barren (above the Upper Productive Coal) Measures is quarried to a limited extent for building purposes and for bases of monuments and other cemetery work, used locally; it is gray, massive, and coarse in texture. Thus far only large surface rocks, some of them 30 feet square and 5 feet in thickness, have been quarried. There seems to be no exposure showing a ledge in place; some of the rocks are on top of the hills. It is uniform in color and texture, works well, may be split horizontally and vertically, and takes carving well for a stone of coarse texture, as raised lettering is sometimes worked on monuments of this material; it stands exposure, becoming harder after leaving the quarry.

Near West Union, Greene county, on the Waynesburgh and Washington road, sandstone of the Upper Barren Measures is quarried for caps, sills, trimmings, and for ordinary building purposes and cemetery work. It is used at Waynesburgh, and the stone-work in the college building at that place is of this material. It is gray in color, massive, of coarse texture, and is obtained by breaking up surface rocks, which are from 10 to 20 feet square and 5 or 6 feet in thickness. These rocks where exposed are covered with a thin, cement-like crust, on which grows a grayish moss. When the crust is broken the stone beneath is found not to be discolored by weather.

Five miles west of Washington court-house, Washington county, on the Baltimore and Ohio railroad, sandstone of the Upper Barren Measures is quarried for caps, sills, curbs, steps, and other building purposes, and used locally. It is gray, coarse in texture, with signs of irregular stratification; the stratum is 20 feet thick, and solid, there being no division in the courses and few joints. The stone-work in the Washington and Jefferson College building at Washington, Pennsylvania, and that in the town hall at the same place, are of this material. The texture and appearance of this stone are uniform throughout the ledge, and the material is among the best found in the vicinity, though the supply of good building stone in this section of the state does not seem to be either abundant or widely distributed.

On the Pittsburgh and Southern railroad, 3 miles east of Washington, Pennsylvania, and on the National pike, about a mile east of that place, there are quarries of sandstone of the Upper Barren Measures, quarried chiefly for foundation stones, caps, sills, and other ordinary building purposes, and used locally. The foundation of Le Moyne's crematory is of this stone. It is gray, coarse in texture, with signs of irregular stratification, uneven bedding, and in courses from 1 foot to 6 feet in thickness, the thin layers often intervening between thicker ones; and in blasting, the thick layers often divide into four or five thin ones.

Near the Pittsburgh, Cincinnati, and Saint Louis railroad, 1½ miles north of Canonsburg, Washington county, sandstone, locally called freestone, of the Upper Barren Measures, is quarried for paving and hearth stones; used also for sills in Washington, Mansfield Valley, and Pittsburgh, Pennsylvania. The stone-work of the Pennsylvania Reform School building, in Washington county, is of this material. It is gray, uniform, of medium fine texture, evenly and distinctly stratified, and evenly bedded. The total thickness of the ledge in this quarry is about 6 feet; the top layer varies from 8 to 20 inches in thickness, then follow two or three layers each about 2 inches, and next the bottom are layers from 8 to 12 inches in thickness, with thinner ones intervening. The bedding is exceedingly even and regular, the surface of the layers being as smooth as if sawed. For paving and hearth stones no dressing is needed except at the edges. The stone splits straight in the direction of the lamination, and vertically, but is hard to dress. It is a favorite in this region for paving and hearth stones.

Near Monongahela City, Washington county, sandstone of the Upper Productive Coal Measures is quarried for ordinary building purposes, and is used chiefly in Pittsburgh and neighboring cities, and in the construction of the Monongahela bridge, Washington county. It is transported by rail and by boat. It is gray, coarse in texture, massive, evenly bedded in courses from 4 to 6 feet thick, and has a good local reputation.

On the Ohio river and the Pittsburgh and Lake Erie railroad, at Stoop's ferry, Allegheny county, the United States government quarries sandstone of the Lower Barren Measures for building purposes, to be used chiefly at Pittsburgh, and to some extent in the construction of bridges at Rochester and Davis Island dam. Transportation is by boat. It is gray, of medium fine texture, massive, evenly bedded, and in thick layers. This quarry has been opened for many years, and worked in a small way, but never to any great extent until the building of the Pittsburgh and Lake Erie railroad, many of the bridge abutments and culverts of which are built of this stone. A house standing near this quarry at Stoop's ferry, built of this stone forty-two years ago, is still in a good state of preservation.

At Walker's mills, on the Cairo and Saint Louis railroad, 12 miles west of Pittsburgh, Allegheny county, sandstone of the Lower Barren Measures is quarried for railroad-bridge masonry, and used on the divisions of the Pittsburgh, Cincinnati and Saint Louis railroad between Pittsburgh and Columbus, and also on the branches running from Pittsburgh to Washington, Pennsylvania, and Wheeling, West Virginia; it is gray, of medium fine texture, irregularly stratified, and unevenly bedded in courses varying in thickness from 18 inches to 5 feet, except the bottom layer, which is in places 18 feet in thickness; none of them, however, are of a uniform thickness throughout, but vary considerably within short distances. Partings of shale from a few inches to over a foot in thickness often intervene between the layers of stone. The lower part of the bottom layer is full of nodules of peroxide of iron, often weighing several pounds each. Coal-plants, known as calamites, are found in the lower portion of the ledge. These quarries are situated on the same ledge (the Morgantown sandstone of the *Second Geological Survey of Pennsylvania*), as the local quarries in the vicinity of Pittsburgh and Allegheny, and the character and appearance of the stone are the same as those of the stone quarried at the latter place. The total thickness of the ledge is about 80 feet, setting in thicker as the quarries progress in the hill. A thickness of about 30 feet at the top is of a thin, shelly, broken character, suitable for railroad ballast, for which it is extensively used by the Pittsburgh, Cincinnati, and Saint Louis railroad. Beneath this there are 50 feet or more of solid stone, lying in regular layers varying in thickness from 18 inches to 5 feet, except the bottom layer, which is in places 18 feet thick. This sandstone, as well as nearly all of the sandstones in the region immediately surrounding Pittsburgh, has some calcareous matter in its composition, and wherever a face of the ledge of stone has been exposed for a long time it is very much honey-combed into fantastic shapes, apparently by the disappearance of this calcareous matter, leaving the more siliceous portions intact. The stone when first quarried is very sensitive to the action of frost, and quarrymen say it is best to get it out long enough before winter to allow the "sap" to dry out.

At Mansfield Valley, Allegheny county, also on the Pittsburgh, Cincinnati, and Saint Louis railroad, Morgantown sandstone (near the top of the Lower Barren Measures) is quarried for bridge masonry, and its character is the same as that of the stone from the other quarries on the formation in this region.

The Morgantown sandstone is quarried quite extensively in the hills within and near the limits of Pittsburgh and Allegheny, and it is used almost exclusively for cellars, foundations, sewers, and other underground work in those cities and vicinity. While its character is such as to exclude it from other building purposes, it seems to answer quite well for underground work, and supplies nearly all the stone used in the cities named for this class of construction. It is a bluish-gray in color, medium to fine in texture, with signs of irregular stratification, the bedding moderately even, in layers varying in thickness from a few inches at the top to 4 or 5 feet at the bottom of the ledge. Thin partings of shale sometimes rest between the thin layers at the top, especially at the outcrop. The usual thickness of the ledge is about 35 feet, though at Wood's Run quarry and other places in the neighborhood it reaches a thickness of 100 feet. There is considerable calcareous matter in this stone, and in such a form as to make it liable to decomposition, especially in the smoky and acid atmosphere of Pittsburgh, and at present the inspector of buildings forbids its use for any purpose of construction except underground work. It was, however, frequently used in the construction of important buildings at Pittsburgh ; the court-house was built of it, and the stone in its walls is decomposing so rapidly that it is probable that within a few years a new building must be provided. The material when first quarried presents a substantial appearance, and it was formerly thought that the immense cliffs of it which were projecting out of the hills everywhere in the vicinity would furnish an inexhaustible supply of building stone of superior quality for all purposes of construction, and many important buildings were constructed of it before the error was discovered.

At Baden, situated on the Pittsburgh, Fort Wayne, and Chicago railroad and on the Ohio river, in Beaver county, sandstone of the Lower Barren Measures is quarried for foundations and other ordinary building purposes, and is used in Pittsburgh, Brownsville, Greensburgh, and vicinity. It was used in the construction of the post-office at Pittsburgh. It is gray, massive, coarse in texture, evenly bedded, in three courses, 8 inches, 8 feet, and 7 feet, respectively, and is considerably broken by irregular joints. It was operated for the two years expiring in August, 1880, by the United States government for stone used in the construction of Davis Island dam.

At Kiasola station, on the Pittsburgh and Lake Erie railroad, in Beaver county, sandstone of the Lower Productive Coal Measures is quarried for ordinary building purposes, and is used in Pittsburgh. The bridge masonry and canal locks in the vicinity are constructed of this material. It is gray in color, of coarse texture, massive, and evenly bedded in thick courses.

Near Beaver Falls, Beaver county, on the Pittsburgh, Fort Wayne, and Chicago railroad, 30 miles northwest of Pittsburgh, sandstone of the Lower Productive Coal Measures is quarried for steps, fronts, curbstones, trimmings, monuments and other cemetery work, fences and walls, and is used in Pittsburgh and vicinity. It was used in the construction of Hostetter's stone front on Fourth avenue, Pittsburgh, and in important buildings in that city. It is gray in color, rather coarse in texture, with signs of irregular stratification, is evenly bedded in layers varying from 6 inches to 5 feet in thickness, with thin shale sometimes between. This is a strong and durable stone, and surface blocks which have slipped from the ledge, and which have been exposed for ages, indicate that it stands exposure well. The quarry is on the crest of a hill 300 feet above the Big Beaver, which flows half a mile from its base and discharges into the Ohio 5 miles distant. The following is a slight description of a section of this quarry: The top layer is a material of uniform color, red when quarried, taking its color from the red iron ore immediately overlying the quarry. A thin bed of shale intervening between each two strata facilitates the working of the rock; between the first and second layers are some thin beds varying from 6 inches to a foot in thickness. No. 2 is a very fine, close-grained, white stone, occasionally of a buff or straw color. It is reported to be the best in the quarry, and ranks well with the different stones used in Pittsburgh for building or cemetery purposes. The supply from this bed is not sufficient for the demand. No. 3 is a hard, heavy, fine stone, always brown in color, except along the cleavage, where it is white. No. 4 is usually a straw or buff color, strong and fine in texture. No. 5 is softest, sawing well, and variegated in color so as to be objectionable for rubble work; intervening is a thin bed of shale of bluish color, under which lies No. 6, resting on a coal bed. No. 6 is blue in color, except the sap coloring, which is buff, penetrating from 1 foot to 2 feet. Nos. 5 and 6 sometimes come together, forming one course. Nos. 3 and 4 sometimes contain "nigger-heads" weighing occasionally from 10 to 20 tons. They are blasted out and thrown over the dump. The lower (No. 6) contains fossil coal-plants; in the other rocks the fossils are silicified. Between Nos. 1 and 2 there are fossils of *stigmaria* quite perfect and entire, and the joints are frequently filled with stalactites. There is a slight dip from northwest to southeast.

At Homewood, Beaver county, sandstone of the Lower Productive Coal Measures is quarried for ordinary building purposes and bridge construction, and is used chiefly at Pittsburgh. It varies from a gray to a brown in color, is coarse in texture, shows signs of irregular stratification, and is unevenly bedded in thick courses; it ranks among the best building stones in the western part of Pennsylvania.

Near Wampum, Lawrence county, Homewood conglomerate of the Lower Productive Coal Measures is quarried for bridge construction on the Pittsburgh and Lake Erie railroad. It is gray in color, coarse in texture, massive, evenly bedded, and in thick courses. The Homewood sandstone, which is the upper stratum of the Conglomerate Measures, furnishes most of the building stone quarried in Lawrence county. It is usually a coarse-grained, white or grayish-white sandstone, but in some localities it is colored brownish-red by peroxide of iron. Other strata, especially the Conoquenessing sandstone, are quarried now and then to some extent in different localities. The quarries near Wampum are operated by stone-work contractors on different lines of railroad passing through the place.

At Sharon, Mercer county, the Homewood sandstone of the Lower Productive Coal Measures is quarried for bridge construction and foundations; it is gray, massive, and unevenly bedded in layers not usually exceeding 3 feet in thickness. Several members of the group near the lower limits of the Carboniferous rocks, known in the *Second Geological Survey of Pennsylvania* as the Conglomerate Measures, crop out in the vicinity of Sharon. Different strata of sandstone in this series, and the Chenango sandstone in the Lower Conglomerate, have been quarried for building stone in this locality, but none of superior quality has been produced. The stone from the quarries now operated is a hard, coarse-grained sandstone that is seldom dressed; it seems to be quite durable, however, and is perhaps the most economical material to be obtained in Sharon for cellar walls and foundations, and blocks as large as are ordinarily desired for bridge work can be obtained in some of the quarries. Since the Erie and Pittsburgh canal was abandoned its stone locks have furnished a large amount of cheap and usually quite good building stone to the section of country through which the canal passed, and particularly from Newcastle north. Some of the quarries from which stone for these locks was obtained have been worked but little since the building of the locks, though when the supply from these is exhausted some of the quarries will doubtless be worked again. Sandstone can be obtained almost everywhere in Mercer county, but it is not all good building stone; the localities that do furnish good building stone are but a few miles apart. About 40,000 cubic feet of stone have been quarried for the foundation of the new county infirmary at Mercer. The rock was obtained from quarries located within a radius of 4 miles surrounding the town. The Sharon conglomerate is quarried near Greenville and Chenango, in Mercer county, for flagging, and is used locally. It is gray, fine in texture, has signs of even and distinct stratification, and is evenly bedded in layers usually not exceeding 8 inches in thickness. This formation has here a peculiar development; the stratum is about 12 feet in thickness, and not solid as usual, but in courses from 1 inch to 9 and sometimes 12 inches in thickness. The rock is a blue, fine-grained sandstone; in some places where it has been thoroughly drained, and the particles of iron have been thoroughly oxidized, it has a gray or buff color; it is an excellent paving material, and is shipped to various points in western Pennsylvania and eastern Ohio for paving sidewalks, and is used almost exclusively for this purpose in the town of Greenville in the first-named state. Sometimes the heavier courses occur in the upper portion of the stratum; the iron in them has been peroxidized, and the stone is used to quite an extent for lintels and water-tables. The natural blocks are seldom rectangular, and there is considerable material broken off in shaping up the blocks. Most of this stone, however, finds a ready sale for building foundations.

At Stoneboro', Mercer county, the Homewood sandstone (top member of the Pottsville conglomerate) is quarried for foundation and bridge construction. It is gray and light brown in color, coarse in texture, massive, unevenly bedded in layers from 1 foot to 4 feet in thickness, and is used chiefly in the vicinity. The stratum of quarry rock is about 20 feet in thickness; it is very much fissured, and the natural blocks are variously shaped, though easily reduced to any required form.

At Rockwood, near Oil City, Venango county, detached blocks of the Conoquenessing sandstone (the middle member of the Pottsville conglomerate) are quarried for bridge construction. The stone is gray, coarse in texture, massive, evenly bedded, and in thick layers where found in place. In Report 2^4, *Second Geological Survey of Pennsylvania*, p. 57, Professor White describes a honey-comb rock found in Crawford county, and near Franklin, in Venango county, and thinks the blocks found in these different localities have come from the same bed, possibly the Conoquenessing sandstone. Some of the blocks at Rockwood show that the lower portion of the stratum from which they were detached has the same peculiar structure, and is probably the same bed.

At Garland, Warren county, detached blocks of the Sharon conglomerate (bottom member of the Pottsville conglomerate) are quarried for bridge construction in the vicinity, and on the Pennsylvania and Erie railroad.

The stone is gray, coarse in texture, massive, evenly bedded, and in thick courses where found in place. The principal quarries are located about 400 feet above the level of the Pennsylvania and Erie railroad. The stone is lowered from the quarry to the railroad on a small car running on an inclined track; two cars are used, connected by a cable passing around a drum. The stratum from which the blocks are quarried, as detached, caps the hill about 100 feet above the level of the quarry. The blocks referred to vary in size from the smallest to blocks containing several thousand cubic yards. Most of the building stone that has been used in this part of western Pennsylvania was obtained from such blocks, and from long exposure the material from them is almost universally very hard and difficult to dress; but since it can be obtained without stripping, it is cheaper on the whole than the softer material which might be obtained by stripping the stratum from which the blocks are detached. It is also less expensive, because, the blocks being already detached, a part of the usual work of quarrying is saved. It is difficult, however, to obtain a large amount of this kind of stone of uniform color; a more uniform stone can usually be obtained from the undisturbed stratum. This variegated coloring is due probably to the unequal effects of exposure on different portions of the surface blocks in the oxidizing of the iron in the composition of the stone, and to the unequal effects of exposure on other ingredients of the rock.

Other localities worthy of special notice where building stone has been obtained in this vicinity are near Sinnamahoning, in the southeastern part of Cameron county, and near Ridgway, in the western part of Elk county. The amount of capital invested is small, considering the real extent of the business in this part of the state. Most of the stone quarried is taken out by builders and contractors, and is used chiefly for foundations and bridge construction, the only considerations being cheapness and durability. Detached blocks are found almost everywhere in the ridge except in Erie county. As these detached blocks have been exposed to atmospheric action for ages it is seen at a glance whether the material is durable; and if it splits well it is quarried, and is used in localities to which it can be most conveniently transported. The sum paid for the privilege of quarrying is seldom more than 10 cents per cubic yard for any amount.

Near Meadville, Crawford county, the Sharon conglomerate is quarried for general building purposes and is used locally. It is a light gray, coarse sandstone, massive, evenly bedded, and in thick courses. The stratum is about 45 feet in thickness, though only from 20 to 30 feet of the upper portion is suitable for building stone; the lower portion is coarse, and sometimes a mere mass of quartz pebbles. The upper portion or quarry rock is quite uniform in texture; it is light gray in color, is easily broken into rectangular blocks by means of wedges; is soft when first quarried, easily dressed, and is quite strong and durable. The quarries are located in the summit of the hill, about a mile and a half northeast of Meadville, and the highway is down-grade all the way to the town. Quarries have been worked in other localities in the vicinity, producing an equally good building stone, but from none of these localities can the material be transported readily to Meadville. The Chenango sandstone, here a brownish-gray stone, containing numerous concretions of peroxide of iron, might be quarried to an unlimited extent near by. It has been quarried to some extent and used in some of the finest buildings in Meadville.

Quartz porphyry.—Mr. A. E. Lehman, Second Pennsylvania geological survey, sent a number of specimens of quartz porphyry from near Fairfield and Graefenburg, Adams county, and from Pine Grove and Laurel Forge, in Cumberland county. These rocks are identified by Dr. T. Sterry Hunt with the orthopelsite porphyries of the Huronian system of Canada; they underlie the Potsdam sandstone of the South mountains, and overlie the Philadelphia gneiss. They are of a purple color, usually indistinctly stratified, and regularly bedded in courses of varying thickness. The structure of the rock is a fine, compact matrix, with distinct crystals disseminated through it; it is well adapted to ornamental work, as it is rich in color, durable, and susceptible of a good polish, and in many places could be obtained in abundant quantities. It has not as yet been quarried for purposes of construction.

SLATE.

The slates of Pennsylvania are used for school slates, for roofing, for mantels, and for flagging, both in foreign countries and in the principal cities of the United States, especially from New York westward. The quarries of roofing slate at East Bangor, Pen Argyl, and near the Wind Gap in Kittanning mountain; at Chapman, in Northampton county, Slatington, Lehigh county; and in fact all the slate quarries in Northampton and Lehigh counties are located on strata of Hudson River age, overlying thin beds of Utica shale, which in turn rest on the Trenton, Chazy, and Calciferous limestones (the magnesian limestone of the great valley, Siluro-Cambrian).

The Hudson River slate formation, 5,000 feet thick more or less, makes two-thirds of the floor of the great Lebanon, Cumberland, or Shenandoah valley, as it is variously called in the states through which it extends, the valley being bounded on the north and west by the Blue mountain, and on the south and east by the South mountain. The Hudson River slate formation occupies the valley from its middle line northward and westward to and up the slope of the North mountain, while the Trenton and magnesian limestones occupy the southern and eastern side of the valley to the foot of the South mountain.

The roofing-slate belt is a continuous strip of varying width extending through Lehigh and Northampton counties close to the foot of and parallel with the Blue mountain. It is not, however, of such a character at all points on the formation as to be suitable for roofing slate. The localities where the material is of such character as to be suitable for the purpose are carefully selected. In fact, the roofing-slate quality is characteristic only of certain beds or small groups of beds at various geographical horizons in the great Hudson River slate formation.

From Report D D D of the *Second Geological Survey of Pennsylvania*, which is soon to go to press, and the revise file of which was kindly loaned for use in this report by Professor J. P. Lesley, state geologist of Pennsylvania, we learn that the whole slate belt referred to as Hudson River slate is an irregular hill country, strongly contrasting with the magnesian limestone country, which borders on the south, both in the comparative number and ruggedness of its water-courses; and that with the exception of Schoharie ridge, in Lehigh county, and perhaps Sandstone ridge, north of Hockendaugua, there are no well-defined ridges marking the outcrops of harder subdivisions of the great slate formation, so that it is difficult to separate the main belt into subordinate belts. The whole mass is one formation equivalent to the Hudson River slate of the *New York Geological Survey*, excepting that along the southern border Mr. Prime reports occasional traces of Utica black slate immediately overlying the Trenton limestone. The southern border of the slate district is everywhere a one-sided hill or steep descent toward the limestone lands. The whole formation is divisible into an upper and lower mass, the upper being more massively bedded, and therefore supporting more elevated country. Its uppermost beds constitute the southern slope of the Blue mountain, but the large and important roofing-slate quarries are all in the lower subdivision of the formation.

It is further stated that these same slates extend along the north side of the valley, through Berks, Lebanon, Dauphin, Cumberland, and Franklin counties, into Maryland and Virginia. There are no slate quarries open west of the Schuylkill on this formation, but the same slate formation goes on across the state, and the cleavage shown by the outcrops has about the same appearance.

Red slate outcrops through the western part of Berks county, and a careful examination may disclose that some of the outcrops will produce suitable roofing material.

In New Jersey, at the Delaware Water Gap, a thickness of 3,000 feet is assigned to the whole mass. Mr. Prime's measurements along the west bank of the river make it more than 5,000 feet. Mr. Chance's independent measurement at the Water Gap places the roofing-slate quarries at 2,350 feet respectively beneath the Oneida conglomerate, and his estimate of the whole thickness of the Hudson River slate formation is about the same as Mr. Prime's. In Berks and Lebanon counties the total thickness is stated at 6,000 feet.

The following is an approximate estimate of the position of the quarries on the formation, beginning with the highest and going down: First, quarries at Pen Argyl; second, Hindbeck quarries; third, Slatedale; fourth, Steinville; fifth, Slatington; sixth, Bangor.

The "ribbons" in the slate, described by Professor H. D. Rogers, are very thin layers, from a few lines to an inch or two in thickness, traversing the rocks in bands parallel to each other and at various distances, not generally exceeding 2 feet. These ribbons indicate the direction of the dip of the strata, being seams of somewhat different composition from the rest of the mass. Between each two of the ribbons the layer of slate is homogeneous or of uniform texture and composition, but a difference in the quality of the slate on the two sides of one of these thin layers is quite common. When we examine a new surface of the slate, the usual and permanent color of which is dark bluish-gray, the hue of these ribbons is nearly black, but on exposure to the atmosphere they show, after some time, signs of spontaneous decomposition, and display a whitish efflorescence which indicates that this part of the slate contains sulphuret of iron. The ribbons are therefore carefully excluded from the slate when the latter undergoes the operations of cleavage and trimming in preparation for the market. In most of the slate quarries near Bangor, Northampton county, which is the northern end of the slate belt, the slate is tough and possessed of some flexibility, cleaving readily, the proportion of waste being comparatively small. Toward the southern end of the slate district of Lehigh and Northampton counties the texture and quality of the slates are slightly different from those in Northampton county, and a greater proportion is manufactured into school slates, and some is also shipped for sidewalk paving. Most of the large quarries in this district are producing on an average twice the amount of slate produced two or three years back, with but one-third more force of men and machinery, showing that within certain limits a large force is more economical than a small one. This is true of the quarries at Pen Argyl, East Bangor, Slatington, and in fact of the whole district. From 1876 to 1880, the foreign demand was so great that but little attention was paid to home trade, there being in fact scarcely any home trade. Slates were so low in price that foreign merchants could purchase here and ship to England cheaper than they could buy at home; at present the increase in price of slates created by the home demand has stopped shipments to foreign countries altogether.

In Report D D D, *Second Geological Survey of Pennsylvania*, there is a chapter on the slate region of Northampton and Lehigh counties, covering all that part of the great Lebanon and Cumberland valley which lies between the Delaware and the Schuylkill rivers, and between the Blue or Kittatinny mountain on the north and the edge of the limestone on the south; and there are notes describing the individual quarries. We are indebted to this report for some of the measurements and descriptive matter in the following remarks concerning some of the quarries which were in operation during 1880. The details given will aid in obtaining definite ideas as to the quarries themselves and as to the structure of the slate.

The Bangor Union Slate Company's quarry is 250 by 130 feet, deep at the deepest place, with from 10 to 20 feet of drift on the surface. The largest bed is 4 feet thick. The synclinal axis which shows in the Bangor quarry also shows in this one, but the plane of the axis dips slightly to the south instead of to the north as in the Bangor. The quarry is worked by five cable derricks, which supply the material to twenty shanties, *i. e.*, the sheds in which the slate is cut into shape for roofing. The derricks are run by an engine which, working a line of shafts, connects with the cable derricks by conical friction-wheels.

Bry & Short's quarry, 300 yards east of the old Bangor quarry, is 200 by 150 by 60 feet, with a dip of 10 feet north; the cleavage is 20° south, and the largest bed is 4 feet thick. The quarry is worked by cable derricks run by steam-power. The school slates are planed at the quarry.

The Star quarry, 500 feet west of the east Bangor No. 2, is 200 by 200 by 50 feet, and the cleavage is 20° south; it is worked by cable derricks run by steam, and there are also horse-power derricks, beside appliances for cutting roofing slate and circular saws for cutting school slates. The ribbons in this and the other quarries usually indicate the direction of the stratification, which in this slate district is usually not parallel with the cleavage, but crossing it at varying angles. Much of the material is quarried in such shape that it may be worked up for ornamental purposes instead of being split into roofing slates.

In the Bangor Slate Company's quarry there is a synclinal axis passing through the center of it about 70 feet below the surface; the cleavage and the plane of the axis dip 5° to the north. There are 30 feet of drift on the top of the quarry. The largest bed is 9 feet 6 inches thick. The synclinal axis, being the same that shows in the Washington quarry and in the Bangor Union, pitches to the west. The hoisting is done by cable derricks run by steam, but horses and carts are also used.

The north Bangor quarry No. 1 is 200 by 200 by 40 feet at the deepest place. There are 20 feet of drift covering the slate, and 1 foot below the drift the material is of such quality that it serves for roofing slate. Cleavage, 10° south and 30° east; dip, 45° south and 30° east. The two largest beds are 4 feet thick, and there is a bed measuring 10 feet along the cleavage. The series of beds extends all the way across the flooring of the quarry and all of them are under 4 feet each in thickness.

The north Bangor quarry No. 2 is a few hundred feet north of No. 1, and is 150 by 100 by 40 feet deep. The dip is 35° south and 30° east; the cleavage is 15° south and 30° east. The beds that are exposed are mostly small, each under 4 feet in thickness.

Jackson quarry is 300 by 200 by 100 feet deep. It is worked by cable derricks run by double cylinder steam-engines. The slates come out in good-sized blocks, some of them 20 feet long.

The Jory quarry is 400 by 200 by 80 feet deep. It is worked in the center of a synclinal axis; the dip of the rocks is slight in the center of the axis; the plane of the axis is vertical, while the cleavage is horizontal. This is the only quarry in which the cleavage can be seen at right angles or at any considerable angle to the plane of the axis. The beds worked are not large, but the cleavage makes such a slight angle with the bedding that large blocks can be taken out.

The west Bangor quarry at Pen Argyl is 125 by 150 by 40 feet deep. The dimensions of the largest slab quarried were 13 feet long by 4 feet wide by 18 inches thick, but slabs 15 by 6 feet by 12 inches thick might be obtained.

Stephen Jackson & Co.'s quarry is 400 by 200 by 80 feet deep; dip, 28° south; cleavage, horizontal; beds from 12 to 25 feet long along the cleavage.

The Chapman quarry is 500 by 300 by 130 feet deep. Cable derricks run by steam are used in hoisting the slabs out of the quarry preparatory to working them into roofing slates. Splitters here make from two to six squares a day, averaging about four. The hoisting apparatus is very complete; a slab weighing 2 tons is hoisted 150 feet vertically and 300 feet horizontally in about two minutes. There is a factory here for making and planing slabs and other sawed material, the appliances consisting of diamond saws, planers, gig-saws, and smoothing table—the diamond saw, by reciprocating motion, cutting through slate at the rate of an inch in five minutes, making about 50 strokes a minute. The slates are all thinly-bedded, split well, and are tough. The blocks come out of the quarry in large, even pieces, some of them 20 feet long. The usual dimensions are 8 by 10 feet or less.

Frederick Prime, jr., in Report D D, *Second Geological Survey of Pennsylvania*, says substantially of the slates toward the southern end of this slate quarry district, in Lehigh county, at Slatington, White Hall, Slatedale, Lynnport, and Steinville, that they are distinguished by bluish-gray or black color, cleave readily into thin slabs, and when the cleavage forms a high angle to the bedding and the slates are free from grit and are otherwise of good quality, they are quarried and are excellently adapted for roofing purposes, school slates, blackboards, and other articles of this nature. Owing to the property they possess of cleaving readily the slates are usually observed with the cleavage predominating to such an extent as to obscure and often to entirely conceal their stratification. As a rule their true bedding can only be observed by means of the wavy lines of a slightly different color from the body of the slates, which are constant and persistent in their passage through the cleavage, these lines indicating the stratification. The quarries of the Lehigh and Northampton district in Pennsylvania are distant about 100 miles from the city of New York and 75 miles from Philadelphia. In 1875, according to Professor Silliman, but five quarries were worked in Lehigh county—the Washington, the Franklin, the Trout Brook, the Bangor, and the Douglas.

The North Peach Bottom Slate Company's quarry is in Whitehall township, on the Lehigh Valley railroad, east of Bethlehem. The largest slab which has been moved thus far was 42 by 10 feet by 20 inches thick, and blocks 40 by 20 feet by 20 inches thick might be loosened. The custom is to reduce the blocks to such size that they may be conveniently hoisted out of the quarry. The form of the natural slabs here is rhomboidal. The slates come out remarkably even and straight; they are 16 feet long, a straight edge touching at nearly every point on a slab of the material. Transportation from the quarry is afforded by means of the Lehigh Valley railroad and Lehigh and Delaware canal. There is but one grade of material quarried, it being all similar in structure and texture. It is reported that roofing slates from this quarry exposed for thirty years are not yet discolored and need no repairs. The slate is sawed, planed, and rubbed by steam-power. The method of draining the quarry is by a siphon consisting of a pipe 1½ inches in diameter and 450 feet long. Mr. John Crump, of the North Peach Bottom Slate Company, states that in his examination of the slates in Pennsylvania and Vermont, and those of Wales, in Great Britain, and of the Angiers district on the Loire, France, he found that the material from this quarry ranks very high in respect to size, thickness, and evenness of the slabs that may be quarried and the hardness, toughness, and uniformity of texture of the material, and for its freedom from ribbon or spots, stains, or quartz veins. The dip of the cleavage in this quarry is about 50° northeast to southwest. The main joints are about 50 feet apart, and about 35 feet below the surface soil sound slate commences half an inch thick, increasing in thickness of strata as it descends. At about 45 feet below the surface the beds are 6 inches thick; at 60 feet, 12 inches thick, and at 80 feet, 20 inches thick. This is the greatest depth quarried thus far, and the proprietors believe that the beds will go on increasing in thickness at a like rate to a depth of 200 feet, at which depth they expect a deterioration.

The color of the slate is blue-black. This slate has been much used by the United States government at Albany, New York; New York city; Topeka, Kansas; Austin, Texas, and Saint Louis, Missouri. The Patent Office building at Washington city has tiling on the top floor of the north side from the North Peach Bottom slate quarries. There are also Chapman slates in the flooring of this building.

Henry & Co.'s quarry, near Slatington, produces material for roofing slate, which is at present transported on wagons 5 miles from the quarry to the railroad station on the Lehigh and Susquehanna railroad opposite Slatington. The largest slab that has been quarried was 10 by 4 feet by 6 inches. The form of natural slabs is irregular. The method of drainage is pumping by water- and steam-power; the hoisting is by steam, and the dressing by hand.

Caskie & Emack's quarry is located 1½ miles northeast of Slatington. The form of the natural slab is rectangular; the dimensions of the largest slab quarried is 30 by 8 feet by 20 inches thick. The quarry is drained by means of a pump worked by steam-power; the hoisting is done by steam-power, and mantel stuff is worked by circular saws and iron planers run by steam.

James Hess & Co.'s (Slatington) quarry produces material for roofing and other architectural purposes. The dimensions of the largest slab quarried here are 10 by 18 feet by 6 inches, but slabs 18 by 20 feet by 12 inches might be moved. The product is marketed throughout the United States. The hoisting and pumping are done by steam. This firm has a factory for manufacturing school slates, and one for manufacturing mantel stuff, blackboards, and tiling.

The Penryn quarry, at Slatington, operated by W. H. Seibert, produces roofing slate, school slates, and the material for blackboards for public schools; also hearth-stones, mantel stuff, and register-stones. The peculiarity of some of the material of this quarry is that some of the beds are a shade or two darker and softer in texture than others, and are easily distinguished in the quarry. The dark stone or beds, when used for roofing, discolor when exposed, while beds of lighter shade, which are harder, when made into roofing slates hold their color, and are very durable. Frequently hard and soft beds lie side by side in the ledge.

In the quarry of David Williams, at Slatington, the form of the natural slabs is irregular. The transportation from the quarry is by rail, on the Lehigh Valley, the Berks and Lehigh, and the Lehigh and Schuylkill railroads. The power employed in draining, in hoisting, and dressing mantels and blackboards is steam; the drilling and dressing of roofing and school slates are done by hand.

The Columbia Slate Company's quarry is situated half a mile west of Slatington, on a branch of the Lehigh Valley railroad, from whence the slates are shipped to various states and some exported to foreign countries. The hoisting and draining are done by steam, the drilling and dressing by hand.

At the Franklin quarry, half a mile west of Slatington, there are two different varieties of dark blue roofing slate, but no soft beds of school slates. The form of the natural slabs is rhomboidal.

Griesimer & Brothers' quarry produces roofing slate exclusively. The form of the natural slab is rectangular. The dimensions of the largest slab which has been quarried are 16 by 5 feet by 4 inches, but slabs 22 by 15 feet by 6 inches might be moved. The slate is transported on the Lehigh and Schuylkill railroad.

Keever & Lutz's quarry produces roofing slate, which is marketed in Berks and Lehigh counties, being transported by wagon and by railroad. The form of the natural slabs is irregular. Hoisting is done by steam, the drilling and dressing by hand.

Laurel Hill Slate Company's quarry produces slate for roofing purposes. The form of the natural slab is irregular. Hoisting is done by steam, the drilling and dressing by hand.

The Lock Slate Company's quarry produces slate for roofing, school slates, tiles, platforms, and steps. The form of the natural slabs is irregular; slabs 27 by 8 feet by 5 feet thick might be moved. A branch of the Lehigh

Valley railroad is built to the quarry. Draining, hoisting, sawing, and planing are done by steam, the drilling and dressing by hand. The machinery consists chiefly of saw-beds, planes, and patent machines for dressing roofing and school slates.

Joel Neff's quarry, near Slatington, consists of three openings on the same ledge of slate. The material is quarried for roofing, and is marketed chiefly in the United States, though some is exported. The form of the natural slabs is irregular; size of the largest slab quarried, 500 cubic feet, but a slab of 600 cubic feet might be moved. The draining and hoisting are done by steam, the dressing partly by steam, and the drilling by hand.

Krum & Moser's quarry, formerly known as the Blue Mountain quarry, produces roofing slate exclusively, which is marketed in the middle, western, and northwestern states, and is transported by railroad and canal. The form of the natural slabs is rectangular, and the dimensions of the largest slab that has been quarried were 18 by 5 feet by 18 inches. Hoisting and pumping are done by steam, the drilling and dressing by hand.

The Industrial Slate Company's quarry, west of Slatington, is operated for roofing slate exclusively. The form of natural slabs is rectangular, and the dimensions of the largest slab that has been quarried were 15 by 4 feet by 6 inches. The draining and hoisting are done by horse-power, the drilling and dressing by hand.

PEACH BOTTOM QUARRIES.—The ledge of slate in which the Peach Bottom quarries are situated furnishes the dark blue, indurated clay-slate almost devoid of calcareous material, as it is of Archæan age, and therefore older than any of the calcareous rocks of Pennsylvania. The following is an analysis of Peach Bottom slates, specimen from J. Humphrey & Co.'s quarry, half a mile east of Delta, York county, from Report C C C, *Second Geological Survey of Pennsylvania:*

	Per cent.
Silicic acid	55.880
Titanic acid	1.270
Sulphuric acid	0.022
Alumina	21.849
Ferrous oxide	9.034
Manganous oxide	0.586
Cobaltous oxide	Trace.
Lime	0.155
Magnesia	1.495
Soda	0.460
Potash	3.640
Carbon	1.974
Water	3.385
Iron bisulphide	0.051
Total	99.800

The percentage of lime in its composition is small compared with that in many other slates, some of which are quite perceptibly calcareous. The nearest belt of calcareous rocks is the magnesian limestone of Lower Silurian age, to the northwestward. Serpentine rock lies on one side of this slate ridge, and asbestus on the other. The ledge at Peach Bottom is several hundred feet in width, varying somewhat in this respect, however, and extending along on the summit of the low ridge which extends in a northeasterly and southwesterly direction. The slate begins in the southwestern part of Lancaster county, Pennsylvania, crossing the Susquehanna river not far from Mason and Dixon's line, passing through the southeastern part of York county, Pennsylvania, and extending into Harford county, Maryland. At the Susquehanna river, on the Lancaster County side, slate was once quarried. The ledge at this point is quite high and steep, but rapidly lowers in passing into York county. The bed of the Columbia and Port Deposit railroad, which passes here, interferes with the disposition of waste.

A few miles farther to the southwest, at Bangor and Delta, and just across the line in Maryland, what is known as the Peach Bottom slate is at present quarried. In quarrying slate for roofing there is always considerable waste on account of material unsuited to the purpose. The quarrymen select locations where there is likely to be the greatest proportion of workable material, of which they judge by the appearance of the slate which extends to the surface. The cleavage planes in most of the quarries are nearly vertical, and are parallel to the stratification; and in some of the quarries there is a set of joints cutting the cleavage planes at angles varying from about 45° to 60°. A noticeable circumstance is that the joints in these quarries are less numerous to the westward. In some of the quarries there is beautiful slate stock which cannot be readily split for roofing slate, but which answers well for other purposes. The following are a few of the buildings in which Peach Bottom slate has been used for roofing: The building of the Bureau of Engraving and Printing at Washington city; the court-house and post-office at Des Moines, Iowa; the Academy of Fine Arts in Philadelphia, and the Westinghouse Air-Brake Company's building, Allegheny, Pennsylvania. This slate ranks high for strength and durability, is not subject to change in color upon exposure, and is tough and fine and smooth in texture. Old buildings in the neighborhood of the quarries have roofs of it which were put on seventy-five years ago, and show no perceptible change in color. It is practically free from sulphur, iron, and lime, the ingredients which when present cause fading and decomposition of roofing slate by exposure. The slates here are manufactured by breaking up the rock first by blasting, then by different processes into pieces of suitable shape and size for splitting by hand, using for this purpose thin chisels of steel, after which they are dressed or cut into shape and size by a machine. The common sizes are 12, 14, 16, 18, 20, 22, and 24 inches in length, and four or five different breadths to each length are made. The average thickness of slate here is about fifty-five pieces to the foot. The material is sold by the square superficial area of 100 feet, weighing about 625 pounds. Some architects in making out specifications call for thicker slates than those made for the trade. All the sizes made rank the same as to quality and manufacture. Vol. I, *First Geological Survey of Pennsylvania*, gives a short description of the quarries that were operated on the Peach Bottom slate belt about the year 1850; and also some statistics concerning the amount of material quarried and the value. It is stated that the prices of slate for the six years ending in 1853 ranged between $14 and $17 per ton—that is to say, from about $4 to $6 per square; that slates of the largest size, 24 by 14 inches, were $69 per thousand; those 16 by 8 inches, $22 per thousand; and those 12 by 6 inches, $12 per thousand.

The following description of the slate belt of Peach Bottom, by Professor Henry D. Rogers, is in the *Report of the First Geological Survey of Pennsylvania* for the year 1853:

Slate belt of Peach Bottom.—The next subordinate belt which the section crosses is the slate range of Peach Bottom and Slate point. The rock here is a dark blue, indurated clay-slate, much of which has the structure of roofing slate, extensive quarries of which have long been successfully wrought at the Peach Bottom cliffs on the eastern side of the river, and also at numerous points west of the river, in York county, and in Maryland. The workable slate belt here is about half a mile wide. The slaty cleavage and the bedding appear throughout to be nearly coincident in their dip, which at the quarries is nearly perpendicular a little southward. The quality of the Peach Bottom slates is very good, and their exportation is slowly augmenting. The belt runs northeastward through the Slate hill from the river, a distance of about 2 miles, and southwestward through York county from Slate point, a distance of about 6½ miles, to the state line. Slate quarries have been opened northeast of the river, along nearly the whole distance mentioned, but never extensively wrought, and in the same detached manner through York county. At Slate hill on the river the slate is quarried in steps or benches, and not in one general breast, though the material is so uniformly pure as to admit of being nearly all wrought. On the east side of the river there are seven quarries near the shore, and four others of smaller size back on the hills, which are at the present time unwrought. On the York County side there is only one quarry at the river, but in the interior of the county there are seventeen more, embraced between a point 2½ miles back and the end of the range 6 miles from the river. The workable slate appears not to extend in Lancaster county northeast of the limit given, but in the other direction there are indications that it is prolonged beyond the distance of the 6 miles named. One of the quarries on the river, Brown's Lower quarry, yields slates which will bear strong stove heat without cracking, and the workmen use flags of it for frying their meat upon; so uniform is the composition of the material, and so diffused and regular the metamorphism, that the original planes of sedimentation or bedding are too indistinct at these river quarries to be discernible. The cleavage-planes, the only visible ones, dip about 80° south to 30° east, and this condition prevails throughout.

General considerations.—In a treatise on slate and slate quarrying by D. C. Davies, F. G. S., London, 1880, he assigns causes for the recent rapid increase in the slate trade in Great Britain. He states that the progress made by this trade during the last quarter of a century in that country has been very marked and rapid; and with the exception of slight checks given to it during the civil war in America, the war between Prussia and Denmark, and that between Germany and France, the progress has been continuous; that during the last ten years the price of slates has increased 30 per cent., and that the present state of the trade may be described as one of such great prosperity as to be limited only by the ability to supply the demand, the demand being far in excess of the supply. This increasing prosperity of the slate trade Mr. Davies ascribes to the rapid extension of railways over the country, which places slates within the reach of numbers of inland towns from which, excepting for special purposes, they were virtually excluded on account of the cost of carriage. The inland town of Shrewsbury was, until the extension of the railway system, a tile-roofed town, while Chester, to which access is had by water, has been for generations a slated town. In Shrewsbury and most of the other inland and formerly tile-roofed towns slates have superseded tiles. The fact that slate is so rapidly and steadily superseding other roofing materials is chiefly due to the increased facility for transportation afforded by the railways, and it is plain that the same causes influence the development of the slate industry in the United States. The railways not only afford ready means of transportation from the slate regions to inland cities which were before entirely excluded from the use of slate, but new business centers spring up along the lines of the railways and thus increase the demand for slates.

There have been within the last ten years some singular conditions in the slate trade both in this country and in Great Britain. The demand increased so rapidly in the British islands during the past ten years that it was far in excess of the supply, while in the United States during that time the trade was in its infancy, increasing rapidly, however; but from 1876 to 1880, owing to business depression chiefly, to an almost entire cessation in building enterprise, and to the custom of using the cheapest materials, the demand was not equal to the production of the slate regions of the country, bringing down the prices of slates so low that they were shipped to Great Britain, even selling at a lower rate than the Welsh slates; and considerable foreign trade sprung up in this way. However, as the prices of American slates in England could not rise any higher than the prices of the Welsh slates in that country without stopping the American trade altogether, exportation was unprofitable to the quarrymen. During 1880 the general resumption of business throughout this country created a sudden demand for American slates at home, the prices ran up to almost double the former rates, and the demand far exceeded the supply.

The Welsh and the American slates are quarried from formations of the same age—that is, strata of Cambrian and Lower Silurian age. The quarries in Buckingham county, Virginia, and in the slate regions of Harford county, Maryland, York county, Pennsylvania, Piscataquis county, Maine, Rutland county, Vermont, and Washington county, New York, are probably of Cambrian age, while the region of Lehigh and Northampton counties, in Pennsylvania, is of the Hudson River division of the Lower Silurian age.

The Welsh slate regions at Festiniog, Portmadoc, Carnarvon, Penrhyn, and other places are from Harlech, and Llanberris, and Trenbech beds of Cambrian age, and the Upper and Lower Llandeilo and the Wenlock strata of Lower Silurian age. A comparison of chemical analyses of the Welsh and American slates aids to determine their relative values as roofing materials. The fact that Welsh slates are shipped to the United States, and at times figure considerably in the American market, and that American slates are exported to Great Britain and Ireland, makes this question one of importance. The following are some analyses of Welsh slates given by Mr. Davies:

ANALYSIS OF ORDINARY WELSH ROOFING SLATE (BLUE).

[Given by Professor Hull. (*a*)]

	Per cent.
Silica	60.50
Alumina	19.70
Iron (protoxide)	7.83
Lime	1.12
Magnesia	2.20
Potash	3.18
Soda	2.20
Water	3.30
Total	100.03

ANALYSIS OF DARK BLUE SLATE FROM LLANGYNOG, NORTH WALES.

[By Mr. D. H. Richards, analytical chemist, of Oswestry.]

Analysis of slate dried at 100 C.:

	Per cent.
Loss on ignition	3.720
Silica	60.150
Protoxide of iron	5.837
Sesquioxide of iron	1.815
Alumina	24.200
Not determined—alkalies, etc	4.278
Total	100.000

ANALYSIS OF THE MATERIAL OF THE GREEN BANDS IN THE BLUISH-PURPLE SLATES OF LLANBERRIS.

[Made at the Royal School of Mines for Mr. George Maw, F. G. S., of Broseley.] (*b*)

	Per cent.
Silica	66.45
Titanic acid	0.63
Alumina	13.38
Protoxide of iron	1.71
Peroxide of iron	1.41
Protosesquioxide of manganese	0.91
Lime	2.86
Magnesia	6.28
Potash	0.05
Soda	0.90
Carbonic acid	1.30
Combined water	3.90
Hygroscopic water	0.13
Total	99.91

ANALYSIS OF THE PURPLE SLATES OF NANTLLE.

[Given in *Kirwan's Mineralogy*, Vol. I, p. 210.]

	Per cent.
Silica	0.48
Argillaceous matter	0.26
Magnesia	0.08
Lime	0.04
Iron	0.14
Total	100.00

For analysis of Peach Bottom, Pennsylvania, slate, see page 110.

a *Building Stones of Great Britain and Foreign Countries.* *b* *Geological Magazine*, 1868, p. 123.

MARYLAND.

[Compiled mainly from notes of Messrs. Huntington, Monroe, and Singleton.]

About one-half the area of the state of Maryland is made up of rocks of the Cretaceous and the Tertiary ages, which in this state furnish no stones of importance for purposes of construction. A line drawn from near Elkton, in the northeast corner of the state, southwesterly through Baltimore to Washington, following nearly the course first of the Philadelphia, Wilmington, and Baltimore railroad and then of the Baltimore and Ohio railroad, would approximately separate the Cretaceous and the Tertiary areas from the Archæan, adjoining them on the northwest. Passing westward from the line described, about the same order of succession of strata as that in Pennsylvania occurs, as follows: The Archæan rocks, furnishing granites, gneisses, serpentines, and slate; next the narrow belt of the Triassic rocks, from which are obtained the Seneca red sandstone and the Potomac breccia marble; the Lower Silurian strata, in which are found the great Magnesian limestone and marbles; the Upper Silurian, Devonian, and in the mountain region near Cumberland, in the northwest corner of the state, the Carboniferous, none of which have as yet furnished much stone for building purposes. A thorough geological survey of this state has never been made.

CRYSTALLINE SILICEOUS ROCKS.

At Port Deposit, Cecil county, near the mouth of the Susquehanna river, a gray biotite gneiss is extensively quarried, and is used chiefly for heavy masonry, such as bridge construction, docks, harbor improvements, and general purposes of construction. It has been much used by the United States government in public works. Among the structures in which this stone has been used are the Susquehanna bridge at Havre de Grace; the Girard Avenue, Fairmount, South Street, and other bridges in Philadelphia, and the principal bridges in Baltimore; Haverford college, Maryland, Taylor college, Bryn Mawr, the depot building of the Philadelphia, Wilmington, and Baltimore railroad, and Saint Dominick's church, in Washington city. There are several churches in Port Deposit built of stone from these quarries, which show that buildings constructed entirely of this material make a very pleasing appearance. The material is of a dark gray color, rather coarse in texture, and very distinctly laminated. The principal set of joints in these quarries has an inclination of about 60°; but a short distance farther up the Susquehanna river these joints become vertical, or nearly so. A notable circumstance connected with the quarries here is that the planes in which the mica is arranged are vertical.

The gneiss which is exposed in the vicinity of Baltimore is the principal resource of that city for ordinary foundations and the rougher sort of stone-work; it is chiefly of gray color, occasionally greenish-gray. The strata are tilted at various angles and the jointing is irregular. Blocks of any size desired may be obtained. Among the buildings in the construction of which this material was used are the United States court-house and the jail in Baltimore; but that used in the United States court-house may perhaps properly be called a granite, as it is very indistinctly laminated. The quarry from which it was taken is at Granite post-office, in Baltimore county, and the material from the same quarry has been shipped to Cincinnati and to Chicago. It is here gray in color, with a slight pinkish tint.

At a quarry of the same material half a mile from this point the whole mass has weathered, leaving immense bowlders, but in the immediate vicinity the general decay is less than is usual in this section; however, there is a noticeable decay along the natural joints, and in this respect it resembles more the gneisses which are quarried farther to the northward on this formation. On one side of the quarry at Granite post-office there is a large mass of mica schist, which differs considerably from the prevailing stone in the quarry. The material nearer to Baltimore is more decidedly gneissoid, and is used more largely in that city for the purposes before mentioned. This stone is what is usually known as the blue gneiss or mica schist of the Atlantic coast, and there are exposures of it at nearly every point along the line approximately parallel to the coast-line and at the junction of the Tertiary and the Archæan rocks. It is the same that is used in Philadelphia, Baltimore, and Washington for the ruder purposes of construction, and varies in character from the different kinds of gneiss to a mica schist. The most noted granite quarries in Maryland are located near Woodstock, Howard county; the quarries, however, being in Baltimore county. A gray biotite granite, sometimes having a pinkish tint, is here extensively quarried for general building purposes and for monumental work, and is shipped chiefly to Baltimore, Washington, and the west. Among the buildings in the construction of which it has been used are those of the Bureau of Engraving and Printing and the National Museum, Washington, District of Columbia; the soldiers' monument, Winchester, Virginia, and the safe-deposit building in the office of the Baltimore and Ohio Railroad Company, Baltimore. This stone varies from an indistinctly-laminated to a massive rock, is a good, safe stone to work, and takes a good polish. The strata are tilted at various angles and the jointing is irregular. Blocks of any desired size may be obtained. In one of the quarries the material lies in the shape of bowlders—a condition which has been brought about by the weathering of the rock. As no glacial action has ever been brought to bear on the strata in this section of the country to remove the weathered portions, the rock is often found covered with a considerable depth of decomposed material.

Near Ellicott City, on the east side of the Patapsco, a biotite gneiss is quarried for curbstones, steps, and for general building purposes, and is shipped to Baltimore and Washington. It was used to some extent in the cathedral in Baltimore. The quarries are in Baltimore county, but Ellicott City, the post-office of this region, is in Howard county. Some of the rock in this vicinity is porphyritic and contains crystals of feldspar an inch and a half or more in length, but they are irregularly distributed through the mass; yet there are places where blocks of some size can be obtained in which the feldspar crystals are quite regular, in which cases the stone is of uniform and handsome appearance. Much of the rock from these quarries has been used in Baltimore and along the Baltimore and Ohio railroad. For 15 miles west of Relay station, on this road, many of the houses are built of this stone; in all, there are about 100 buildings constructed of it, and Professor Huntington reports that he knows of no other place in the country where there are so many stone buildings in an area of the same size. Among the other places from which specimens of gneiss and granite have been obtained are the Relay House, the Winans estate at the mouth of Gwynn's falls, Orange Grove station, and Ilchester, on the Baltimore and Ohio railroad.

With regard to texture the material here varies very much, some of it being quite fine and some coarse. The general dip of the rock is north-northeast.

At the mouth of Gwynn's falls some of the rock is properly a granite, but passes into a gneiss on one hand and a binary micaceous granite on the other, presenting a width of 30 feet on the front. The general dip is about 45° north-northwest. Professor P. H. Uhler regards all the granites of this region as inclosures—that is, entirely surrounded by rocks of a different character—and cites numerous examples to sustain his views; he does not find any intrusive rocks. The strike is north-northeast.

A specimen of granite was forwarded from Montrose post-office, 3 miles east of Rockville, Montgomery county, by Professor Munroe, who reports that the mass of granite here has simply been exposed. It is comparatively easy of access, the location of the exposure being on the hillside, but there is considerable depth of stripping.

Soap-stone exists here also, and was formerly quarried. It comes in direct contact with the granite.

In the Archæan rocks of Maryland is a variety of serpentines, some specimens of which in the census collection in the National Museum have been polished, and present the most brilliant green appearance.

Near Dublin, Harford county, 32 miles northeast of Baltimore and 62 miles southwest of Philadelphia, a compact and massive green serpentine (sometimes called "precious serpentine") is obtained. This material is fine in texture, of great hardness and tenacity, of a beautiful green color, and is susceptible of a fine and brilliant polish. It is a late discovery, and the quarries are not yet fully developed, but blocks that will dress to the size of 5 by 4 by 2 or 3 feet may now be obtained. The Green Serpentine Marble Company, of Harford county, Maryland, is making extensive preparations for quarrying this material, and Professor F. A. Genth, of the university of Pennsylvania, has published a report on the material. He reports that the supply of serpentine is practically inexhaustible, that it is situated in a most favorable position for quarrying on a large scale, and with an abundant supply of water-power to manufacture it into marketable forms. Professor Genth's description of the mineralogical character of this stone is as follows:

It is a variety of massive serpentine, somewhat resembling williamsite, and shows sometimes a slightly slaty structure. It occurs in various shades of green, from a pale leek-green to a deep blackish green, and, from a small admixture of magnetic iron, more or less clouded; rarely with thin veins of dolomite passing through the mass. It is translucent to semi-transparent; it is exceedingly tough, and its hardness is considerably greater than that of marble, scratching the latter with great facility. The analysis of a deep green translucent variety gave the following results:

	Per cent.
Silicic acid	40.06
Alumina	1.37
Chromic oxide	0.20
Niccolous oxide	0.71
Ferrous oxide	3.43
Manganous oxide	0.09
Magnesia	39.02
Water	12.10
Magnetic iron	3.02
Total	100.00

Hardness (or that of fluor-spar), 4.00; specific gravity, 2.668.

Its green color is due to the oxides of chromium, nickel, and iron present.

In a polished condition it appears to me to be practically almost unalterable, as the polished surfaces do not admit of the absorption of atmospheric agencies which cause the decomposition.

I have above stated that a black, mottled serpentine underlies the green, forming a bed of about 800 feet in thickness. It is not sufficiently developed, but is very conspicuous alongside of Broad creek. It weathers more readily than the green, changing into a white rock spotted with black. The fresh rock, in thin plates, is of a very pale greenish-white color clouded with black. It is softer and less tenacious than the green.

The analysis shows it to be a variety of serpentine, like the green, with an admixture of a larger percentage of magnetic iron. It contains:

Silicic acid	40.39
Alumina	1.01
Chromic oxide	Trace
Niccolous oxide	0.23
Ferrous oxide	0.97
Manganous oxide	Trace
Magnesia	38.32
Water	12.86
Magnetic iron	6.22
Total	100.00

Hardness, 4; specific gravity, 2.669.

It is also susceptible of a good polish, and for some purposes may become a valuable ornamental stone.

About 6 miles north from Baltimore, and near the line of the Northern Central railway, is found a serpentine varying from a light to a dark green in color, but it has been but little quarried as yet.

This rock is very well adapted to be used as ashlar in the walls of churches and other buildings. In a church in Baltimore a small portion of this stone has been used with the serpentine from Brinton's quarry, Chester county, Pennsylvania, similar in appearance in every respect. The area of this rock exposed at this point is about 100 acres. Experience with this material goes to prove that it is durable and stands exposure well, but the surface rock shows considerable disintegration; this, however, is not an argument against the durability of the stone in this region, where, as before stated, no glacial or other denuding influences have removed the product of decomposition. An area of serpentine near Deer Creek, Harford county, is represented by a specimen in the collection.

Fifteen miles northwest of Baltimore, on the Liberty road, a steatite or soap-stone is quarried. It is used in lining furnaces and stoves, for registers, and the manufacture of sinks, ice-trays, etc. The color is a greenish-gray. It has defects, which are due to honey-combing occasioned by pyrite cavities.

In the vicinity of Cockeysville and Texas, 16 miles north of Baltimore, on the Northern Central railroad, is a small isolated area of Lower Silurian limestone bounded by rocks of Archæan age, and on this area are located well-known marble quarries. This stone was employed in the construction of Christ church and in the columns and platforms of the city hall, Baltimore, Maryland; the Father Matthew centennial fountain, Fairmount park, Philadelphia; exterior walls of the Washington monument, and the columns and heavy platforms of the Capitol extension at Washington. Blocks 28 by 10 by 3 feet have been quarried, and blocks as large as can be transported by the usual means might be obtained. The stone lies chiefly in large rectangular and nearly horizontal masses. It is usually of a coarsely crystalline texture and of a white or light color. The drilling and sawing are done by steam-power. It is worthy of note that almost all of the marbles of commerce so extensively quarried east of the Alleghanies are from strata of Lower Silurian age, the principal exception being the Snow Flake marble quarried in Archæan strata at Tuckahoe, Westchester county, New York.

At Hagerstown, Washington county, in the great Lower Silurian limestone valley, lying to the west of the South mountain, the limestone is quarried for local use. It is here a magnesian limestone, and specimens analyzed by Mr. Dewey at the National Museum contained alumina and graphite. It was employed in the construction of the Protestant Episcopal and Methodist Episcopal churches in Hagerstown. Professor Charles E. Munroe reports these quarries on a belt locally called Cedar stone, a few hundred feet in width, extending for a distance of several miles, and believed to be peculiar in the fact that the upper layers furnish the most durable stone. There are a number of other localities in the region surrounding Hagerstown and in the same geological horizon as are the Hagerstown quarries. Worthy of mention in this connection is a black limestone found in the Chesapeake and Ohio canal from 4 to 6 miles below Williamsport.

Fogel's quarry, at Four Locks post-office, on the same canal, was worked extensively for stone to be used in the construction of the locks. A variety of light-colored limestone, locally called "Knuckle stone", is found near Benevola post-office; and at the same place there is a quarry of white and variegated marble which was worked for 40 years; it closed in 1858, owing to lack of good facilities for transporting the stone, the quarry being 15 miles from the nearest railroad.

At Keedysville, on the Washington County railroad, a gray magnesian limestone containing black lines is quarried, and is used largely in Hagerstown for steps, underpinnings, and curbs; it resembles the white limestone of Carroll county in the fact that it works easily only in the plane of stratification. It contains a little iron and a silicate.

There are many localities in Maryland where ledges of building stones are but little developed, and from which specimens were collected for the Tenth Census. Among these may be mentioned a siliceous limestone, containing protoxide of iron and a little magnesia, from Liberty pike, Mount Pleasant district, in Frederick county.

Getzendaner's quarry, on the Hagerstown pike, near Frederick, furnishes the "Potomac" or "calico" marble, a calcareous breccia of Triassic age which was quarried at Point of Rocks to obtain the material of which the columns in the old hall of Representatives at the Capitol building, Washington, were constructed. Representative specimens furnished from the Getzendaner quarry show the stone to be here, as in the other points in Maryland and Pennsylvania where it is exposed, a breccia made up of fragments chiefly from the great magnesian limestone to the northwest; its chemical composition being almost the same as the latter.

In a report of the geological survey of Maryland, made in 1833, by Ducatel and Alexander, it is stated that the Potomac breccia marble occurs along the Potomac river, commencing a short distance above the mouth of the Monocacy, reaching nearly to the Point of Rocks, and extending along the valley on the eastern side of the Catoctin mountain to within 2 miles (west) of Fredericktown, at which point it is contiguous to the red sandstone and the blue limestone; and that the formation reappears near Mechanicstown.

Near New Windsor and Union Bridge, in Carroll county, and in the neighboring portions of Frederick county, is found a magnesian limestone which has apparently been subjected to considerable metamorphic action. The signs of stratification are often destroyed, and the color varies from a white with pinkish patches or bands to a pink. A chemical analysis discovers but little variation in the chemical composition of different specimens of this stone; they usually contain much lime, sufficient magnesian carbonate to entitle them to the name "magnesian limestone", a little iron, sometimes in the form of a protoxide, and occasionally a silicate.

SANDSTONE.

There are no large or important sandstone quarries at present operated in Maryland, though, at several localities in the state, sandstone of superior quality for purposes of construction exists in inexhaustible quantities. The most noted quarry of this material is the celebrated Seneca sandstone quarry on the Potomac at the mouth of Seneca creek, 20 miles above Washington city. This material belongs to the Triassic formation described in other portions of this report. The stone was extensively used in the construction of many large public buildings in Washington, including the Smithsonian Institution; the Freedman's Bank building, now the Department of Justice; the Fourteenth Street Lutheran Memorial church; the District jail; and a reference to the remarks on stone construction in the city of Washington will show the other purposes for which it has been used there. There are good facilities for transportation from this quarry to Washington and to all other points along the Chesapeake and Ohio canal.

Specimens of quartzite of Archæan age were collected at Dickerson post-office, Montgomery county, on the Metropolitan branch of the Baltimore and Ohio railroad and the Chesapeake and Ohio canal. It has been used to some extent in the construction of aqueducts, bridges, and furnaces. The aqueduct of the Chesapeake and Ohio canal over the Monocacy river was built of this stone. It is of rather coarse and uniform texture; and its use in the aqueduct shows that it is proof against the action of dampness and freezing, as that structure was built nearly fifty years ago, and there are yet no visible signs of decay of the material. This stone would be suitable for curbs and paving blocks.

At Cumberland, Alleghany county, white sandstone of Medina age is quarried for curbs, steps, and trimmings. It has been used also for bases and cemetery work, and was used in the trimmings of the Protestant Episcopal church and in the construction of the Methodist Episcopal church and the market-house in Cumberland. The material thus far obtained has been very large detached bowlders, found about 7 miles north of Cumberland. The ledge exposed in Wills mountain is about 500 feet in thickness, but this has not yet been quarried, as the material is more readily obtained from the detached rocks before mentioned. Through the narrow valley, about 300 yards wide at the base of this mountain, two railroads run. The stone varies considerably as to its firmness, depending upon the depth in the bed; the upper part is so soft as sometimes to yield to the hand, but the lower part is quite strong and compact.

Professor C. F. Chandler, in a report on the mineral resources of Cumberland, gives the following analysis:

	Per cent.
Silica	98.35
Sesquioxide of iron	0.42
Total	98.77

Another exposure of the same stone is found east of Cumberland, on the Chesapeake and Ohio canal; and there is also a yellow sandstone of Oriskany age, which has been used to a limited extent for building purposes in Cumberland, especially in the construction of the Methodist Episcopal church. It is not quarried at present. The stone varies very much as to firmness; the stratum which is sufficiently firm for building purposes lies at a depth of about 30 feet and is about 18 inches in thickness. When apertures in which water can collect exist in this stone the frost soon disintegrates it, but if the surface is dressed it is quite durable, and buildings in Cumberland in which it has been used, some of them built 15 or 20 years ago, are now in a perfect state of preservation. The stone in this quarry has a dark yellow color. The strike of the strata in this vicinity is a little east of north, following about the course of the mountains. There is but little dip in the strata of either the Medina or the Oriskany sandstones so far as can be seen from the exposure. A dark red sandstone crops out at Frankville and continues to Oakland, in Garrett county. It has been quarried at intervals by the railroad company, for use chiefly in protecting-walls for embankments, and in these structures it seems firm and durable. Tyson gives this material as Potsdam sandstone.

Professor Munroe reports that a white sandstone of excellent quality is quarried to a limited extent at Knowlesburg, and he traced it to the westward from this point as far as Newburg, in West Virginia. He also states that east of Tunnellton it begins to appear above the bituminous coal, which fact proves it to be of Carboniferous age.

SLATE.

The principal slate quarries in Maryland are in the Peach Bottom district, in Harford county, near the state line. The ridge upon which these quarries are situated extends into York county, Pennsylvania, and a number of the quarries are on the Pennsylvania side. The whole is described in the treatise on the building stones of Pennsylvania. The principal quarries both in Maryland and in Pennsylvania are all within a radius of a mile, and produce exactly similar material. For roofing purposes this slate is of a highly superior quality.

On the Baltimore and Ohio railroad, at the village of Ijamsville, Frederick county, there is an exposure of roofing slate which was formerly quarried for this purpose, and several roofs in the vicinity were made during the eighteenth century, and are now in good condition, which speaks well for the quality of the material. These slates are of a beautiful sky-blue color, and are reported not to fade. No roofing slate has been made here since 1873.

VIRGINIA.

[Compiled mainly from notes of Messrs. Huntington and Munroe.]

In Virginia, as in Maryland, the surface rocks of quite a large area of that part of the state lying next the Chesapeake bay and the Atlantic ocean are of Tertiary age and furnish no good building stones. The coarse and durable gray sandstones formerly quarried by the United States government at Aquia creek for the construction of the White House, the old portion of the Capitol, and other public buildings in Washington that were built in the early part of the century, are probably of this age; though, as no complete geological survey of the state has ever been made, the stratigraphical relations of many of its rocks cannot be pronounced upon with certainty. The preliminary reports by Professor W. B. Rogers previous to 1838, and the work done in neighboring states where the conditions of the strata are to some extent analogous, have developed the same general facts concerning the geology of the state. The band of Archæan rocks setting in to the westward of the Tertiary and running approximately parallel with the Appalachian mountains, furnishes granites, gneisses, and slates. The narrow Triassic belt resting upon the Archæan rocks in places supplies the red or brown sandstone which is quarried extensively at Manassas, and the diabase or trap quarried near Catlett station, Fauquier county, and near Leesburg, Loudoun county.

The Triassic sandstone extensively quarried for building purposes at Manassas bears a strong resemblance to the Seneca sandstone at the mouth of Seneca creek in Maryland, it being of the same horizon. The location of the Manassas quarry is near the top of a slight eminence. The strata here are nearly horizontal; there is, however, a slight dip to the south. Only the upper portion of the ledge to the depth of about 20 feet has as yet been quarried. The courses are of various thicknesses up to 6 feet, but the usual thickness is from 5 to 6 feet. Blocks 40 by 20 by 4 feet in thickness have been loosened in the quarry, and a block containing 88 cubic feet was shipped. Between the courses a greenish shale occurs which has a smooth, soapy feel, and when exposed to the atmosphere turns red. The principal markets for this material thus far are Washington, Baltimore, Danville, Virginia, and Charleston, West Virginia. Among the buildings in the construction of which the stone has been used are the District jail, Washington, and the government buildings at Danville, Virginia, and at Charleston, West Virginia. In these structures it was used for trimmings.

The quarries of diabase or trap before mentioned are located on dikes which cut the Triassic formation. That on which the Catlett Station quarry is located is apparently nearly parallel to Cedar Run creek; so far it has been quarried only for paving blocks and for sewer construction in Washington.

The quarry near Leesburg, Loudoun county, is scarcely developed. A fine dwelling was built of this material by C. R. Paxton, near Leesburg. As is usual with diabases, these stones are hard and difficult to work, but work safely and take a good polish.

To the westward of the strata already described the surface rocks are chiefly Silurian, Devonian, and Carboniferous; none of them have as yet furnished much material for building purposes, although a proper exploration would doubtless discover important resources in them. On the Valley railroad, 2 miles northeast of Staunton, Augusta county, there is an argillaceous limestone of Lower Silurian age, locally called slate, which is quarried for slate stock by the Red Bud Slate Company.

A limestone slightly magnesian in character and of Upper Silurian age is quarried chiefly for interior work, furniture, and other ornamental purposes, at Craigsville, Augusta county.

Returning to the Archæan rocks, it may be said that they have thus far been the most important resource for building stone in Virginia. The principal quarries thus far developed are located in Chesterfield and Henrico counties, in the immediate vicinity of Richmond. These quarries have all the advantages of good water transportation, as they are located on the James river, and the material may be shipped by schooner to all points on the Atlantic coast. The stone is a gray biotite granite having the same general characteristics as the gray granite so extensively quarried in the other Atlantic states farther north. The following are notes concerning some of the most important individual quarries of this region:

The quarry of the Richmond Granite Company, on the Richmond and Alleghany railroad, near Richmond, Virginia, produces a massive gray granite used for general building purposes, paving stone, and monumental work, and is shipped more or less to all the states and cities south of New England and as far west as Nebraska. Much of the material is dressed at the quarry, polishing-works being located on the grounds; and at present there is more activity here than at any other quarry in Virginia. A very large quantity of stone has been taken from this quarry, which has been accessible for many years by canal. This, however, has been discontinued, and a railroad now runs to the quarry. Comparing this rock with that of other quarries in the vicinity of Richmond, it appears that the feldspar crystals are larger than those generally seen elsewhere, but they are often irregular in shape and have a brownish color, which shows very distinctly on the polished surfaces. Blocks of any size desired may be obtained.

The Old Dominion granite quarry has furnished material for many important public buildings throughout the country, with principal markets in Richmond, Washington, Norfolk, Lynchburg, and Philadelphia. Among the prominent structures in which this material has been used are the post-office buildings at Richmond, Philadelphia, and Harrisburg. This quarry is well located for working, as it lies along the Richmond and Danville railroad, and the stone is lifted from the quarry upon the cars ready for shipment. There are as to color two varieties of stone in this quarry; one, a light gray, penetrates the darker after the manner of veins, but there is scarcely any perceptible difference as to texture. There are some peculiarities in regard to the joints in this quarry, and along each joint below the general surface decay is a thin layer of calcite, the lime of which was probably derived from the plagioclase feldspar so abundant in this granite. The waste from the quarrying and cutting of this stone is disposed of by being crushed by a rock-breaker, which is elevated so that the crushed material falls into a car and is transported to various points along the road and used for ballast. Professor J. H. Huntington, who collected the data from this region, expresses a doubt as to whether this granite is of Archæan age, and states that there is evidence that it is much younger than has been generally supposed, and that a study of the granite south of the Old Dominion quarry, along the border of the coal-fields, and at Fredericksburg, would probably furnish facts not heretofore known, and might determine the age of these rocks.

At Manchester, in Chesterfield county, is located one of the oldest as well as one of the most important quarries in this section. The surface rock is decayed to a considerable depth, and in some instances bowlders are left in the general decay; but below the point where the general decay ceases the natural joints seem free from discoloration or change, and are nearly horizontal.

In the Tuckahoe district, Henrico county, is a granite quarry recently opened, though in the same locality is situated one of the oldest quarries of this section, and from it the stone for the Washington monument at Richmond was obtained. The quarry, however, is not now operated. The resistance to decay in this rock is very notable, as there are some outcrops that are quite sound on the surface; the jointing is also peculiar, the principal joints conforming to the general slope of the hill on which the quarry is situated. Next to the river the rock is fine grained, but northwest of a quite well-defined line it becomes coarser.

In Amherst and Campbell counties, near Lynchburg, a bluish-gray biotite gneiss is quarried for general building purposes, and is used in Lynchburg, Danville, Richmond, Alleghany, and other cities of this region. It was used in the construction of the Female Orphan Asylum building at Lynchburg. This rock is quite similar to that found in many places along the Atlantic coast, and resembles very much the Potomac gneiss or mica schist in the vicinity of Washington. The quarries in Amherst county are on the left bank of the James river, opposite the city of Lynchburg. The strata are more or less bent and distorted, but in many places they are quite regular, and readily split into layers of from 3 to 6 inches in thickness.

The Fishing Creek quarry is about a mile and a quarter from the station of the Norfolk and Western railroad in Lynchburg. The strata are regular and dip 42° southeast. The material is remarkable in being quite free from iron, and in this respect differs from this stone elsewhere on the Atlantic coast.

A gray, sometimes greenish-gray, biotite granite is quarried in the Namozine district, Dinwiddie county, for general building purposes, and is used chiefly in Petersburg and Norfolk. It was used in the construction of the post-office and custom-house at Petersburg. A notable feature of the granite in the vicinity of Petersburg is that in many places it stands in bold ledges that have for ages defied the disintegrating agencies which have acted with such effect on nearly all the rocks in this latitude. Nowhere else south of the southern limit of the glacial action by which the decayed portions of surface rocks have been removed can granite be seen in such sharp, well-defined ledges as in the vicinity of Petersburg, and there are very few places in regions where the decayed rock has been removed by glacial action that ledges can be found which show on the surface so little sign of decay. The stone from this locality was used at fortress Monroe for the beds for gun carriages, and it is said that where concussion would fracture other stones, this remains intact. It was also used at the Ripraps, at the outlet of Chesapeake bay. The material is for the most part a solid mass, free from joints.

Specimens of granite representing ledges but little or not at all quarried were collected from Verdon depot, Hanover county; and of mica-schist, considerably quarried for foundations and the ruder purposes, generally, in Washington, from near the Chain bridge in Fauquier county, a few miles above Georgetown, on the Potomac river.

SLATE.

In Buckingham, near New Canton and Ore Banks, Buckingham county, a very superior quality of roofing slate is extensively quarried and shipped to the principal cities of Virginia and to Washington, and is quite extensively used as a roofing material in the latter place. It is of a bluish-black color, and has the pearly luster peculiar to the best slates. The following description is by Professor J. L. Campbell:

> The fine roofing slates of Buckingham are worthy of special consideration, as well on account of the quality as for the quantity of the material there found. The belt of slate is on Hunt's creek, a branch of Slate river. The quarries extend up this creek for several miles, with a trend practically parallel with Slate river, and at a distance of from 1 mile to 2 miles east of it. The slates are intersected by numerous veins of igneous quartz, not unlike, in general appearance, the gold-bearing veins; and also by occasional trap dikes, one of which crosses an old opening in the Nicholas quarry. The heat from these igneous rocks has doubtless been a very potent agency in giving the slates that highly indurated, metamorphic condition that renders them so durable, while a uniform lateral pressure acting at right angles to their planes of stratification has given that peculiar structure which results in an easy and regular cleavage when fully quarried.
>
> Some of these quarries have been worked for more than half a century. The principal ones are all that need be named. What is known locally as "Perrow's big quarry", owned by Mr. J. M. Norvell and other persons at Bremo, is on Hunt's creek, 1 mile east of Slate

river and 2 miles from the James. A vast quantity of slate has been taken from this quarry, but when we visited the place it was suspended on account of some conflict of claims. The Nicholas quarry, a little farther up the creek, is worked on a large scale, and stones shipped from Bremo by the Richmond and Alleghany railroad. Messrs. Edwards and Robertson's quarry, in the same vicinity, is largely opened, very successfully operated, and its products shipped by the same route. The strata, or rather laminæ, of slate in all these quarries are nearly vertical and have a very uniform strike north 25° east, which is about the average bearing of all the strata between Slate and Willis rivers.

At present nearly all the slate from these quarries is split and shaped for roofing purposes, except where special orders are to be filled. Its strength, durability, and uniformity of texture have given it a national reputation. * * *

The same belt of slate appears on the north side of the James, on the Cocke estate, a short distance above Bremo station, but has not been opened to a sufficient depth to test its quality at that point.

Another belt of slate, apparently of the same geological associations and age as the one just described, lies near the southeast base of the Blue ridge, in both Amherst and Bedford counties, cut through by the James river 4 miles below Balcony falls. It is extensively exposed about 2 miles northeast of the river, where a Lynchburg company has opened a quarry that yields a slate of fine appearance and of finer grain than that of the Buckingham quarries. A small opening has also been made on the southwest side of the river, by the Alleghany Coal and Iron Company, sufficient to prove the existence of slate of good quality, and to indicate the presence also of a large quantity. I have subjected samples from this belt to crucial tests, which they bore remarkably well.

There is a number of other points within reach of the railroad at which slate of promising appearance crops out on the surface, but the true character of the material can be determined only by actual openings to such depth as will reach beyond the limits of long-continued weathering.

MARBLE AND LIMESTONE.

Marble and limestone quarries have not thus far been much developed in Virginia, though there are several points where these materials have been quarried to a limited extent for local use. The most extensive and best known quarry of this class of rock in Virginia is at Craigsville, Augusta county, where what is known as "coral marble" is quarried, chiefly for interior work in buildings, and for furniture and ornamental purposes generally. It is shipped to New York, Baltimore, Boston, Cleveland, Chicago, Milwaukee, Cincinnati, Saint Louis, and other cities of the country. In texture it is fine, semi-crystalline, fossiliferous, and of a pinkish-gray color. There is quite an extensive area here of this material of uniform character. Specimens dressed at the National Museum show that it takes a good polish. Specimens of limestone, representing ledges which have thus far been but little quarried, were received from the following places in Virginia:

A magnesian limestone from near the Natural bridge, Rockbridge county, locally called marble, but properly a magnesian limestone, sometimes containing a silicate; a magnesian limestone, locally called marble, from Timberville, Rockingham county, and a dolomite from the same locality; a dolomite, locally called marble, from Madison Run station, Orange county; a stalactite from Luray cave, Page county; and a marble from Greenwich, Rockbridge county.

SOAP-STONE.

Specimens of steatite or soap-stone were received from various points in the state, but this material has not thus far been used for purposes of construction.

NORTH CAROLINA.

The following statements and descriptions are made up from the schedule reports furnished by Professor W. C. Kerr and W. H. Kerr:

The same order of strata occurs in North Carolina, generally speaking, as in Virginia and the South Atlantic states. The Tertiary, Eocene, and other later formations occupy a belt next the sea-coast, and are not important sources of building material. A shell-limestone of Eocene age, used for underpinnings, fences, mill-rocks, and lime, is quarried near New Berne. It seems to be made up entirely of marine shells. This stone can be hewn into shape by axes, but does not stand exposure well.

Material of the same nature is quarried at Rocky Point, Pender county, and has been used to some extent in the breakwater and other harbor improvements at Wilmington. It is transported by flatboats on the Northeast river, and to some extent by rail on the Northwestern railroad. This material is more compact than the New Berne shell-limestone; the rock lies beneath the surface at a depth varying from 1 foot to 6 feet, has a thickness varying from 1 foot to 5 feet, and underlies an area of about 4 square miles. An area of about 100,000 square yards has been quarried over. The rock sometimes overlies a loose, partially-decomposed lime-rock of a foot or two in thickness, and sometimes a bed of marl 2 or 3 feet thick is superimposed. This marl carries from 85 to 90 per cent. of carbonate of lime, and is used as a fertilizer after passing through a pulverizer. Professor W. C. Kerr, state geologist, states that the material withstands considerable crushing weight, and is very serviceable in rough work.

TRIASSIC ROCKS.

A narrow belt of Triassic age extends through the center of the state, and furnishes fine, compact red sandstone of superior quality for building purposes. Professor Kerr, who has collected for the National Museum a representative set of building stones from this state, sent specimens from rocks of this age from the following places: Wadesboro', Anson county; Sanford, Moore county; 3½ miles east of Egypt, Chatham county; near Durham, Durham county.

That quarried near Wadesboro' is used for ordinary building purposes, sills, steps, grindstones, and whetstones. It is of fine, compact, uniform texture. The principal markets are Charlotte, Wilmington, and neighboring places. The color of this stone varies from a dark brown to a brick-red, and occasionally a buff. The Triassic sandstone quarried at Sanford is used chiefly in Raleigh, and may be seen in the Raleigh court-house. This stone lies in nearly horizontal strata, which are from 1 or 2 to 4 or 5 feet in thickness, with a depth beneath the surface varying from 1 foot to many feet. It is worked and can be quarried at small cost, stands exposure well, and is being quite extensively introduced as a building and trimming stone. It is soft when first quarried, but in a week or two becomes quite hard and takes a fine dressing.

The sandstone quarried near Egypt is used for building purposes, and is marketed chiefly in Raleigh. It is a durable, fine, brown sandstone, used to some extent for grindstones during the war, and is locally used as a general building material and in the construction of iron furnaces. The strata have a dip to the south of 12°, and strike east and west. The stone outcrops in the side of a considerable hill, and is worked with little difficulty.

The Triassic sandstone quarried near Durham is chiefly of a pale gray color, though some of it is brown, and of fine to medium texture, occasionally coarse. Among the buildings in the construction of which it was used are the Raleigh Bank building and the dwelling of Mr. Speight. It has been used for 30 years or more in Raleigh and vicinity. It is comparatively easy to work, and is durable.

ARCHÆAN ROCKS.

The Archæan rocks, setting into the westward of this Triassic belt and occupying the whole of the middle and western parts of the state, form one of the most important sources of building stone in North Carolina. They furnish fine gray granite of superior quality at many points. These granites in many cases differ but little from those quarried in the New England states, but have not the advantage of being so near the sea-board as to be accessible by water transportation; they are usually massive, showing scarcely any signs of stratification, but gneiss of good quality for building purposes is abundant. Specimens of granite were forwarded by Professor Kerr from Charlotte and from Davidson College, Mecklenburg county; Lexington, Davidson county; from various points in Alamance county; Louisburg and Cedar Rock, Franklin county; Salisbury, Rowan county; Asheville, Buncombe county; Rockingham, Richmond county; Danbury, Stokes county; Mount Airy, Surry county; Winston, Forsyth county; Concord, Cabarrus county; Garibaldi and Gastonia, Gaston county; Tosneot, Edgecombe county; Greensboro', Guilford county; Mount Mourne and Mooresville, Iredell county; Oxford, Granville county; Warrenton, Warren county; Buckhorn Falls, Harnett county; Shelby, Cleaveland county; red granite from Cotentney creek, near the Weldon railroad, Wilson county; gneiss from near Greensboro' and Jamestown, Guilford county; Henderson, Vance county; Shelby, Cleaveland county; near Louisburg, Franklin county; Henry's station, McDowell county; Morganton, Burke county; Hickory, Caldwell county; Statesville and Mooresville, Iredell county; Northington's ferry, Harnett county; and Raleigh, Wake county.

The granites and gneisses at most of these localities have, so far, only been slightly used for local purposes. The following notes afford some information respecting their nature and availability for building purposes at some of the different localities:

Ten miles northeast of Greensboro', Guilford county, the gneiss shows no observable traces of iron or other material to produce disintegration, and the exposed surface is sound and durable. The blocks lying at the quarry seem nearly as fresh as when first quarried. This quarry was first opened some years before the late war, furnishing good rock for mill-dams in the neighborhood. Subsequently some stone was quarried for other purposes during the war and near its close, but no regular quarrying has been done there since. The material varies from medium fine to rather coarse in texture; it is gray, fairly uniform, works with comparative ease, and splits readily in rectangular blocks and in any desirable thickness. The surface exposure at the opening indicates the presence of an extensive supply of the material. The stratum in which this quarry occurs, or the line of its outcrop, was traced for some distance in a general northeast direction, and in it two or three thin exposures were found, indicating the probable presence of good material in considerable quantity.

Ten miles west of Greensboro' is found a gray, medium-fine to coarse gneiss, used to some extent for railroad work and for ordinary building purposes. The quarry is located about 3 miles north of Friendship, a small station on the line of the Northwestern North Carolina railroad, so that the facilities for transportation are fair.

On the line of the North Carolina railroad, near Lexington, the granite has been quarried to some extent for railroad and local purposes; the material is fairly uniform and of medium-fine to coarse texture, and varies in color from gray to bluish-gray. The facilities for transportation at present are not good. There are other granite ledges in this vicinity, however, which are more accessible, and the facilities for quarrying are favorable.

At the shops of the North Carolina railroad, in Alamance county, granite is found which is above the average in quality both as to durability and the ease with which it can be worked. It is fine, even-grained, and light gray to gray in color. Though no very considerable opening has been made, there are indications of the existence of a considerable quantity of this stone in the vicinity. The stone is much used by residents of the vicinity, and is highly esteemed. Specimens of it may be seen in monuments and bases at Graham, North Carolina, and elsewhere.

Two miles north of the North Carolina Railroad shops the granite underlies a considerable extent of ground, and crops out in such a way as to indicate accessibility and ease of working. The outcrops on the hillsides are very favorably located for quarrying, and present an exception to the general rule in this vicinity, as the strata are not tilted. An examination of the specimens sent from this place by Professor Kerr indicates that the granite beds in this region underlying considerable depth of earth promise to afford a material much better in working qualities, as well as more even in structure, than that commonly found on the surface or at outcropping points.

At Louisburg, Franklin county, a medium-fine, uniform, gray granite is found. It was used in the construction of the jail at Louisburg. The rock comes to the surface in great masses, being bare for many rods and at several points in and near the town.

Four miles south of Salisbury, Rowan county, is found a medium-fine, uniform, gray granite. The rock crops out in a huge ledge called Dunn's mountain, in fact, it constitutes a range of high hills running northeast and southwest, and 300 or 400 feet above the surrounding country. On the summit of Dunn's mountain the rock projects above the surface in huge bowlder-like masses from 15 to 20 feet high, some of them containing hundreds of tons. The process of quarrying is merely the splitting of these masses. Some of these blocks contain minute octohedral crystals of magnetite disseminated through the mass, which may be easily removed from a powdered specimen with a magnet. They do not affect the quality of a stone, and discolor it only for a short time on a dressed surface.

Near Henderson, Vance county, a gray, rather fine grained gneiss of very uniform texture is quarried, chiefly for railroad construction; it was employed in the construction of bridges over Haw and Deep rivers, the foundation of the post-office at Raleigh, and other structures. This material works well and easily, is comparatively hard, very durable, and is much used in the neighboring region.

Seven miles below Asheville, Buncombe county, a granite of fine and uniform texture is quarried for local purposes; it is a light gray in color, is easily wrought, splits readily into any regular form and size, and stone-cutters prefer it to any other rock in the region.

The gneiss near Jamestown, Guilford county, has been employed to some extent for railroad work and local purposes, and was used in the construction of bridge piers at Deep river, on the railroad. It is a fine, even-grained, gray gneissoid granite, and gives strong indications under the hammer of working unusually well. The nearest point on the railroad is 3 miles.

At Mount Airy, Surry county, the granite forms a ridge; it appears either at the surface or a few feet below, and outcrops at short intervals within a radius of 2½ miles of the place. One hill, within a mile of Mount Airy, 120 feet high shows an exposure of about 40 acres of this rock extending from its base to the top. The granite shows no jointage structure, and the hill is to all appearances an unbroken mass. The granite splits readily, is quarried and dressed with great facility in blocks of enormous size, and is of a durable character.

Four miles south of Winston, Forsyth county, the granite is a dark gray in color and splits readily into required shapes. The stone is quite uniform in texture and structure, though the amount of quartz contained varies somewhat in different parts of the quarry. This granite is durable and has been used for ordinary stone-work in the vicinity. It takes a fine polish and looks well when bush-hammered, but as yet there has been no demand for the material in fine construction. There is an inexhaustible supply, and blocks of any required size may be obtained.

Nine miles south of Salisbury, Rowan county, there is a homogeneous, durable, feldspathic granite of a pinkish color which is used for sills, steps, culverts, and like work. The ledge has an extensive surface exposure, and a jointage structure which aids materially in its working. The stone can be readily obtained in blocks of any required size.

Ten miles south of Salisbury a very hard, dark, granitic rock has been quarried chiefly for the rougher purposes of construction, such as streets, curbs, and door and window sills. It contains quite a large percentage of quartz, is compact and durable and is susceptible of good polish, although not so well adapted to ornamental work as are other rocks in the vicinity. There is a cap-rock 4 feet in thickness, which has been chiefly used, as it is apparently unaffected by the weather. This ledge presents several acres of surface exposure.

At Barringer's mill, Rowan county, a very hard quartzose granite, locally called "millstone grit", is considerably used for millstones, and to some extent as a building material. It is found in large exposures 12 miles north of Concord and 11 miles south of Salisbury. This stone is quite homogeneous and uniform as the outcrop is traced north and south from the quarry, and the supply is inexhaustible.

A fine, uniform, gray granite is found 6 miles northeast of Concord, Cabarrus county. On the Mount Pleasant road, in this county, the stone has an exposure where it has been blasted out in grading. It has an outcrop in two directions, that crossing the road having a general direction a little east of north, while the other has a general direction at right angles to this. The second outcrop can be traced for a quarter of a mile. This material, owing to its fine grain and compact structure, is susceptible of a good polish. It is of a light pink color and splits readily into regular shapes.

A coarse-grained porphyritic granite is quarried 3 miles north of Garibaldi, Gaston county, chiefly for trimmings, curbs, bases, and monuments, but it has also been used n great quantity for bridges and other building purposes. There are two outcrops in bluffs 1½ miles apart, both being very favorably located for quarrying. This is a good, durable granite, works easily, and is susceptible of a good polish. It can be obtained in blocks of any desired size.

At Gastonia, on the Dallas road, in Gaston county, a hard, fine-grained porphyritic granite is quarried to some extent for ordinary building purposes. The ledge forms a hill on the west side of Long creek, 1½ miles from the crossing of the Dallas and Gastonia road. It is hard, compact, takes a fine polish, is a durable stone, well adapted to all ordinary building purposes, and was used in the construction of the court-house in Dallas. Its highly porphyritic structure renders it somewhat difficult to give it a fine dressing, but it splits readily into regular shapes. The supply is inexhaustible, readily accessible, and blocks of any required size may be obtained.

One and a half miles northwest of Shelby, Cleaveland county, there is a fine hornblendic gneiss. It is a very handsome stone, splitting remarkably well in planes parallel to those of its lamination. This rock seems to harden on exposure. The outcrops and surface exposure extend half a mile in length. There is quite a large quantity of stone accessible, but the exposure most favorable for quarrying is in a bluff some 80 feet in height.

At the point where the Wilmington and Weldon railroad crosses Cotentney creek, in Wilson county, a red feldspathic granite, uniform in texture and structure, is found. It works easily, splitting readily, and takes a beautiful polish. This rock has not yet been quarried for general purposes, having only been used for the piers of bridges and other railroad structures. The rock is found outcropping on both sides of the creek, and is traced for a mile or more up stream. At George Barefoot's mills it crops out in a ledge 40 feet above the bed of the creek.

Two and a half miles north of Tosneot, on the Wilmington and Weldon railroad, in Edgecombe county, a dark gray, rather coarse porphyritic granite of excellent quality is quarried to a considerable extent for general building purposes. It is used chiefly by the Wilmington and Weldon railroad in the construction of bridges, culverts, etc., and there is a railroad into the quarry. The stone is much used in Wilmington for street curbing and general building purposes. It splits readily, but is quite hard. The outcrop can be traced for a quarter of a mile, and the rock can be had in any quantity. There is a quarry of stone differing a little from this in texture at Rocky Mount, 8 miles to the northwest of this point.

Ten miles east of Greensboro', on the line of the North Carolina railroad, in Guilford county, the granite is not now quarried except for occasional local purposes. The stone here is of rather variable quality, but good material was obtained for the large arched culvert over Rock creek, about a mile east of the quarry. The stone is of medium and coarse grain and of fair quality. The outcrop at various points in the neighborhood indicates that better openings than the one mentioned might be found near by, and that a well-developed quarry on this ledge would produce building stone of excellent quality as soon as the surface rock is removed.

The red granite 2 miles southwest of Hillsboro', Orange county, has as yet only been used by the North Carolina Railroad Company. It is a superior and beautiful building stone, and takes a fine polish.

The gneiss near Louisburg, Franklin county, is of a pinkish-gray color, fine in texture, and works well; there is an extensive surface exposure of the rock.

A compact, hard granite, coarse to medium in texture, is quarried locally for foundations at Cedar Rock, 9 miles east of Louisburg. The stone is found in a surface exposure of several acres, and the supply is inexhaustible. The top bed of rock is of a whitish color, while the bed immediately underlying it has a decided red tinge. The stone is very durable.

A fine-grained hornblendic gneiss is found 1 mile east of Henry's station, McDowell county. It has been used chiefly in railroad construction, and the quarry was quite extensively operated during the construction of the Western North Carolina railroad. The stone obtained from it is very compact and hard, and when polished presents a handsome appearance.

The gneiss 2½ miles west of Morganton, Burke county, is fine in texture and works readily, having quite a perfect cleavage in one direction. It outcrops in a bluff which gives a good quarry face.

The granite on the Carolina Central railroad, 3 miles west of Rockingham, Richmond county, is coarse and porphyritic in texture, and has a peculiar olive color unlike any other stone in the state. The rock projects above the surface in bowlder-like masses from 10 to 15 feet high, and extends along the railroad for half a mile. Its principal use thus far has been in railroad construction.

The gneiss 4½ miles northwest of Hickory, on Catawba river, Caldwell county, is a handsome stone, but has as yet only been used for railroad work. It is easily quarried, and the facilities for transportation are good. The stone is fine and compact in texture, and stands exposure well. It has an outcrop in a bluff on the bank of the river which gives a quarry face some 75 feet in height.

A fine, compact, gray granite has been quarried for railroad bridges, and to a limited extent for other purposes of construction, 5 miles south of Statesville, at Poison Springs, a mile west of the Atlantic, Tennessee, and Ohio railroad, in Iredell county. It shows a good exposure and is easily worked. The strata in the quarry have a dip of 20° to the northeast and a strike northwest and southeast.

A mile southeast of Davidson College, in Mecklenburg county, a fine hornblendic granite of excellent quality for building purposes is found. There is but little stripping, and a large amount of good stone might be obtained near the surface.

A beautiful white feldspathic granite has been quarried for local purposes 5 miles southeast of Davidson College and 4 miles east of the Atlantic, Tennessee, and Ohio railroad, in Mecklenburg county. It is of a uniform, rather coarse texture, and carries a large percentage of biotite, which gives it a spotted appearance. This stone has an extensive surface exposure of about half an acre. It is hard, but splits readily into regular shapes. The ledge has a dip to the northwest of 15°, and strikes northeast and southwest.

The granite at Mount Mourne, Iredell county, is of a coarse porphyritic texture, stands exposure well, and is suited for ordinary building purposes. There is an extensive surface exposure of the rock, and it can be had in any quantity. Although the texture is coarse, the stone is compact and takes a good polish.

A hard, dark-colored hornblendic granite of fine texture is quarried to a limited extent for building purposes, bridges, and culverts, 3 miles east of Mooresville, on the Atlantic, Tennessee, and Ohio railroad, in Iredell county. The rock carries some pyrite, but not enough to affect seriously its weathering qualities. The ledge has a strike north and south, which can be traced by a surface outcrop for three-quarters of a mile.

Three-quarters of a mile from Mooresville, Iredell county, are two varieties of quartzose gneiss, which have a well-marked line of contact. They are like in structure and composition, but differ remarkably in color. These stones work well and are durable. The outcrop occurs in the side of a hill, and can be traced for a quarter of a mile. The materials would take a good polish, and from their texture, composition, and color it may be inferred that they would be invaluable for ornamental as well as for general purposes. The direction of the outcrop is northeast and southwest, and there is a dip of 10° to the northwest.

At Warrenton, Warren county, a white porphyritic granite is much used for local building purposes, and was used in the construction of the jail. The stone stands exposure well; there is a large surface exposed, and the ledge is so situated that quarrying operations could be conducted with comparative ease.

Nine miles southwest of Warrenton there is a ledge of very pretty fine-grained, rather dark gray granite. It has been used locally for monuments, steps, posts, and work of that class. It is used in the construction of the "Annie Lee" monument.

At Northington ferry, 16 miles from Lockville, Harnett county, there are outcrops of fine schistose and slightly calcareous gneiss in the bluff of the river. The material splits very readily along the plane of lamination, but with difficulty in other directions.

A gray porphyritic granite has been quarried at Buckhorn falls, on the Cape Fear river, Harnett county, for the construction of canal locks and dams. There are good facilities for transportation by river and by railroad.

At Raleigh, Wake county, a quarry has been opened in a bare surface exposure and driven to a depth of 40 feet; it has been operated mainly to furnish material for the penitentiary building, but the stone is also used for culverts, flagging, and works of that class in Raleigh. It is a gneiss of fine to medium texture. At another quarry in the vicinity a fine-grained gray gneiss has been quarried for general building purposes for the last 75 years. It was used in the construction of the capitol and to some extent in the penitentiary buildings at Raleigh.

A short distance from the Carolina Central Railroad track, at Charlotte, Mecklenburg county, the leopardite porphyry is found—so called from the peculiar spotted appearance of the rock. It has been used locally for curbs, sills, steps, and other building purposes. There are few joints in the ledge, and blocks of any desired size may be obtained. The joints are so disposed as to give the natural blocks a rhomboidal shape. It takes a fine polish and is a beautiful ornamental stone, but difficult to work.

MARBLE AND LIMESTONE.

Professor Kerr forwarded specimens of marble and limestone, representing ledges of importance as sources of building material, from the following localities: 3½ miles northeast of Murphy, Cherokee county; Valley Town, 19 miles northeast of Murphy; 1½ miles from Red Marble gap, Macon county; Warm Springs, Madison county; and 10 miles north of Marion, McDowell county.

These marbles and limestones are of Archæan age, according to Professor Kerr, excepting the limestone at Warm Springs, which, he states, may be of later age.

Near Murphy two very distinct marbles outcrop together, one white, fine, and changing to somewhat darker color on exposure, while the other is quite dark and somewhat striped. The white rock is somewhat cut up by jointage, while the other has a massive structure and can be readily sawed into blocks of any shape and size. The stone has been worked to some extent, but never sufficiently to procure a good quarry face. The dark marble is close, compact, has a metallic ring, and takes a beautiful polish.

Nineteen miles northeast of Murphy there is a gray marble with white stripes, which is fine and compact in texture and polishes well. No quarrying has been done here, yet blocks of any size can be readily obtained. The strike of the strata is southwest and northeast, the dip 80° east. In the same vicinity a light gray marble of fine and compact texture, and susceptible of a fine polish, can be had in large quantity, having an extensive outcrop in two places; dip 80° east; strike, southwest and northeast.

At still another place in this vicinity two marbles are found outcropping together, one of a smoky-white color, and the other of a dark or variegated color; both are classed high as ornamental stones, and are susceptible of a fine finish.

One and one-half miles below Red Marble gap there is a marble which has a very extensive outcrop. It occurs in the side of the mountain in ledges 150 feet or more in height. In color it is varied, being of a flesh-color, striped with blue, yellow, or both. It is close, fine, and compact in texture, takes a beautiful polish, and can be obtained in blocks of any size. A railroad in course of construction will pass by the base of this cliff, and there is excellent water-power three-quarters of a mile below for sawing. The outcrops of these marbles are on the west bank of the Nantehala river for a distance of 3½ miles, and seem to overlie a coarse slate which dips 60° to the southeast. The direction of the strike of the strata is east by north.

Near Warm Springs, Madison county, the formation which Safford considers the Knox dolomite crosses the French Broad, rising in steep cliffs along the river on both sides to a height of 40 or 50 feet. It is limestone of a gray to light ash color, fine and uniform in texture. It has as yet been but little used, as the region is thinly settled, but it is a good material for ordinary building purposes.

The dolomitic limestone 10 miles north of Marion, McDowell county, has not as yet been much used for purposes of construction, but is well adapted for general building purposes and for ornamental work. The surface rock is much cut by a jointage, but as the stone outcrops in the side of a hill it is easy to reach a depth which will avoid this difficulty. It varies in color from steel-gray to white.

SOAP-STONE.

Specimens of talc or soap-stone representing ledges of importance were forwarded by Professor Kerr from the following points: 7 miles northeast of Murphy, Cherokee county; 4½ miles from Greensboro', Guilford county; Nantehala river, Cherokee county; from near the North Carolina Railroad shops, Alamance county; and from Deep river, Moore county.

It is all of Archæan age, according to Professor Kerr. It has been used to a limited extent for chimneys, fire-places, hearths, lining for furnaces, and cemetery work.

A pure talc is found on the Nantehala river 5 miles below the Red Marble gap, and again 6 miles east of Murphy, on the line of the Georgia and North Carolina railroad. At the last-named place the talc has an outcrop with white marble in a ledge of considerable extent.

At another point on the Nantehala river, in Cherokee county, there is a very pure talc, translucent, in thin plates, and has been much used as a white-earth. Thousands of tons have been hauled to the railroad and shipped to New York, ground and bolted. It is equal to the finest French chalk.

On the Deep river, in Moore county, the soap-stone is very fine grained pyrophillite. The layers are usually less than a foot in thickness; it has been chiefly ground and bolted and used as a white-earth; much of it is also employed for lining furnaces and building hearths and furnaces. It is used locally and shipped to New York in large quantities.

The method of transportation is by boat 15 miles to the Cape Fear and Yadkin Valley railroad.

FLORIDA.

E. A. Smith, in the *American Journal of Science*, April, 1881, gives the following remarks concerning the geology of Florida:

Almost the whole state of Florida, including the middle and western parts of the peninsula, has for its underlying formation the white or orbitoides limestone of Vicksburg (Upper Eocene) age. This is bordered on the east by a stratum of Miocene limestone, and the edge of the whole peninsula, together with the southern part, including the everglades, is of post-Pliocene or recent formation. The keys are of this recent age, and the coral limestones, which have been much used there, are composed of fragments of the same animals as now live in the gulf. The Hawthorne stone is of Eocene age and contains bones, etc., that identify it. These Vicksburg limestones, more or less covered by beds of stratified pebbles, sand, clay, and marl, form the soil of the state.

The orbitoides (Upper Eocene) limestone is not quarried to any considerable extent owing to the small demand for stone of any kind, but it is locally used for chimneys and house pillars in towns in every section of the state; in Gainesville and neighborhood it is much used. This limestone is often simply a mass of shells, and sometimes orbitoides mantelli is the almost exclusive constituent. The Saint Augustine coquina, or shell-limestone, is used to some extent for local building purposes in Florida. A specimen forwarded to the National Museum, by C. M. Terry, was taken from the basement of a house, and was probably quarried a century or more ago. Other specimens recently taken from the quarry are in the collection, and by comparing the two it is seen that the coquina is a durable stone in the climate of Florida, though there is no doubt it would rapidly disintegrate in the more severe climate of the northern states. The quarries are not operated at present; they are located on Anastasia island, about 2 miles from Saint Augustine. The rock lies very near the surface none of the excavations are more than 6 or 8 feet deep. The stone can be cut with an ax, and is taken out in such shape and size as is required for building. The old city of San Augustine was built wholly of this rock; the quarries were evidently opened more than 200 years ago, as there are houses and broken sections of walls which are older than this. Fort Marion is built partly of coquina. This fort as it is at present dates from about the middle of the eighteenth century. There is a large number of houses in the city that were built one hundred years ago.

On entering a house built of the coquina a sense of dampness and a cool, moist, atmosphere is experienced. The rock seems to possess the capacity of receiving and holding the moisture of the atmosphere; for this reason, and because wood and bricks are cheaper, the coquina is not now extensively used for building stone.

There is another material near Saint Augustine which is called the "shell" sandstone; it is formed on the beaches there by the grinding up of the shells by the sand, which is more or less like that found on all our beaches, except that where this material is formed the shells are more abundant. It is a recent formation and is hardened by the lime in the sea-water, which is doubtless derived from the shells. These shells are almost entirely bivalve or lamellibranchs, and perhaps a few gasteropods. Mr. Rathburn of the Smithsonian Institution says that almost all of them are lamellibranchs.

Another interesting example of this shell-limestone and the manner in which it is formed is given by Professor Hartt in a publication concerning a sandstone on the Brazilian coast, revised by Richard Rathburn, and published in the *American Naturalist* of June, 1879. It is shown that these reefs are composed of analogous material to the Florida coquina, though they contain more siliceous matter. The solidification is mostly confined to the zone which lies just above and below the level of low tide, and the solidified material rests upon an insecure foundation of loose material. The formation is accounted for in the following manner: The waters of the tropical seas are highly charged with calcium bicarbonates; as the tide rises this water is absorbed by the porous sand, and on the retreat of the tide the solution is concentrated by evaporation, aided by the intense heat of the sun, and the solution becomes saturated in the sand both above and below the level of low water. The consolidation is also aided by lime holding solutions which filter through these stones from the land. This hardening of the sandstone takes a long time, as is shown by the circumstance that these beaches which are in the process of formation or disintegration are not hardened.

At Key West coral limestone is quarried, and numerous public and private buildings are erected of it. There are no quarries now worked although the entire island is composed of it, and in fact the whole of southern Florida is a coral reef. This stone has thus far only been of importance for local use.

There are few stone quarries in the state of Florida. At Hawthorne Mr. C. A. Simmons has opened a quarry, the stone of which is said by the state chemist to consist almost entirely of silica, possibly containing 5 or 6 per cent. of lime, and of a quality for glass-making. It contains petrified bones, and the geological age of the formation is Upper Tertiary. The stone has been gotten out for chimneys, sugar furnaces, and millstones, and to a limited extent for building purposes, but has not been shipped, for lack of means of transportation, but chimneys in the neighborhood were built of it thirty years ago. The rock is very soft when first taken out of the earth, but hardens on exposure to the air and sun. The largest stone taken out was a cube with a 34-inch edge, but a cube two or three times that size might be taken. The supply of this material is reported as inexhaustible, and it is sold at the quarry for 28 cents per cubic foot. It can be cut with a hand-saw, and two men can cut out 1,500 bricks of a size 4 by 8 by 16 inches in a day, each piece being equal to eight ordinary bricks. A railroad will soon be built in the neighborhood.

TENNESSEE.

[Compiled mainly from notes of Messrs. Cotton and Gattinger.]

The colored marbles of East Tennessee are widely known and quite extensively used in this country for ornamental purposes. There are several varieties of beautifully-variegated marbles here possessing superior qualities, the ease with which they are dressed giving them an advantage over the colored marbles found in the Lake Champlain region; though these harder marbles are better for tiling and for other uses where the material is subjected to abrasion. The East Tennessee marbles have been used for decorative work in some of the most important buildings in our own country, including the Capitol at Washington.

The following is a list of some of the buildings in which the marble from the quarry of Mr. E. D. Dougherty, near Mooresburg, Hawkins county, may be seen: United States Capitol, United States Treasury, Washington, District of Columbia; state-house, Columbia, South Carolina; Ninth National bank, Park National bank, Seamen's Savings bank, Cisco building, Grand Central hotel, New York city; residence of William G. Fargo, esq., Buffalo, New York; Lutheran church, southwest corner Broad and Arch streets, Second Presbyterian church, the marble residence of George W. Childs, esq., Schenck's building, and Guy's hotel, Philadelphia, Pennsylvania; First National bank, Chicago, Illinois; residence of Mrs. E. W. Boyle, and that of Mr. John M. Mueller, Cincinnati, Ohio. This quarry is the oldest in East Tennessee, having been opened for the purpose of getting ornamental stone for the Capitol building at Washington. The stone has not been used for general construction on account of the high price which it commands for ornamental work, the price per cubic foot at the nearest railroad station being from $2 to $3.

The marble from the quarry of the Knoxville Marble Company is used for both construction and ornamental purposes. This is the most extensive quarry in Tennessee, and the oldest one in the vicinity of Knoxville. It was opened by the United States government to get stone for the construction of the custom-house and post-office buildings at Knoxville, the stone for the outside of the superstructure being bush-hammered and the mantels and other ornamental pieces polished. The floor tiling is made of this stone and Maclure limestone. A considerable quantity of this marble was also used in the state capitol at Albany, New York. The quarry is located at the junction of the French Broad and Holston rivers, and the stone is carried by boat 4 miles to Knoxville. A bush-hammered surface of this marble has a nearly white color, which, on exposure, becomes still whiter. It is susceptible of being highly polished, and when so polished has a pink tinge and shows wavy, dark lines running through it. It is highly esteemed for mantels and table-tops, because it is not easily stained, and it is also quite largely used for cemetery work. Tombstones which have been exposed for thirty years do not show the slightest signs of disintegration or wear. The stone possesses sufficient strength for the heaviest structures.

Messrs. Frierson and Morgan operate two quarries within 2 miles of Knoxville, one of them producing a white marble and the other a pink material known as Knoxville marble. Analyses made of the white marble show it to be an almost pure carbonate of lime. Marble from this quarry was used in the construction of the custom-house at Memphis, and the shaft of the Lee monument at New Orleans is made of it. The amount of this marble which may here be quarried is practically inexhaustible. The pink-marble quarry shows about the same characteristics as the quarry of the Knoxville Marble Company. The former is located on the northwest side and the latter on the southeast side of what is known as the Knoxville Marble basin. The limestone crops out on the west side of the pink-marble quarry of Messrs. Frierson and Morgan.

Near Chattanooga, Hamilton county, a bluish-black limestone of the Lower Silurian period is quarried for general building purposes, the stone being used chiefly in that city. The quarry is very favorably located for transportation, being on the bank of the river. The rock is broken up by joints, though blocks large enough for ordinary purposes of construction can be obtained. It dresses quite easily, making a cheap as well as durable building material.

The Cincinnati limestone of the Lower Silurian period is quarried for foundations and underpinnings in the vicinity of Nashville; this material is not of very good quality, but it is the most accessible to the Nashville market, and furnishes most of the stone for ordinary construction purposes in the city. The stratum of limestone quarried is only a few feet in thickness, and but a small portion of the stratum is available for building stone. At a quarry known as the Reservoir quarry, now operated by Messrs. Callahan and Welsh, is a layer about 20 feet below the surface and about 7 feet in thickness, which is considered the best of any found in the vicinity of Nashville, and is the stone most used for buildings in that city. Above this layer there are but from 2 to 5 feet in all of stone suitable for building. The waste material is used for macadamizing streets, and some of the limestone is suitable for burning. Most of the stone found in the vicinity of Nashville disintegrates rapidly when set on edge, and is therefore unfit for curbing; this rapid disintegration is also seen where the stone has been set on edge in buildings, but where it is laid on its natural bed it is quite durable; some stone suitable for curbing is, however, obtained from the quarry known as the College Hill and Vanderbilt.

OHIO.

[Compiled mainly from notes of Professor Orton.]

SANDSTONE.

SUB-CARBONIFEROUS.—Those rocks of the sub-Carboniferous period, called the Waverly group in the *Geological Survey of Ohio*, are the most important as to production of building stone in the geological scale of the state. The following shows the arrangement of this formation, according to Professor Orton:

1. Maxville limestone, in patches.
2. Logan group.
3. Cuyahoga shale.
4. Berea shale.
5. Berea grit.
6. Bedford shale.

No. 1 occurs but seldom. No. 2 consists of fine-grained sandstones overlying and alternating with massive conglomerates in central and southern Ohio. Its thickness is about 100 feet. The Waverly conglomerate is a member of this group. No. 3, about 300 feet in thickness, is a blue argillaceous shale in many parts of Ohio, but in many places contains scattered courses of sandstone of great value. In southern Ohio these are concentrated and become very valuable. No. 4 is from 10 to 30 feet in thickness and is the equivalent of the Waverly block shale of southern Ohio. No. 5 is the Berea grit, the great quarry rock of northern Ohio. It is from 10 to 75 feet in thickness and extends in a belt from Williamsfield, in the southeastern corner of Ashtabula county, westward into Erie county, and thence nearly directly southward in Adams county to the Ohio river. This stratum of sandstone, where it has its best development, consists of heavy sheets with often a course at the top of thin broken layers called shell-rock. However, in many localities these thin layers are unbroken, even, and compact, and are quarried extensively for sidewalk paving. No. 6 is from 10 to 100 feet in thickness, and furnishes no building stone except in Cuyahoga county.

The line of outcrop of the Berea grit across the state from north to south is very near the dividing line between the formations of the Carboniferous age on the east, where the building stone is almost exclusively sandstone, and the formations of Devonian and Silurian ages on the west, where it is almost exclusively limestone.

The Waverly group, with its well-marked alternations of shales and sandstones, enters the state from Pennsylvania in its northeastern corner. The northern line of outcrop of the Berea grit in Ashtabula and Trumbull counties is for the most part deeply drift-covered, and in places it has been cut out by valleys of erosion. From Parkman, in the southeast corner of Geauga county, it can be traced in an almost continuous line of outcrop around to the Ohio river. In Parkman township, as far as exposed, it lies in thin, ripple-marked sheets.

In Mesopotamia, Trumbull county, a quarry of some importance is worked by the Mesopotamia Freestone Company, one mile west of the town center. The stone is used for buildings, flagging, bridges, etc., in the immediate neighborhood, and is of excellent quality. The nearest railroad station is 7 miles away. This company has just taken the contract to furnish the trimmings for the blocks now building at Burton, Geauga county. From this quarry the Berea grit passes northward, and its outcrop may be traced along the line between Geauga and Ashtabula counties to the southeast corner of Lake county, where it turns to the southwest and follows along the line between Lake and Geauga counties into Cuyahoga county.

The Berea grit is quarried at Windsor, in the southeast corner of Ashtabula county. This quarry marks the most northeasterly locality where the Berea grit has any special economic value as a building stone; though even here the stone is much inferior to that to be obtained over quite an extent of country from Berea, Cuyahoga county, westward to Berlin Heights, Erie county. The pyrites and protoxide of iron contained in the stone at Windsor produce bad discoloration on exposure to the weather. As a source of material for heavy masonry this locality is invaluable, as Ashtabula county has no other stone well adapted for this purpose, and the Windsor quarry has furnished a large amount of stone for heavy bridge construction on the railroads and highways in this county. The quarry is located about 6 miles from the nearest station, and has the same disadvantage as the Mesopotamia quarry for shipping stone.

The most important quarry operations in these counties are carried on in Howland township, 3 miles northeast of Warren, Trumbull county. This stone had been known for many years, and was worked in a small way before the present company began operations. The stone is adapted to the special use of flagging on account of the extreme regularity of its beds, its composition, its strength, and its durability. In evenness of bedding it is remarkable among the quarries of the county. Blocks 10 feet square and 1½ inches thick are extracted, which a straight-edge laid upon the surface would touch at every point. Slabs but 1 inch or 2 inches in thickness have such strength that they go without question into general use. Their fine-grained composition causes them to wear in a uniform manner, and they always give a good foothold. The only defect in the quarry is that the north and south joints do not run evenly; but, as these joints are so far distant from one another as to preclude the possibility of transportation of the included masses, this defect is of but little moment. In one case a single strip 150 feet long, 5 feet wide, and 3 inches thick was raised in the quarry. The layers, although so very closely packed together, are perfectly distinct, adhering to each other scarcely more than sawed planks in a pile.

All the townships in this neighborhood avail themselves of this extraordinary supply of flagging, and the town of Warren is said to be the best paved town in the state; Mahoning avenue may be mentioned as exhibiting on its western side some of the finest flagging that has ever been laid. It has been sent to distant cities in northern Ohio, western New York, and western Pennsylvania, and examples of it may be seen in Pittsburgh, Mansfield, Hornellsville, Akron, etc. It has been used for general building purposes to a limited extent.

The quarries are drained by ditches with a constant good fall. In the flagging deposit proper there are found from four to seven courses, varying from 1 inch to 6 inches in thickness, the 6-inch course being the best and highest priced. The same general character of the stone holds in the adjacent territory, but is subject to some variation of quality. It is of a light gray color, and is the geological equivalent of the stone which is extracted from the Portsmouth and Buena Vista quarries at the southern extremity of the formation on the Ohio river.

The Cuyahoga shales, in which the Austin flag-stones are found, occupy the highest position in the Waverly group in this county, and in the southwestern corner of the county the conglomerate of the Carboniferous formation makes its appearance in a ledge called the Braceville ridge, which rises to 100 feet above the flat surrounding country, and occupies a part of the four townships of Warren, Newton, Braceville, and Lordstown. It is almost entirely destitute of soil, and its prominent points are conspicuously grooved and striated by glaciers. This rock has been the dependence of several generations for building stone in the surrounding region, but no large quantity has ever been extracted at any one time.

Over a surrounding area of 75 square miles whatever stone is used for foundations, well stones, and bridge stones is mainly taken from this ridge. The quarry operations are mainly carried on in the way of "gouging"—that is, in extracting the stone wherever it can be obtained to the best advantage without reference to future quarry operations. Although no quarries are systematically worked, several are in readiness for operation at any time; and it is safe to say that, in the aggregate, $1,000 worth of stone per year is extracted. The material is a strong and enduring sandstone, containing but few pebbles, and is of especial value since the flat country for many miles around is destitute of stone.

The Berea grit is quarried extensively at Newburgh and at Euclid, in Cuyahoga county. A quarry has been recently opened on the east side of the Cuyahoga river, near Independence, and the stone has also been quarried at East Cleveland. The smaller quarries have not been considered in the tables.

As a flagging material this stone is considered by many to have no equal in northern Ohio. It is now used almost exclusively for paving the sidewalks of Cleveland and in many other northern cities, especially in the state of Michigan. It is a fine-grained, compact sandstone of a very beautiful blue-gray color when first quarried, a circumstance which caused it to be extensively used for the trimmings of buildings, although its exposure to the weather has frequently modified its appearance. It is not considered safe to use this material for building purposes except for foundations and bridges, as it frequently contains iron sulphide, the oxidation of which produces stains; and when it has not this defect the color due to weathering is not so uniform when the face of the rock is exposed in a wall as when the bed is exposed in a pavement. A greater amount of the sulphide of iron is contained in the stone at Newburgh than in that at Euclid; and it must be added that examples can be cited where the Euclid stone has presented an unmodified appearance after years of exposure in buildings.

The whole stratum of the rock at Euclid is about 20 feet in thickness, and the different sheets are from 2 to 4 feet thick. As a rule the stone is sawed into slabs.

The outcrop of the Berea grit comes from the northeast, and enters the county in Mayfield township. It has no special economic value in the northeastern part of the county, but near Chagrin Falls, in the southeastern part, it lies in thin sheets, and is quarried to some extent for flagging purposes. At Bedford it will not compare favorably with the stone from some of the other localities for purposes of building; but it is especially valuable for manufacturing into grindstones, which command a high price in market. That variety of stone which is applicable for grinding springs is especially in demand. The material is a rather coarse grained and homogeneous sandstone, filled with little brown spots of iron oxide. In some portions of the stratum lenticular nodules of this oxide occur from one inch to several inches in diameter, and render these portions worthless; but as they occur only at certain horizons they are easily separated from the better material.

At Independence a stone possessing more of the characteristics of the Amherst stone is quarried, especially applicable for the manufacture of grindstones, although it is used to a considerable extent as a building stone. The material has been used in the city hall and in some other buildings at Cleveland. These quarries are located in a bluff, the outcrop of stone being about 4 miles long and 1 mile wide, and usually covered by a drift deposit from 1 foot to 5 feet in depth, although in some localities the rock is quite bare.

The Berea grit is at this place only from 30 to 40 feet in thickness, and only the top 10 feet have been extensively quarried, as immediately below this there lies a stratum of worthless rock from 3 to 12 feet in thickness. Below this, good material for grindstones and building stones is obtained. This has been little quarried on account of the cost of drainage and that of removing the worthless rock referred to. Only large grindstones, which are best adapted for dry grinding, are manufactured from this material, and it is said that the stones do not glaze when used for this purpose.

The statistics in the tables scarcely give a correct idea of the magnitude of the industry at Independence, as the rock has been quarried in many localities in this bluff besides those now operated.

At East Cleveland the Berea grit becomes 60 feet in thickness; and although it does not possess all the desirable qualities of the Amherst and Independence stones, the Cleveland architects prefer it for foundations on account of its superior strength and its accessibility. It has not been used for any important superstructures in the city, the more excellent stone, before mentioned, being so readily supplied to this point.

The Brooklyn quarries, which are situated just to the south of Cleveland, produce a material which is of about the same quality as that found in the East Cleveland quarries, but the rock is more broken, and is used mostly for foundations and underpinnings. Its broken character allows it to be easily quarried, but large blocks are not so readily obtained.

The largest sandstone quarry in the county is situated in Berea, where an immense amount of material has been extracted for building purposes and for small grindstones. Nearly 40 acres of the Berea grit have here been quarried out to an average depth of about 40 feet. The stratum is from 65 to 75 feet in thickness, and has been quarried to the bottom in but few places. The individual sheets are from 2 inches to 10 feet in thickness, and usually are very even in their bedding. The rock all lies below drainage level and seems to have been but little, if at all, disturbed since its deposition. Joints very seldom occur. The stone is usually soft in the quarry and is very easily channeled. It is of a blue-gray color and a little darker as a rule than the Amherst "blue-stone". A larger portion of the formation here is of the so-called "split-rock" character than at any other locality where it has as yet been quarried, and this characteristic is also more perfectly developed here than anywhere else.

The material is not so applicable for the manufacture of large grindstones as is that obtained in Lorain county, or at Bedford and Independence in this county. Small grindstones can, however, be manufactured more cheaply at Berea, because the rock can be split into thin slabs of any desired thickness with little or no waste. The manufacture of whetstones is also quite extensive.

These quarries produce building stones of an excellent quality, although great care must be taken in the selection of the material, as some of it contains sulphide of iron in such amount as shortly to disfigure the surfaces, even discoloring a portion of the wall below it. The material is, however, carefully graded in such a manner as to distinguish the good from the bad stone. For bridge-building purposes the Berea stone is considered the best of the sandstones of northern Ohio, since it possesses greater strength. Tests made by J. B. and W. W. Cornell indicated that a 1½-inch cube would withstand a pressure of 15,400 pounds. The Berea stone has been extensively used throughout the whole country, and may be seen in the following: The Merchants' Bank of Canada building, Young Men's Christian Association buildings, and Montreal Telegraph buildings, Montreal, Canada; post-office building, Bank of Montreal building, and the Garland & Mutchinson building, Ottawa, Canada; post-office building, London, Canada; post-office building and Bank of Toronto building, Toronto, Canada; court-house building, Hamilton, Canada; Senator Fessenden's monument; Methodist Episcopal church, Brookline, Massachusetts; New York Clipper buildings, block corner Cliff and Fulton streets, a figure of Christ 10 feet high, and Church of the

Transfiguration, New York city; Berea hall, Brooklyn, New York; court-house, Camden, New Jersey; Normal school, Saint Agatha's church, and Saint Luke's Episcopal church, Philadelphia, Pennsylvania; United States custom-house and post-office, Dover, Delaware; Young Men's Christian Association buildings, Normal School buildings, and Traders' National bank, Baltimore, Maryland; Baltimore and Potomac Railroad depot, *National Republican* newspaper building, British minister's residence, and Lewis Johnson & Co.'s Bank building, Washington city; court-house, Napoleon, Ohio; court-house, Marysville, Ohio; Exchange building, Bronson's block, and Madison hotel, Toledo, Ohio; court-house, Sidney, Ohio; Beckman's building, Cleveland, Ohio; court-house, Winchester, Indiana; court-house, Crawfordsville, Indiana; Masonic temple, Indianapolis, Indiana; court-house, Wabash, Indiana; court-house, Noblesville, Indiana; the Ogden block, Dickey block, and McCormick block, Chicago, Illinois; United States custom-house and post-office, Port Huron, Michigan; court-house, Menomonee, Wisconsin; asylum for the insane, Oshkosh, Wisconsin; Cleveland viaduct, representing bridges.

Three miles west of Berea a large quarry is worked, and in the immediate neighborhood three other quarries are situated, which have not been tabulated here because they produce but very little building stone, and the material is almost exclusively manufactured into heavy grindstones. The total value of the grindstones produced from the four quarries was over $10,000 during the census year. Good building stone could not be advantageously extracted, as the rock is very much broken up. Never more than 12 and usually not more than 7 feet of the rock are quarried, for below this the rock is more broken, and is called "shell-rock". The waste products of the quarries are sold for a mere nominal price for foundations and underpinnings. As the rock lies above drainage it is a very desirable material for trimmings on account of the permanency of its color. The grindstones sell for a little above the average price.

Stone quarried at West View is considered equivalent to the Amherst stone.

In addition to the large quarries mentioned the Berea grit is quarried in a small way to satisfy the local demand. Cuyahoga county forms one of the most important quarry districts in the United States.

Extracting and dressing the Berea grit is the chief industry in Erie and Lorain counties. The material produced from this and the adjoining regions, under the name of the Amherst building stone, is the most highly esteemed of any in the state, and it has been extensively shipped to Canada. There are large areas of good stone near the surface, away from railroad transportation, which have not been opened. Quite a variety of stones, as regards structure, can be furnished from this formation, increasing the number of uses to which it may be applied.

The Amherst quarries in Lorain county are located in a series of ledges which were once the shore-cliffs of lake Erie. The elevated position of these stones is a very great advantage, since the light and uniform color seems due to the fact that this elevation produces a free drainage, and the stones have been traversed by atmospheric waters to such a degree that all processes of oxidation which are possible have been nearly completed. The elevation also facilitates the extraction. Spur-tracks from the Lake Shore and Michigan Southern railroad pass through most of these quarries and supply means of transportation, and the C. and F. V. railroad furnishes means of access to those quarries not in direct communication with the above road.

The Berea grit at Amherst, as well as elsewhere, varies considerably in character and solidity within limited distances, and the ledges in which the quarries are situated apparently represent the more massive portions of the stratum, which have resisted erosion and have hence been left in relief.

An idea of the arrangement of the strata in quarries can be obtained from the following section, which is exhibited in the quarry of L. Halderman & Sons, at Amherst:

	Feet.
Drift material	1 to 3
Worthless shell-rock	6 to 10
Soft rock, for grindstones only	12
Building stone	3
Bridge stone	2
Grindstone	2
Building stone or grindstone	10
Building stone	4 to 7
Building stone or grindstone	12

The floor of the quarry, moreover, consists of good stone, which has been drilled for 12 feet, indicating a still greater thickness of stone which could be extracted.

The other quarries of the region exhibit a similar diversity of material, although the arrangement is not often the same. As regards colors, the stones may be divided into two classes, called buff and blue. The buff stone (Plate E E) is above the line of perfect drainage, and, in the section above given, this extends as far down as the 2 feet of bridge stone, forming a total depth of 23 to 27 feet. In most of the Amherst quarries the relative amount of buff stone is greater.

As will be noted from this section, the different strata are not applicable alike to the same purposes, and the uses for which the different grades of material can be employed depend principally upon the texture and the hardness of the stone. The softest and most uniform in texture is especially applicable for certain kinds of grinding, and is used for grindstones only, and the production of these forms an important part of the quarry industry. In its different varieties the material is applicable to all kinds of grinding, and stones made from it are not only sold throughout this country, but are exported to nearly all parts of the civilized world. Some of the finest-grained material is also used in the manufacture of whetstones. There are various points in the system of the Berea grit where the stone is adapted to this use, but such a manufacture is best carried on when joined with a large interest in quarrying, so that the small amount of suitable material can be selected; and thus it happens that only at Amherst and at Berea are whetstones manufactured in large quantities.

The stone which is especially applicable for purposes of construction is also variable. That which is of medium hardness and of uniform texture is used for building purposes or for grindstones; some is too hard or not sufficiently uniform in texture for grindstones, and is used for building purposes only; and the material sometimes found which is difficult to quarry and to dress is used for bridge-building purposes only.

As regards appearances there is much diversity in the material produced in this region. There are differences due to diversity of textures, of colors, and of methods of stratification, yet these are seldom recognized by the casual observer. Differences in color give rise to the terms "blue" and "buff" previously referred to, and differences in methods of stratification give rise to the terms "split-rock", "spider-web", and "liver-rock". The regularly and evenly stratified stone is classified as split-rock; that in which the stratification is irregular and marked by fine, transverse, and wavy lines is classified as spider-web; the homogeneous stone which exhibits little or no stratification is classified as liver-rock. These lines of stratification are frequently marked by the presence of black ingredients which are composed of mica and carbonaceous matter. As regards composition, these stones are mainly a siliceous sand; and analyses show that the dry material contains usually as much as 95 per cent. of silica, with a small amount of lime, magnesia, iron oxides, alumina, and alkalies. When first taken from the quarry it contains several per cent. of water, and as long as this is retained the stones cut easily; upon its loss they harden. Analyses made for the Clough and Columbia Stone Companies show that their stones contained respectively 5.83 per cent. and 7.75 per cent. of water when wet, and 3.39 and 4.28 per cent. of water when dry. The stone is extracted during only eight months of the year, since it is injured by being quarried in the winter and subjected to hard freezing while still containing this quarry water. The winter months are, therefore, occupied in stripping and channeling. The average thickness of this sandstone formation is more than 60 feet in these counties, and in many places, as, for instance, at the Brownhelm quarry, it is over 80 feet in thickness. An acre covered by stone only 50 feet in thickness would furnish over 2,000,000 cubic feet. Many very fine buildings, both in the United States and Canada, have been built of the so-called Amherst stone, among which may be mentioned the Canadian Parliament buildings, and most of the public buildings in Toronto; and there is no city in the Union in which stone is extensively used where examples cannot be found in which this stone is used for trimmings and ornamental work.

Near Peninsula, in the northern part of Summit county, on the west bank of the Cuyahoga river, is a valuable outcrop of the Berea grit which has been very extensively quarried in the past, and shipped by canal to Cleveland and thence by lake to various lake ports, principally to Buffalo, New York. The base of the Berea grit is here several feet above the canal. The stone is still shipped quite extensively by canal, and also by the Valley railroad. The principal market at present is Akron. About 16 feet of the upper portion of the stratum are used for general building purposes; below this is a 7-foot course, used principally for the manufacture of mill-stones, for hulling barley and other grains; below this, the bottom course, about 5 feet in thickness, is a rather hard material, used quite extensively for paving purposes. The cap-rock is here about 20 feet in thickness; below this the first 6-foot course of building stone contains more protoxide of iron than the Amherst buff, and has a darker color. The remaining portion of the stratum contains less iron, and much of it is almost white.

The Peninsula stone has the reputation of being exceedingly strong, but it is harder and less homogeneous than that from the Amherst quarries.

The Berea grit has two lines of outcrop in Summit county, one on each side of the Cuyahoga river. The one on the east side passes down to Northampton township, where the stratum lies below the drainage level and contains a considerable amount of soluble compounds of iron, and has a very perceptible odor of petroleum, so that the material is not suitable for building purposes. The stratum has not been quarried to the bottom in this locality, but only about 18 feet in depth. The sheets or layers, so far as quarried, vary in thickness from 6 inches to 6 feet. The blocks of stone are mostly sawed into slabs for sidewalk paving. Still farther south, on the west line of outcrop in the northern part of Portage township, a quarry has recently been opened for the purpose of supplying material for sidewalk paving, and some for steps, caps, sills, etc. This material is similar to that in the above quarry, except that so far as quarried it contains no perceptible traces of petroleum.

The exposed strata of rock in Huron county show evidence of great disturbances and displacement. Sharp synclinal and anticlinal axes are visible in the majority of these exposures, and are most conspicuous in the Berea grit.

In Mr. Perrin's quarry the stratum dips at an angle of nearly 45°. The sheets vary in thickness from 8 inches to 10 feet. This stone is used principally for bridges and foundations. The rock is quarried by first blasting out with powder large masses, which are afterward cut by means of wedges into the sizes required.

In Mr. Grannell's quarry the rock has been less disturbed and lies in nearly a horizontal position. The sheets here are not so heavy as in the above quarry, but the quality of the material is about the same. The layers vary from 1 inch to 5 feet in thickness, and those 6 inches and less in thickness are used principally for paving purposes. The thinner sheets are raised from their bed by means of wedges and bars.

Still farther south in this county, in Fairfield and Greenfield townships, the stratum of the Berea grit is made up almost entirely of thin sheets.

In a quarry in the latter township the sheets vary in thickness from 1 inch to 2 feet, the prevailing thickness being from 1 inch to 6 inches. The material is used almost exclusively for paving purposes, for which it is well adapted, being strong and durable, though much of it is deeply ripple-marked and does not make a smooth pavement.

The line of outcrop of the Berea grit formation is marked by a series of quarries which cross the eastern tier of townships in Crawford county. (*a*) The quarries in Polk township are at present of much less importance than those in Jackson township in the vicinity of Leesville. Quarries have been worked in this vicinity for thirty or forty years. The quarry of the Leesville Stone Company is located about one mile north of the railroad station, but a spur-track is now nearly completed from the main line of the railroad to the quarry. The material from this quarry has earned a good reputation, and the stone has been quite extensively extracted during the last few years. The rock lies below the level of perfect drainage, and in both color and texture it is similar in appearance to that quarried at Berea, but on exposure to the weather its color changes to light gray. Blocks of any desired dimensions may be obtained in this quarry, and the method of quarrying is the same as that employed in the Berea and Amherst quarries. The material is employed for all general building purposes, most extensively, however, for the construction of bridge abutments and piers. It finds its principal markets along the line of the Pittsburgh, Fort Wayne, and Chicago railroad, from Crestline westward into northern Indiana. This quarry is locally more important from the lack of building stone suitable for heavy masonry along this portion of the railroad. Other quarries less favorably located are worked, some with considerable variation in quality, but furnishing material for local use.

In Plymouth township, in the northwestern corner of Richland county, the Berea grit is quarried for the construction of foundations and bridge work in the vicinity of the quarries. Some flagging material is also obtained from the quarry of Mr. Bevier. The material developed in this locality is inferior in quality to the Leesville stone, and on exposure to the atmosphere it is more liable to suffer detrimental discolorations.

The Waverly conglomerate furnishes nearly all the stone for ordinary purposes of construction in the town of Mansfield. In one quarry about 60 feet of rock is exposed. It is considerably broken up; the upper 30 feet being in thin layers, and the lower 30 feet in layers from 1 foot to 6 feet in thickness. Much of this material is beautifully colored in wavy bands of black, yellow, red, and gray, and would make a very ornamental stone if it were not so soft and easily worn by abrasion. It has been used to some extent for purposes of ornamentation in the town of Mansfield. In some of the colored material the red predominates, and the stone is harder but less beautiful in appearance, but it does not exist in large quantities. In another quarry the material is less broken up, and is more uniform in quality, texture, and color.

The Waverly conglomerate in this locality is a coarse-grained sandstone, but rather finer than in most other localities where it is quarried. The light-red and gray-colored samples forwarded to the National Museum were found to be very good and safe stones to work. The dark-red colored specimen is rather coarse and loose in structure.

A section of the quarry of Mr. D. W. Zent, at Belleview, exhibits the following arrangement of strata: (*a*)

	Feet.
1. Earth	2 to 4
2. Coarse pebbles of drift	8 to 10
3. Sandstone in thin layers	15
4. Sandstone in massive layers	8
5. Sandstone in layers of 1 foot to 4 feet	15

There is but little variation in the character of the material except in color. The material has been used principally in the construction of railroad bridges on the Chicago branch of the Baltimore and Ohio railroad. Considerable of the material is used at Lexington, Ohio, and in the neighborhood of the quarry. Only a small amount of powder is used in the extraction of the stone, and the amount of production is controlled by the demand for stone by the Baltimore and Ohio Railroad Company. The layers of stone are from 6 inches to 6 feet in thickness, and open joints occur from 4 to 5 inches in width. About 60 feet of rock are exposed in the quarry at the present time, and the formation has not yet been quarried out to the bottom. The color of the layers near the top of the quarry is brownish; farther down some of the stone has a yellowish appearance, and at the bottom of the quarry is a layer of mottled or clouded stone, a blending of red and brown.

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a Geological Survey of Ohio, Vol. III, p. 321: "Geology of Richland County," by M. C. Read.

An abundance of stone of indifferent quality may be obtained in the vicinity of Wooster from the Waverly formation. A little north of the town a much-broken sandstone is quarried to some extent for the production of material for building foundations and cellar walls.

The most important quarry in this locality is in the Waverly conglomerate. In this quarry blocks of any desired dimensions may be obtained, and the stone is used principally for the construction of foundations and bridge work. At the joints the material shows a discoloration to a depth of about 1 inch due to weathering. A quality of material rather superior to the above is obtained from the Carboniferous or Sharon conglomerate in Chippewa township, in the northeastern part of the county.

In the quarry of the Walnut Grove Stone Company, operated here, large blocks are obtained for bridge-building purposes, and some of the material quarried is used for the construction of foundations. The principal markets for the material are at Orrville and Wooster, and some is transported to Akron, in Summit county. The material is a coarse-grained though quite firm and durable sand rock, very suitable for heavy masonry. At the natural joints in the quarry the material shows but little discoloration from the effects of weathering. The marketable material here comes almost to the surface; it is necessary to remove only about 3 feet of drift material before the marketable product is reached. The material is quite soft when first quarried but hardens upon losing the quarry water.

The stratum in which the quarries near Massillon, Stark county, are located, according to the concurrent testimony of all the geologists of the Second Pennsylvania geological survey, is the second or middle sandstone of the great Carboniferous conglomerate; it immediately overlies and often cuts out the lowest coal, known as the Sharon seam. Dr. J. S. Newberry, in the *Report on the Geological Survey of Ohio*, confirms the designation of Carboniferous conglomerate for the Sharon conglomerate which lies below the Sharon coal. The Massillon sandstone, in the quarries near the town of Massillon, is quarried by means of channeling and wedging. The courses vary in thickness from 2 to 8 feet, the lower courses being the thickest. The stratification is somewhat undulating, and the courses are not uniform in thickness. Blocks of stone of any desired dimensions may be obtained from any of the quarries devoted to the production of building stone. The entire thickness of the stratum is about 60 feet. This material is employed principally for general building purposes, but it is also manufactured into grindstones, chiefly for dry grinding. According to the testimony of Mr. J. P. Burton, of Massillon, the Massillon sandstone, when subjected to a temperature of 900° F., yet remains in perfect condition. He has used the material for many years in his furnace-stack at the Massillon blast-furnace; and the stone which stood the above test was taken from the quarries of Messrs. Warthorst & Co. and used for a hearth. The texture of the stone is not the same in all the quarries about Massillon, and the finest-grained material is obtained from Mr. John Paul's quarry, about 5 miles north of the town. The upper layers in this quarry are crushed for glass-sand and the lower layers for steel-sand, and but little of the material is used for purposes of construction. Powder is used for removing the cap-rock, which varies in the different quarries from 2 to 10 feet in depth, and for extracting the material for glass- and steel-sand.

All three horizons are worked for the Youngstown market. The Briar Hill and Bear Den quarries belong to the middle horizon, and those of Austintown to the highest. The ledges in this locality, as a rule, grade upward in fineness, and the upper stones give the best results when dressed. All of them are nearly pure silex, and the waste material of the Briar Hill quarry is all ground or crushed and sold to the steel works; much of it is adapted also to coarse-glass manufacture. The rock of the middle ledge is colored in bands and lines with iron peroxide, which robs it of beauty, but interferes in no way with its durability. In all northeastern Ohio there is no limit to the amount of strong, massive, and durable building stone to be obtained. The quarries in the middle division of the conglomerate series, on account of the more favorable situation of the outcrops, are more largely worked than the quarries in the upper and lower divisions.

The Austintown quarries have been worked at intervals since the country was settled. The stone is light-brown in color, rather coarse, but uniform in texture. It is used to some extent for purposes of ornamentation in Youngstown, but its principal uses are for general building purposes and bridge work. Flag-stones of fair quality are also quarried here for the local demand, from a horizon just below the sandstone ledge. Blocks of any desired dimensions may be obtained from the middle division of this series, and the material is used principally for general building purposes, bridge work, and to a small extent for ornamental fronts. The principal market for all these quarries is Youngstown. Some material is shipped from the Briar Hill quarry to Pittsburgh and some is used for purposes of construction by the New York, Pennsylvania, and Ohio railroad.

Stone for local uses may be obtained almost everywhere in Tuscarawas, Holmes, and Knox counties, and for this reason no extensive quarry is worked. A quarry was opened and developed for the purpose of extracting material for bridge construction on the line of railroad running near the quarry, but is now nearly abandoned, because this railroad obtains building stone in cuts through the same stratum. This stone lacks the uniformity of texture and color demanded for the better class of work.

There are a number of ledges of sandstone, about 20 feet in thickness, found at different horizons in the Lower Coal Measures in Tuscarawas county, and they all furnish some building stone. A considerable portion of the building stone used in the county is obtained from masses of rock which have been detached from the solid ledges.

The stone from the quarry of the Tuscarawas Valley Coal and Iron Company is finer in texture and of a more uniform color than any other stone obtained in the county. It is used for "bottom" in the blast-furnace belonging to this company, and resists the action of heat uncommonly well. The principal uses of the material from these quarries are for constructions of foundations, underpinnings, and bridges in the vicinity in which the quarries are located.

Almost everywhere in Holmes county there are lying on the surface large masses of rock which have been detached from the strata of the Coal-Measure sandstones. These detached masses supply the local demands for building stone, and no quarries are developed in the ledges.

Near the central part of Knox county, from 3 to 7 miles northeast of Mount Vernon, large masses of rock lie loose upon the surface. These have not been transported to their present station, but have been left in loose blocks on the surface by the undermining and removal of a portion of the soft shales that immediately underlie the stratum of sandstone. The quarry operations represented by Messrs. Bartlett Brothers are worked in these masses of sand-rock. This stone is considered the best material for building purposes to be found in the vicinity of Mount Vernon. It is used for all general building purposes, including caps, sills, columns, etc., in the town and through the neighboring country. It is estimated that about 250,000 cubic feet may be obtained in some places from the surface of half an acre in area. This material has been a source of local supply for about seventy years.

The Waverly conglomerate, which is quarried near Howard station, is not so highly esteemed as is the stone of the Carboniferous conglomerate, described above. The demand for it is principally for use in the construction of railroad bridges, arches, culverts, and to some extent for foundations and underpinnings Some is shipped to Columbus, Ohio. The layers of stone in this quarry vary in thickness from 6 inches to 6 feet, and blocks of any required dimensions may be obtained. It is rather soft when first extracted, but hardens on exposure to the weather.

In Morrow county the Berea grit crops out, and is quarried in North Bloomfield, Washington, Gilead, and Lincoln townships. Its total thickness varies from 15 to 40 feet in different localities. The thin layers of its upper portion are very even and compact, and make an excellent flagging material. The most favorable development of the flag-stone occurs near Iberia. At this place the layers vary in thickness from 1 inch to 6 inches, but 2½ inches is the most common thickness; the total depth of flag-stone is about 20 feet, below which from 18 to 22 feet of heavier layers occur. The quarries are located in the bed of a stream, and only the thin layers are extracted. The amount of flag-stone that may be quarried in this vicinity is practically inexhaustible. At present the material is carried on wagons 2 miles to the nearest railway shipping-point, and a considerable portion of the product of the quarries is carried on wagons to the town of Galion, in Crawford county, which is the principal market for the stone quarried in the northern part of Morrow county.

The thickness of the heaviest layers in the county is only about 2½ feet.

The Berea grit crosses the eastern part of Delaware county, and at Sunbury quite important quarries have been developed. It has here been worked to the depth of about 20 feet, as deep as natural drainage is available. Good building stone might be obtained below this depth, but artificial drainage would be required. Plate F F represents a surface of the Sunbury freestone. This material bears a close resemblance to the Euclid "blue-stone" of northern Ohio. The layers vary in thickness from 3 inches to 3 feet. The thin layers are quarried for flagging stones, and the heavy ones for general building purposes and to some extent for ornamental work. The material finds its principal markets at Delaware, Mount Vernon, Columbus, and Orrville, Ohio. Examples of it may be seen in the building of the Ohio Industrial Home for Girls in Delaware county, and in the National Bank building at Delaware.

The sandstone of the Berea grit in the eastern part of Franklin county has considerable local value, because on each side of its outcrop the surface of the country is occupied by a belt of shale from 8 to 10 miles in width, the belt on the west being entirely destitute of building stone and the one on the east is nearly so. The formation has, however, in this part of the state lost many of the valuable qualities which characterize it in Erie, Lorain, and Cuyahoga counties. On account of its accessibility, however, it has been used quite extensively in Columbus, the Ohio Institution for the Blind being constructed of it as well as several stone fronts.

The entire product of a quarry 10 miles east of Columbus is sawed at the quarry for caps, sills, ashlar, etc., and shipped to various points along the lines of the Baltimore and Ohio and Pan-Handle railroads, but principally to Columbus.

The greater portion of the surface of Licking county is occupied by the rocks of the Waverly formation, but a portion of the eastern part of the county is occupied by the conglomerate and Coal-Measure rocks. The Waverly conglomerate crops out in bold cliffs over quite an extensive area in Madison and Hanover townships. It has been quite extensively quarried in this vicinity for use as material for construction on the lines of railroad running through this section of the county. It is a rather coarse-grained sandstone, in some localities quite uniform in texture, and in others containing pebbles sometimes an inch in diameter. It is rather soft when first quarried, and works rather easily, but hardens on exposure. In some places sections of this conglomerate 100 feet in thickness are exposed in ravines. The quarries now operated are located in the banks on each side of the Licking river. One quarry is located in the north bank, at the foot of which runs the Ohio canal, which furnishes the means for transporting the material to Newark and Columbus, where it finds its principal markets. Another quarry is located in the south bank, at the foot of which passes the Baltimore and Ohio railroad. The material is used quite largely for heavy masonry along the lines of railroad, and for general building purposes at Newark and Columbus. It varies in color from gray to light brown. The cap-rock necessary to be removed seldom exceeds 4 feet in depth, and consists principally of soil, loose sand, and gravel.

This material may be obtained with equal advantage on the line of the Pan-Handle railroad, and there is no limit to the amount of strong and durable sandstone which may be extracted in this vicinity. A quarry 1½ miles south of Newark, in the Cuyahoga shale, furnishes a fine-grained and homogeneous material, at present used principally for foundations at Newark and Columbus, Ohio. Trinity church, at the latter place, was constructed of this material, and the only defect noticed in the stone is the discoloration. It gives evidence of both strength and durability when laid on its natural bed, and when it is quarried sufficiently early in the season to allow it to become thoroughly dry before being subjected to the action of frost.

The Waverly sandstone seen in Fairfield county in the cliffs along the Hocking river is generally coarse-grained, often passing into a true conglomerate; and it shows the same character in the hills and highlands west of the river. It is more commonly of a rich yellow color, but sometimes of a darkish brown. In many places the stone is firm in texture and capable of resisting great pressure without crushing. (*a*) The stratum in which the quarries near Lancaster are worked is solid, and about 30 feet in thickness. There are but few joints, and the largest sized blocks may be obtained. The material is used principally for bridge construction, canal locks, and general building purposes. The principal markets for this material are Columbus, Centerville, and Lancaster, Ohio. The material for the superstructure of the Saint Joseph's cathedral at Columbus was obtained from the quarry of Messrs. Sharp & Crook, and that for the foundation of the same structure from quarries in the Waverly conglomerate near Hanover, Licking county. The amount of cap-rock to be removed is from 3 to 4 feet in some localities, and as much as 25 feet in depth in other places. Powder is employed in quarrying.

The Lithopolis quarries are located in the lower portion of the Cuyahoga shale of the Waverly group. There are several horizons of building stone in the Waverly group, but this particular portion of the Cuyahoga shale is quite rich in quarries, especially in southern Ohio. There is a number of important quarries in the upper member in different parts of the state, as indicated in the tables. The lower portion of the Cuyahoga shale has no economic importance in the northern part of the state. The only important quarry in the whole formation in northern Ohio is that of the Austin Flag-stone Company, in the upper portion of the shale. In southern Ohio the most important building-stone quarries are in the lower portion of this shale.

The stone quarried at Lithopolis and at other localities at or near the same horizon is commonly denominated freestone. It is a fine-grained sandstone, usually in quite thin courses; is sawed easily, and answers a very convenient purpose for caps, sills, and stone fronts. Columbus, Ohio, is the principal market for the product of the quarries.

Stone for the ordinary purposes of construction may be obtained in various localities in Hocking county, but only one quarry is developed in the Waverly conglomerate near Logan, and the material from this has but recently come into the market through the facilities for transportation afforded by the construction of the Hocking Valley railroad. There are no important quarries below this point in the Hocking valley. The stratum of the Waverly conglomerate in this locality consists of three layers, each about 10 feet in thickness. The rock underlies an area of four or five acres with a cap-rock but a few feet in depth, consisting of clay and gravel, which is easily removed. The quarry is located close to the railroad and is capable of supplying any demand for material likely to be made upon it. It finds its principal markets at Columbus, Lancaster, and London, Ohio, and has been shipped to some extent to Marion and Winnemac, Indiana.

When a canal was constructed through the valley fifty years ago, it furnished easy transporation for the great ledges of sandstone that bound the valley for a dozen or more miles, and the stone from Waverly, Pike county, soon became famous in Columbus and central Ohio generally as Waverly stone. The name was early extended to a great group of associated sandstone and shales of sub-Carboniferous age, as has recently been proved, but the real age was long an unsettled question; hence comes the Waverly group of Ohio geology. It is the first sandstone, except the local Euclid blue-stone, reached in ascending the geological scale of Ohio that can be quarried. The stratum is best shown from Waverly south for 10 or 12 miles. It dips below drainage just south of the county line on the river's bed. For these 10 or 12 miles it is reached on all the ravines on each side of the river. The stone about Waverly has been followed back under such heavy cover that the increased expense of quarrying has ruled the material out of the market. A quarry at Piketon has just been made possible by the Scioto Valley railroad, constructed four years ago. There is, however, no first-class stone now available in this quarry. There are 26 feet exposed in it in courses varying from 1½ to 24 inches in thickness. There is a great amount of reliable stone in the stratum and a great amount that is treacherous. It is by no means equal in uniformity of quality to the Berea stone of northern Ohio. It formerly furnished a grindstone grit of great local value. The stone is always ripple-marked and bears other evidences of having been formed on a shore-line. It is usually of a uniform gray color, but there is also a variegated variety clouded with red which is one of the most striking stones of the state.

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a Geological Survey of Ohio, Vol. III, p. 594.

The above, however, is but an inadequate statement in regard to the range of quarries that for many years held the first place in southern Ohio. Many other ledges of at least equal value have now been rendered available by the new lines of railroad communication.

The Waverly stone, where it has not been subjected to atmospheric influences, has the characteristic bluish-gray color of the Berea grit formation in other parts of the state. The difference in composition between the weathered portion and the blue-stone is shown in the following analysis made by Professor Wormley for the *Report on the Geological Survey of Ohio:*

	No. 1 (white-stone).	No. 2 (blue-stone).
	Per cent.	*Per cent.*
Silicic acid	91.30	91.00
Protoxide of iron	0.86	1.17
Sesquioxide of iron	0.06	0.30
Alumina	5.79	5.20
Lime	Trace.	Trace.
Magnesia	0.32	0.28
Water, combined	1.30	1.80
Total	99.63	99.75

Near Cynthiana, where the variegated variety above referred to occurs, there is also found a very white, fine-grained variety, and the following analysis shows this to be very nearly of the same composition as that above, without the oxides of iron:

	Per cent.
Silicic acid	91.35
Iron, sesquioxide	Trace.
Alumina	6.00
Lime, carbonate	0.75
Magnesia, carbonate	0.34
Water, combined	1.00
Total	*a* 99.44

The Waverly brownstone quarries lie at a horizon about 40 or 50 feet above the Waverly stone, or Berea grit, in its southward extension. They lie very near the horizon of the famous Buena Vista stone of Scioto county. A number of the best stone fronts at Columbus, Ohio, have been constructed from the product of these quarries. The stone is brown only on the outcrop; when found a few feet under cover it assumes a dark blue color and loses its value as an ornamental stone. The blue variety contains a large amount of soluble iron protoxide which produces a bad discoloration on exposure to the atmosphere. The following analysis made by Professor Wormley for the *Report on the Geological Survey of Ohio* shows the composition of the Waverly brownstone:

	Per cent.
Silicic acid	73.90
Protoxide of iron	.....
Sesquioxide of iron	13.44
Alumina	8.56
Lime	Trace.
Magnesia	0.46
Water, combined	3.30
Total	99.66

The quarry which has been the most important is located about half way between Waverly and Piketon. Here the stone forms a massive bed 8 feet in thickness. The same ledge has been worked along the valley on both sides of the Scioto river for 10 or 12 miles. That quality of stone still remains in easy reach, though some of the quarries have already yielded all their brownstone to the market. The depth of cap-rock to be removed in these quarries nowhere exceeds 15 feet.

All the ravines that reach the Ohio valley below Portsmouth for 20 miles disclose a large amount of excellent building stone, but in the ravines that are found from 2 to 4 miles below there is a horizon disclosed that lies low enough to be easily reached, and that is naturally covered by an easily-eroded cap, so that a very considerable amount of building stone has been found readily accessible. This horizon is at about the middle of the sub-Carboniferous system in Ohio.

The Portsmouth quarries have been worked since the first settlement of the Ohio valley. During the last fifty or sixty years a great number of separate quarries have been opened, but all on the same horizon. When the stripping becomes heavy a slight change in location is made. The land is considered of no great value for any other than quarrying purposes. Some locations prove better than others, and these are being worked more systematically of late years.

a Geological Survey of Ohio, Vol. II, p. 623.

At the quarry of Messrs. Reitz & Co. the stone occurs in layers from 6 to 24 inches in thickness. These courses are frequently separated by an inch or two of shale. Joints do not occur frequently to interfere with the systematic working of the quarries. For flagging the stone is unequaled in the Ohio valley, as it wears evenly, always gives foothold, and is in every way satisfactory. It is well adapted to sawing, and is used quite extensively for general building purposes. The material finds its principal markets along the Ohio valley, through Ohio, West Virginia, Kentucky, and Pennsylvania. It has been used in the construction of the court-house at Athens and the Children's Home building at Gallipolis, Ohio, and the Western penitentiary of Pennsylvania, at Allegheny.

The quarry of Mr. J. M. Inskeep is located about 12 miles below Portsmouth, on the Ohio river, at a horizon about 60 feet above the Buena Vista stone proper. There are 30 feet of rock in about 20 different layers. The lowest course, about 32 inches in thickness, is the most valuable stone. This course is covered by 4 feet of blue shale, which is the largest mass of shale in this section. The other shale deposits are but little more than partings between layers of sandstone. The courses are remarkably even in thickness, but those above the lowest do not yield a strictly first-class material. For the last three or four years this quarry has supplied material quite extensively for the Columbus market, and a number of fine stone fronts have been constructed from it. The stone varies considerably in quality, and needs to be carefully inspected.

The southwestern portion of Scioto county and the southeastern corner of Adams county, two adjoining districts, were once the most important localities in Ohio for the production of building stone. In the earlier days of the state an engineer of reputation, employed upon the construction of canals, became conversant with the then known building stones of the state, and recognizing the great value and accessibility of the ledge, commonly known as the Buena Vista Freestone ledge, bought a large territory here, and began the development of the quarries in a large way. Other horizons of good rock were found at various levels, but this one bed, by its color and quality, supplied the Cincinnati market almost exclusively. Its reputation spread throughout the whole Ohio valley and beyond. Large quarries were opened on both sides of the river, government patronage was secured, and material for the construction of custom-houses and other public buildings was ordered from the Buena Vista quarries. So great was the demand for this stone that material of poor quality as well as of good was hurried into the market. The greenstone while full of quarry water was laid in massive walls, and the bad behavior of this material soon excluded the stone almost entirely from the market. It is, however, as good now as when it earned its high reputation, but needs careful and conscientious selection and suitable seasoning.

Just below the horizon of the Buena Vista stone lies the Berea shale, a bed of highly bituminous and very fossiliferous black shale, ranging from 15 to 30 feet in thickness. Its bituminous composition makes it a source of petroleum, which rises into the sandstone courses that lie above it. This is the source of one of the worst impurities of the Buena Vista stone. When followed under cover it is found loaded with petroleum or with tar, which seems not only to disfigure the stone but to weaken it to some extent; and other impurities in the stone are masked for the time by this bituminous matter. The oil-bearing stone is tolerated only in rough, heavy work. Some of the stone contains sulphide of iron, which, on exposure to the weather, becomes oxidized to the sulphate and goes into combination with compounds of aluminium, and appears on the surface of the stone as a white efflorescence which has the characteristic taste of alum. Grains and nuggets of pyrites appear in the shales associated with this sandstone, but are not very perfectly visible to the naked eye in the city ledge (the name now applied to the stratum proper of Buena Vista stone). The rock is quarried by channeling and wedging in the same manner as in the quarries of the Berea grit in northern Ohio. No stone is extracted for the market during the winter months, but this time is occupied in removing the cap-rock and in channeling. The behavior of the material when properly selected is apparent in a number of important structures in Cincinnati, and that of the unselected material may be seen in the custom-house and other buildings in Chicago. The material has also been used with good and bad results in a number of other cities and towns, including Louisville, Kentucky, Pittsburgh, Pennsylvania, and Detroit, Michigan.

Carboniferous.—The Carboniferous conglomerate (Sharon conglomerate of the *Second Geological Survey of Pennsylvania*) furnishes the only important building stone in Portage county. This formation in Ohio geology is commonly called "the Conglomerate".

In Franklin, Mantua, and Nelson townships, where it is well seen, it is a coarse, drab-colored sandstone, in places thick set with quartz pebbles from the size of a pea to that of an egg. It is quarried in these localities to a small extent for local purposes.

At the quarry of Messrs. Case & King, in Windham township, it is finer, whiter, and more homogeneous, and answers quite well for architectural purposes. It is rather too coarse for fine work, but it is strong and durable and well adapted to bridge building and all other plain and massive masonry.

In Summit county the Carboniferous conglomerate underlies all the higher portions of the county and forms the surface rock over all the middle portion, except where cut through by the Cuyahoga and its tributaries; though generally covered and concealed by beds of drift, it is exposed and quarried in all the towns north of Akron. In the valley of the Cuyahoga it forms cliffs sometimes 100 feet in perpendicular height. The rock is about 100 feet in thickness, generally a coarse-grained, light drab sandstone, but in some localities, and especially near the base of the formation, becoming a mass of quartz pebbles, with just enough cement to hold them together. (*a*)

All the accessible material that is now known in this formation is applicable to ordinary purposes of building. Although it is quarried in many different localities for local supply, it is worked extensively in but two localities—at Akron and in Twinsburg township. The quarries at Akron are worked principally to supply the town with foundation stone and the immediate vicinity with bridge stone. The quarries in Twinsburg township are at present worked quite extensively to supply material for the construction of bridges on the Cleveland and Pittsburgh and the Connotton Valley railroads.

A section in Mr. Parmelee's quarry exhibits 18 inches of soil and gravel, 15 feet of coarse sandstone in which thin strata of pebbles occur from 1½ to 4 feet apart, and 6 feet of very coarse conglomerate underlaid by shale. The 15-foot course of sandstone occurs in a solid mass, which separates easily where strata or sheets of pebbles called "bed-seams" occur. In the Akron quarries the stone is fine-grained and more homogeneous than in the Twinsburg quarries. In Mr. Hugill's quarry the rock has been quarried to a depth of 40 feet, and the material obtained is a coarse-grained sandstone free from pebbles. Formerly, in a quarry known as Wolf's quarry, near Akron, a local stratum produced a deep reddish purple sandstone, perhaps the most beautiful building stone ever produced in the state, which was used quite extensively in Cleveland, and two residences on Euclid avenue are constructed of this material. At Cuyahoga Falls a similar material has been quarried to some extent for the construction of buildings in the town. The quantity of this variety of building stone is apparently not large, and it seems that it is nowhere known at present where it can be profitably quarried in a large way. The Wolf quarry has not been worked for a number of years.

The stone quarried for building purposes in Coshocton county is obtained from blocks detached from strata of sandstones of the Lower Coal Measures. The stratum from which the blocks quarried by the parties represented in the tables have been detached is a solid ledge 30 feet in thickness, and lies a few feet above the horizon of the Zoar limestone. The material is usually a light-colored sandstone, though some of it has a reddish color, and some is a finer-grained white sandstone. The stone used for the construction of locks on the Ohio canal, through Coshocton county, was obtained from these quarries. The stone has the reputation of enduring well ordinary atmospheric influences, but not of withstanding a high degree of heat. It is principally used for bridge building and foundations in the vicinity of the quarries.

Material for ordinary purposes of construction is obtained in various localities in Muskingum county from the Coal-Measure sandstones, but there is no extensive quarry at any place except about half a mile east of Zanesville. This quarry furnishes by far the largest part of the stone used for construction in and about Zanesville. It has been used quite extensively for building canal locks, foundations, and for sidewalk pavements. Some of the oldest buildings in Zanesville are constructed entirely of this material, and it is found that the stone is more capable of resisting atmospheric agencies than of resisting the abrasive action to which it is subjected in sidewalks. This material is easily obtained in great abundance and of fair quality, and is the most important among the building stones found in the neighborhood of Zanesville, except perhaps the sub-Carboniferous limestone with which it has been recently brought into competition.

The most important building-stone quarry in Noble and Guernsey counties is near Cumberland, on the line between the two counties. The stratum quarried is solid and about 10 feet in thickness. The material is a dense fine-grained sandstone, rather hard, but susceptible of being finely carved. It is of a gray or light-brown color where it has been subjected to atmospheric influences, but as the excavation progresses into the hill a material of a bluish-gray color is obtained. Joints in this stratum are filled up with a hard calcareous matter deposited from solutions of the material from a limestone ledge a short distance above the sandstone. The size of blocks determined by these joints is about 30 by 15 by 10 feet. The material is employed for all general building purposes, principally at Cambridge. It is used in the superstructure of the court-house in process of construction at this place. The foundation stone for this building was obtained near Cambridge, from a quarry worked only to supply temporary demands.

Stone for the ordinary purposes of construction may be obtained in various localities in Jefferson county from the different sandstone strata of the Coal-Measures, which occupy the whole area of the county; but the only quarries that have been developed are those near Steubenville, in the Upper Coal Measures.

One quarry furnishes stone for general building and paving purposes, used principally in the town of Steubenville. The material has a bluish color where it has not been exposed to atmospheric action, and at the natural joints discoloration has penetrated into the rock from 10 to 18 inches. This liability to discoloration makes this stone unfit for the finer purposes of construction.

A better material for purposes of ornamentation is obtained from the quarry where two separate and distinct strata of sandstone in the Upper Coal Measures occur. There are, in reality, two separate quarries, located at different heights, at the side of a hill west of Steubenville, near the Ohio river. The material from these quarries is used largely for cemetery work, bases of monuments and tombstones, vaults, etc. That from the upper quarry

a Geological Survey of Ohio, Vol. I, p. 212: "Geology of Summit County," by J. S. Newberry.

is better adapted to fine work, but it is not so extensively used, because the material is not as accessible as that in the lower quarry. The Episcopal church at Steubenville was constructed of stone from these quarries.

Belmont county is well supplied with material for the ordinary purposes of construction from the sandstones of the Upper Coal Measures and the Lower Barren Measures; and some of the quarries furnish material quite well adapted for ornamentatal purposes. The most important quarries are those in the eastern part of the county, near Martin's Ferry and near Bellaire. These quarries are located in the hills several hundred feet above the Ohio river. The quarry of Mr. Charles Siebrecht is located about 100 feet high in one of these hills. The stratum is a solid mass about 30 feet in thickness. The material is used for general building purposes, principally at Martin's Ferry. The stone-work of the suspension bridge across the Ohio river at Wheeling, West Virginia, is constructed from this material.

The total thickness of the sandstone ledge quarried by Mr. Robinson, near Bellaire, is about 40 feet. The rock, for a depth of 17 feet from the top, is very uniform in texture and general appearance. The portion of the ledge below this is in irregular masses, unfit for building purposes, and is locally called "nigger-head". The layers of stone in the upper 17 feet are quarried for building purposes, and vary in thickness from 4 to 7 feet. This is esteemed as the best material for building purposes found in Belmont county. The arches and abutments of the Baltimore and Ohio Railroad bridge across the Ohio river at Bellaire, and of a number of other bridges on the same railroad, are constructed of this stone. The material finds its principal markets at Bellaire, Ohio, and at Wheeling and Benwood, West Virginia. Traces of coal vegetation are found occasionally between the layers of stone in this quarry. A short distance above this sandstone a vein of coal occurs, and above this a limestone stratum 20 feet in thickness, quarried for furnace flux.

The ledge of rock in Mr. Hutchinson's quarry is about 30 feet in thickness, and is considerably broken into irregular masses. The stone is fine-grained, rather hard, and difficult to cleave in any direction. Near the middle of the ledge are two layers, each about 20 inches in thickness, which are more regular; the rock, however, is found less broken as the excavation advances into the hill. Since this quarry is constantly worked for ballast, it has the advantage of selecting its best material for purposes of construction. However, stone more regular in structure and better adapted to building purposes is quite abundant in this locality. There is also a good flagging stone found here in a different stratum; but this is quarried only occasionally for temporary demands. The product of the quarry of the Baltimore and Ohio Railroad Company, near Barnesville, is used largely for ballast. It has been used to some extent for purposes of construction on the Baltimore and Ohio railroad. The stratum in which the quarry is located is about 30 feet in thickness, but has only been worked to a depth of 14 feet. The stratum contains few joints and has no divisional planes of stratification. Stone of such fair quality for all ordinary building purposes is so generally distributed throughout this part of the county that it is picked up wherever needed to supply the occasional local demands, and no extensive quarries are developed at any place for the production of building stone.

In Washington county strata of sandstone belonging to the upper series of Coal Measures are quarried for the production of building stone and grindstones in the heavy ledges along the Ohio River hills. The most important quarries are located near Marietta and Constitution. The arrangement of the different sandstone strata, with their alternate shales, coals, and fire-clays, is as follows:

Heavy sand-rock	30 feet.
Blue shale	9 feet.
Heavy sand-rock extensively quarried for grindstones	25 feet.
Sandy shale	20 feet.
Heavy sand-rock quarried in places	36 feet.
Shale, somewhat ferruginous	4 feet.
Coal, Hobson's seam	1 foot to 6 inches.
Fire-clay and shale	4 feet.
Interval to Ohio river	a 42 feet.

The quarries near Marietta and Constitution are all, except Mr. T. B. Townsend's, worked in the grindstone stratum, and produce, besides grindstones, material for all general building purposes. The building stone is used principally at Marietta and at various points along the Ohio river. In different portions of the stratum there are sufficient varieties of texture to furnish all kinds of grits used for wet grinding, and the grindstones are shipped to all manufacturing points in the United States. The rock splits readily in the direction of the stratification. The advantages offered for the transportation of the product by the proximity of the quarries to the Ohio river greatly aid their development.

The quarry of Mr. Townsend is located on the Muskingum river, and is devoted to the production of a material mainly for bridge-building purposes, and some for general purposes of construction. The section exposed in this quarry exhibits 65 feet of sand-rock, which becomes still heavier as the quarry progresses into the hill. It consists of layers from 4½ to 18 feet in thickness. In the lower portion of the quarry the material is rather finer in texture and superior in quality to that in the upper portion. The quarry was opened for the special purpose of obtaining stone for the ice harbor, now in process of construction at Marietta; but it also furnishes material for other structures.

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a *Geological Survey of Ohio*, Vol. II, p. 472: "Report of Second District", by E. B. Andrews.

LIMESTONE.

CINCINNATI GROUP.—The southwestern corner of Ohio is covered by what is called the Cincinnati group of limestones, a geological formation equivalent to the Hudson River beds of New York. These rocks were very early quarried and used for construction purposes, although the special quarries that are at present in operation have been much more recently developed. Quarries once located on the outskirts of Cincinnati have suspended operations on account of the growth of the city. The material is mentioned in the early reports upon the geology of Ohio as having been used in 1838 for building, burning into lime, macadamizing roads, and even for ornamental purposes. (*a*)

Professor Orton gives the following as the order in which the beds which constitute the Cincinnati group in southwestern Ohio are arranged:

The Point Pleasant beds, 50 feet thick, constitute the lowest of the series. The Cincinnati beds proper overlie these, and are 425 feet thick. The Lebanon beds are the highest, and are 300 feet thick. Quarries are developed in each of these horizons. The rocks wherever they are quarried are very much alike, and are called in commerce blue limestones. As a rule they are filled with fossils, and occur in layers that are from half an inch to 12 inches in thickness, which are interstratified with beds of shale or clay. Professor Orton says that while this blue limestone has been used from the first settlement of the country, it has hitherto enjoyed the reputation of being serviceable rather than beautiful; but within the last few years it has been so treated by combination with other building stones as to produce very fine architectural effects, as can be seen in the recent buildings of the city and suburbs of Cincinnati. (*b*)

The quarries in the Cincinnati group of limestones are located near Cincinnati, more on account of the local demand for the most accessible stone than for the superior quality of the material at this point. There are limestones in the river bed which are upon the same level as the quarries which produce excellent stone at Covington, upon the opposite shore. These beds are overlaid by 250 feet of shales, which are called by Professor Orton the "Eden shales"; and these in turn are overlaid by the so-called "Hill Quarry" beds of limestones, from which most of the stone used in the county is derived.

Six quarries of importance are at present in operation at Cincinnati with exposures of from 40 to 75 feet, of which some 10 to 25 feet is distributed throughout the section in layers from 1 inch to 10 inches in thickness. Slabs 6 feet long and 6 feet wide can be extracted.

The lime which is burned from the stones of the Cincinnati group is dark and unfit for plastering, but for foundations, etc., it is of especial value, as it possesses some hydraulic capacity. Specifications for cellar walls, bridge abutments, etc., in this region always call for Cincinnati lime.

It is thus seen that the stone is interstratified with beds of shale, which forms from one-fourth to one-third of the whole section. In other parts of the series the proportion of stone falls to one-tenth of the thickness of the section, the main mass being composed of shale or clay. The stone seldom exists in such condition as to make a building stone that can be used in fronts, and it is mainly employed for rough construction, although some of the churches in Cincinnati have been built from it.

As the dip of the blue-limestone beds is mainly to the north, while the direction of the Ohio valley at Cincinnati is toward the south, by proceeding up the river layers of the formation are brought to the surface that are lower than any occurring in the river quarries of the city. The Point Pleasant quarries, in Clermont county, are consequently situated in a different and lower level, and Professor Orton states that this section furnishes the most desirable building stone of the blue-limestone series. It dresses more easily and possesses a better shade of color, combined with a general exemption from the weathered seams that disfigure the higher beds. The quarries are situated at the water's edge, and river transportation enables the stone to be brought to the city easily. In a church on the corner of Eighth and Elm streets, Cincinnati, the appearance of the stone can be seen to the best advantage. As the demand for the stone is local, the annual production fluctuates between wide limits, and the value of the product has sometimes fallen very low. There is quite a large number of small quarries in the neighborhood, each producing from $200 to $300 worth of stone annually.

The quarries in Butler county, from which are extracted the blue limestones of the Cincinnati group, are situated at and near Hamilton. The character of the stone and the method of its occurrence are the same as those of the other limestone obtained from this group. A quarry at Hamilton exhibits a section 40 feet thick, of which 18 feet are of stone distributed in layers of varying thickness throughout the whole section. The individual layers are from 1 inch to 12 inches in thickness, and the heaviest layers are found at the bottom.

The limestones of the Cincinnati group are all highly fossiliferous, and the number and variety of the forms found in them have given to them a geological celebrity. The quarrying operations are constantly bringing to light rare and interesting species, but the specimens which were collected and sent to the National Museum as typical contain a predominating number of fossils of the species Chaetetes, with the shells of brachiopods cemented together by limestone. When polished the stones appear very beautiful on account of the diversity and delicacy of these fossil forms, but owing to the presence of clay in the cementing material the polish is not uniform

a Professor Locke in *Second Annual Report on Geological Survey of Ohio*, by W. W. Mather, 1838.

b *Report of the Geological Survey of Ohio*, Vol. I, Part i, p. 378.

over the whole surface. This does not detract especially from the value of the stone for ornamental purposes, since the fossil forms which give the stone its beauty by receiving the highest polish are thereby brought into prominence.

The fragments of fossils of which the stone so largely consists were apparently first washed together along with the clayey limestone and mud which forms the cement, and which fills the interiors of the fossil forms. This was apparently solidified into a vesicular rock, and the cavities were subsequently filled with clear crystalline calcite. The process of such formation is frequently seen in the Ohio limestones, some of which are porous, and are filled with cavities which are but partially filled with new crystalline product. Analyses were made of these limestones by Dr. Wormley for the *Report on the Geological Survey of Ohio.* (*a*)

The Point Pleasant rock, which is considered to be the best for building purposes, was by him shown to have the following composition:

	Per cent.
Siliceous matter	12.00
Alumina and iron oxide	7.00
Calcium carbonate	79.30
Magnesium	0.91
Total	99.21

NIAGARA GROUP.—The rocks of the Niagara period occupy that portion of Preble county in which quarries are extensively developed. The Niagara limestones in Ohio are very often called the Cliff limestones, because they stand in bluffs along the river valleys, and they are more esteemed as building stones than the rocks of the underlying Cincinnati group.

The following sketch by Professor Orton shows the arrangement of the rocks in this county: (*b*)

Upper Silurian { Niagara group; Clinton limestone } { Guelph. Springfield stone. Niagara shales. Dayton stone. }

Lower Silurian, Cincinnati group, Lebanon division.

The approximate thicknesses of the divisions are about as follows:

	Feet.
Niagara group	75
Clinton limestone	15
Cincinnati group	225

Of these stones the blue limestone is quarried in the southern part of the county, and was formerly the main dependence in that region as a source of lime, but the Cliff limestone was brought subsequently into universal use as a substitute.

The Clinton limestone has been largely in demand for chimney-backs, and has been found especially desirable for all those constructions which are exposed to fire or heat. It is an unevenly-bedded stone, often sandy in texture, but no quarries are so extensively developed in it as to merit consideration.

The stone which is quarried near Eaton is the geological equivalent of the building stone of Springfield and Yellow Springs. One of the largest and oldest of the quarries is 3 miles northeast of Eaton; another, 5½ miles northeast of Eaton, is smaller. A section of the first quarry shows 6 feet of so-called cutting stone at the bottom overlaid by 4 feet of a good building stone with 3½ feet of drift material upon the top. A number of grades of material are quarried, and stone suitable for flaggings and copings, as well as for fine and rough constructions, is obtained.

It is stated that a stone 10 by 12 feet in superficial dimensions has been taken out, and that very much larger stones can be obtained. It is principally used for rough building purposes and is sent to Eaton, Ohio, and to Richmond, Indiana, by team and by rail.

These quarries yield an unusually fine quality of flagging stone, the material lying in very even courses of suitable thickness. An analysis of the limestone was made for the Ohio survey by Professor Wormley, (*c*) and the composition of the stone is shown to be as follows:

Calcium carbonate	49.75
Magnesium	35.87
Alumina and iron oxide	4.40
Siliceous matter	9.40
Total	99.42

a *Geology of Ohio*, Vol. I, Part i, p. 374.
b *Geological Survey of Ohio*, Vol. III, Part i, p. 405.
c *Report of the Geological Survey of Ohio*, Vol. III, Part i, p. 409.

The largest quarries in Preble county are located at New Paris. The building-stone courses are here accessible, but the production of burned lime is the chief industry, yielding twelve-nineteenths of the gross earnings; the lime is distributed mainly to the westward by the railroads leading out of Richmond, Indiana. The quarries produce also flaggings, copings, bridge and building stones—in fact, the material for any construction can be here obtained.

Immense blocks are said to have been quarried at this place. The chief market for the stone quarried at New Paris is in eastern Indiana. The specimens sent to the National Museum from Preble county are all of a drab color, compact, and rather earthy in appearance, incapable of taking a high polish, and possessing a characteristic appearance due to the presence of porphyritic crystals of a clear, glassy nature, and which become very prominent upon the smooth or polished surfaces. These glassy crystals are of calcite, and the forms of the fossils which are sometimes seen are filled with the same glassy material. The earthy ground mass, which constitutes the bulk of the rock, will not dissolve in dilute acid, and is of a dolomitic character, as is shown by the analyses that have been cited. The stones consist of irregular, minute grains, which are closely fitted together with rhombohedral crystals of dolomite developed among them. All of the sections when magnified show very numerous but exceedingly small particles of pyrites. This is what probably produced the 4 or 6 inches of sap or discolored rock adjoining the natural clefts.

The limestones quarried at Piqua, Miami county, are from the lowest horizon of the Niagara formation, (*a*) and are therefore the exact equivalents of the Dayton stone. They are immediately underlaid by the Clinton limestones, and the glacial action has plowed away the stones of the Springfield and Covington type which once overlaid them. The material here extracted is of good quality. The stone lands sometimes bring $2,000 per acre near Dayton, and their value is indicated by the circumstance that, although the stone is not more than 16 feet in thickness, it is frequently extracted in places where 20 feet of dirt and drift must be removed from above it. The stone belonging to this horizon is usually very strong, specimens having been found to resist a crushing force of 30 tons on a 2-inch cube. The quarries are situated at and directly south of Piqua, upon the west side of the river, with the exception of one quarry 2½ miles south of the town. The material is sent by rail, canal, and team to the neighboring towns and cities of Ohio and Indiana, where it is used mostly for rough building purposes. No prominent structures have as yet been constructed from it. The thickness of the strata varies, and it is therefore possible to obtain slabs suitable for pavements. Indeed, it is claimed that slabs 20 feet square from some quarries are accessible. The town of Piqua is mostly paved with this stone, utilizing for this purpose the poorer and inferior layers. The walks would be greatly improved by the use of the better layers.

In the quarries immediately at Piqua about 2½ feet of the lowest layers are heavy and thick, and are used for bridge stones. Then follow about 7 feet of building stone, overlaid in one quarry by 1 foot of well stone and 2 feet of drift, and in the others there are 7 or 8 feet of drift to be removed. Quarries below the town are overlaid by 22 feet of drift, the lower portion of which is composed of fragments of broken limestone, of all sizes and shapes, piled together with an intermixture of gravel. This stone, like the Dayton stone, is mainly composed of calcium carbonate, which, it is said, usually constitutes over 90 per cent. of the whole. That it varies, however, between quite wide limits is shown by the circumstance that of the two specimens sent on one is quite dolomitic, and will dissolve but little in dilute hydrochloric acid. It contains streaks and clear crystalline spots, which are of calcium carbonate, and under the microscope in minute structure it is found to contain more or less of sharply-defined crystals, which are probably of dolomite. The stone in some of its layers contains more or less of pyrites, and is mainly of the variety which is called blue limestone. Some of it will receive a tolerably fair polish, and when thus treated it has a prettily-mottled structure, or a gray- and white-banded structure, according as the blocks are polished upon a plane parallel or perpendicular to the stratification.

The Dayton limestone is an evenly-bedded, massive, gray carbonate of lime, which is sparingly charged with fossils, and which is quarried from the very lowermost courses of the Niagara formation. It is found in firm, heavy courses that are at times 10 feet in thickness, though often very much less. So-called cutting stone is obtained from these beds. This term "cutting stone" is generally employed to designate stone which comes out in large blocks suitable for steps, platforms, etc. Cutting stone is sharply distinguished from building stones in all the quarries of western Ohio, and brings several times the price per cubic foot. The thinner and inferior strata serve a great diversity of uses.

Although stone of excellent quality occurs in various portions of Montgomery and Greene counties, the market has been thus far largely supplied by the quarries situated in the neighborhood of Dayton. Five quarries have there been opened in a belt which lies a mile and a half east of the town, whose sections exhibit 5 feet of the so-called cutting stone, overlaid by from 10 to 18 feet of drift. They produce all kinds of building stone (graded in from three to six grades), which is mainly sent to Dayton and to Cincinnati. The court-house and some of the churches in Dayton were constructed of this stone.

Another quarry in this same horizon, situated 7½ miles north of Dayton, has only 5 feet of drift to be removed; but, on the other hand, the thickness of the stratum of cutting stone is least in this quarry. The court-house at Sidney, Ohio, is built of this stone.

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a Geological Survey of Ohio, Vol. III, Part i, p. 468: "Geology of Miami County," by John Hussey.

At a quarry operated 6 miles east of Dayton the deposit consists of 4 feet of cutting stone, overlaid by 6 feet of a yellow-colored stone, the whole capped by 9 feet of drift. Two miles farther to the east lies a quarry which contains 4 feet of cutting stone overlaid by 3 feet of drift. The last two quarries are in Greene county.

Quarries have been opened in the same stratum of stone in the neighborhood of Xenia, and these have been widely known and extensively worked. This is in fact one of the three localities to which the contracts for the foundations of large works in Cincinnati were formerly confined, the specifications calling for Xenia, Centerville, or Dayton stone. This is the easternmost exposure of the last-named stone. The Dayton limestone is a peculiar and exceptional member of the great Niagara series in southwestern Ohio. It lies in lenticular masses of comparatively small extent, perhaps not more than two or three square miles occurring in any one area. Throughout Montgomery and Greene counties the shale, which forms the next succeeding layer of the Niagara formation, has in almost all cases been removed by erosion, and thus it happens that the stone is immediately covered with the deposits of bowlders, clay, and dirt, as described. The glaciers which have produced this result have polished and striated the rocks in many cases.

The composition of the Dayton limestone is shown from the following analysis, made by Dr. Locke in 1838: (*a*)

	Per cent.
Calcium carbonate	92.40
Magnesium carbonate	1.10
Iron protoxide	0.53
Insoluble material	1.70
Soluble silica	0.90
Water	1.08
Total	97.71

The stone from the McDonald quarry, near Xenia, has been analyzed by Professor Wormley, (*b*) with the following result:

	Per cent.
Calcium carbonate	84.50
Magnesium carbonate	11.16
Alumina and iron oxide	2.00
Siliceous matter	2.20
Total	99.86

When examined under the microscope these stones, as illustrated by the samples sent, are found to be composed largely of fossil fragments, which are so broken and destroyed as to be unrecognizable to the unaided eye. These fragments are united by an extremely fine ground mass, in which here and there a sharply-defined rhombohedral form is porphyritically developed. These porphyritic crystals are quite prominent in the stone from the Huffman Stone Company's quarry, near Dayton. A section of this stone was treated with dilute acid, when everything dissolved with the greatest facility, with the exception of these porphyritic crystals, which may consequently be supposed to be rhombohedrons of dolomite which have developed themselves in the mass of calcite.

Although stones of such excellent quality are obtained from the Dayton beds, it is necessary to mention that stones occur in which pyrites exist in large crystals at least half an inch square. Pyrites is recognizable in the thin section of all specimens sent to us, though this ingredient is not so disastrous in a stone of this nature as it is in other more porous stones, in which the pyrites would not merely be reached much quicker by the decomposing agencies, but in which the products of decomposition would more quickly find their way through the cracks and crevices of the stone. The material has attained a high reputation. It was used at one time extensively at Chicago, and the lowest story of the Chamber of Commerce edifice is built of it. Cincinnati has used it largely, but for the last 15 or 20 years it has not been shipped so extensively to these points.

Beds of the Dayton limestone are developed in Clinton county. They have been quarried at Wilmington and Centerville, but the old quarries which have been reported as in active operation during the census year are situated 1¼ miles southwestward from Lumberton. The quarry consists of 5 feet of stone, which is mostly used for rough building purposes, and is overlaid by 2 feet of drift. The material is hard, very compact, and capable even of assuming a quite high polish. It is also very noticeable that the rock, which to the unaided eye appears so compact and non-fossiliferous, really contains a very great number of fossil fragments. It also contains some pyrites, distributed through the mass in the form of very sharply defined cubical crystals, which in the specimens sent are entirely invisible to the unaided eye, and which cannot be called deleterious. There are yellowish spots and streaks in some of the layers, but this appears to result from the inclusion of clayey material rather than from the oxidation of the iron sulphide. The stone from this quarry finds its market principally in Clinton and Fayette counties.

The rocks in Clarke county (*c*) are like those found in Montgomery and Greene counties, but the important quarrying operations are all carried on in the upper beds of the Niagara formation, which are typically developed

a *Report of Progress upon the Geological Survey of Ohio*, 1869, p. 152.

b *Geological Survey of Ohio*, Vol. II, Part i, p. 669.

c *Geological Survey of Ohio*, Vol. I, Part i, p. 450: "Geology of Clarke County", by Edward Orton.

at and about Springfield. These beds are of particular value, as they possess a greater thickness than any one of the underlying formations in the county, and cover a much wider area. In the same quarries building stones of excellent quality are combined with material that is converted into peculiarly excellent lime. The accompanying section of the rocks at Springfield indicates the relationship of the beds.

The underlying shale occupies the position of the limestone which is quarried so extensively at Dayton and at Piqua. The overlying beds of building stone have given the name to the so-called Springfield division of the Niagara, and the less compact layers of the overlying so-called Guelph formation are broken up and burned.

The Springfield building stone is a carbonate of lime and magnesia, containing only small percentages of silica and alumina. Its usual color is a light drab, although blue and yellow courses occur. The light-colored stone sometimes is defaced by faint reddish streaks which are caused by the presence of iron oxide, and which render the stone unfit for some of the finer uses. The thickness of this deposit of building stone is not more than 20 feet, and is usually less. The lowest courses are blue in color, and although massive in appearance, they sometimes prove treacherous as building stones, for they are liable to lose their dressed surfaces, while their seams widen and they undergo a slow disintegration. The walls of the jail in Springfield furnish an illustration of these characteristics. The drab courses are almost all of durable building stone, and furnish an invaluable supply of building material for Springfield and the adjacent country.

The difference between the blue and the yellow courses in most of the limestones of Ohio appears to depend upon whether the iron exists as pyrites or as oxide of iron. The pyrites existing in a fine state of subdivision appears black even under the microscope, and the blue color of the stones apparently disappears with the oxidation of the pyrites. This furnishes an illustration of the circumstance that stones are often improved by decompositions which take place inside the beds, for if their value is not thereby destroyed there is much less danger of a disintegration by a decomposition of the quarried stones.

From quarries within 1½ miles west of Springfield the material for the culverts in the state road were obtained, and the material for the bridge at Marysville and for the Masonic hall at Urbana. These quarries are known as the old state quarries, because the material was used in many constructions on the state road. The quarries are large, but the stone from them is used chiefly in building cellar walls, foundations, and other rough work of a similar nature.

Two miles west of Springfield are situated four quarries which furnish similar stone, that is used in Springfield, Dayton, Urbana, London, and Marysville. In all of them the cap-rocks are burned into lime, and the larger portion of the profits results from its sale.

In all cases it is the overlying Guelph beds which are burned, as the courses of building stones contain a considerable percentage of silica and alumina, and cannot be converted into good lime, although some of this material makes a fair cement. The lime product of these quarries finds its way in small quantities as far as New Orleans. It is mild, cool, and strong, and also very white. There is no trouble in laying seven bricks with one spreading of mortar, and skillful workmen can lay twelve bricks with one spreading. The superior quality of this lime is worthy of note, since it is ordinarily considered that the value of lime is diminished by the presence of magnesia.

The composition of the Springfield limestones is shown by the following analyses of the middle and upper beds in Mr. Frey's quarries near Springfield. These analyses were made by Professor Wormley for the *Report on the Geological Survey of Ohio:* (*a*)

	Middle bed.	Upper bed.
Calcium carbonate	54.70	54.70
Magnesium carbonate	44.93	42.37
Alumina and iron sesquioxide	0.20	1.00
Siliceous matter	0.10	1.50
Total	99.93	99.57

It is thus seen that the rocks are very nearly typical dolomites. They vary somewhat in composition, but not so as to at all influence their value as building stones. They possess an open and porous structure, and are incapable of assuming a polish or being used for ornamental purposes. In their microscopic structure they are seen to be of the crystalline granular type, the fossiliferous character being obliterated from the microscopic structure, although fossils are not rare in the rock.

The Yellow Springs quarries produce a magnesian limestone which is very easily worked, and the larger part of which is durable. These quarries are upon the same horizon as the Springfield quarries, and produce stone of the same nature. The courses vary in thickness from 4 to 14 inches, and some of them answer very well for cutting stone. The same qualified commendation can be given to them for flagging, but the quarries have not been extensively developed with the end in view of producing this material. For general masonry the stone has proved very serviceable, and for economy is not surpassed by any stone in the state. There are two colors, which are obtained from different courses, and which are denominated as blue and drab; the blue courses weather to drab in exposed

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a *Geological Survey of Ohio*, Vol. I, Part i, p. 474.

places, but it is not certain that all of the drab beds have been made by oxidation of blue layers. The blue beds sometimes prove treacherous, and even the firm and massive appearance of the stone furnishes no safe guide in judging of its power to withstand the atmosphere. By far the larger portion, however, is excellent in this respect, and the drab courses are almost without exception satisfactory.

Three-quarters of the gross earnings of these quarries are, on an average, obtained from the sale of lime, sent to market under the name of the Springfield lime, which is the standard for southwestern Ohio.

A section of the quarry shows at the bottom some layers of building and cutting stone, above which is a 10-foot bed of solid limestone containing pentamerous fossils, and above are 18 feet of the "shelly" limestone, which is burned. The principal quarry at this place produces stone for bridges, steps, and sills, which are principally used in the vicinity of Yellow Springs. The composition of the stone from this quarry is indicated by the following analysis by Professor Wormley: (*a*)

	Per cent.
Calcium carbonate	51.10
Magnesium carbonate	41.12
Sand and silica	5.40
Alumina, with a trace of iron oxide	1.40
Total	99.02

The quarries in Miami county resemble those at Springfield, and are located in the same geological stratum. They are rendered valuable by the circumstance that for 50 miles in some directions there is no other developed quarry. To the northeast, north, and northwest the region is heavily buried under beds of drift, and consequently building stones are inaccessible. The material from the Covington quarries is distributed, therefore, very widely. The stripping is light, the drainage easy, the quantity and quality of the stone are both excellent, and great variety exists in the thickness of the various strata.

The Covington stone is chiefly used for building and bridge construction, and it is mostly consumed in Covington, Ohio, and Winchester and Marion, Indiana. Some bridges on the Pan-Handle railroad have been constructed from this material. At the town of Covington there are six quarries in active operation, as indicated by the table. Some of these must soon be given up, for they lie within the city limits, and houses are being now constructed in their immediate neighborhood.

The material resembles that which is quarried at Springfield in being porous and easily cut. Of the specimens sent to the museum one was blue and one yellow, and upon examination it was found that they differed not merely in the circumstance already mentioned, in that the blue layers contain unoxidized pyrites and the other hydrous iron oxide, but the blue specimen was a dolomite which would not effervesce in acids, while the yellow specimen was much more calcareous. In microscopic properties this stone presents no peculiarities. It belongs to what we have designated as the porphyritic type; that is, it contains rhombohedral crystals of dolomite developed in a mass of formless grains of calcite.

In Shelby county the upper portion of the Niagara formation is developed, and several quarries have been opened, the products of which are almost entirely burned into lime. Building stones can be there obtained at any time and in any quantity desired.

Hancock county is occupied by rocks of the Niagara and Helderberg periods, and although the Niagara rocks which from here extend in a narrow strip northward to lake Erie appear to be separated from that great area of Niagara rocks in which the Springfield and Dayton quarries are situated; they probably extend beneath the Helderberg rocks that intervene and form a portion of the same deposit. The rocks quarried at Findlay possess characters almost identical with those of the Springfield stones. They possess a rather porous and open structure, are drab in color, and occur in courses from 3 to 12 inches in thickness. The stone is strong and durable, and none of it has as yet shown any bad effects from exposure to moisture or frost. It is rather hard to dress, and stone-workers call it "plucky". The horizontal surfaces are generally roughened by small angular prominences which fit into corresponding depressions in the superimposed layer, forming the structure which is known as "suture" jointings. The dip here is very slight, and the top course in all of the Findlay quarries is evenly bedded and about 1 foot thick. The "seams" (open joints) are from 25 to 100 feet apart, and those joints usually run at right angles to these seams at greater or less intervals. For this reason, if the quarry is stripped over a sufficient space, the rock can be obtained without blasting. The material from these quarries is used for foundations of buildings and for bridge abutments in the county, and last year some was shipped to Seneca and Allen counties.

In composition the stone from the Findlay quarries is dolomitic and possesses the characters of the upper Niagara beds. In microscopic structure it is beautifully crystalline, the whole mass of the rock being made up of an aggregate of more or less well-defined rhombohedral crystals.

It appears that blocks much larger than can possibly be required are obtainable here, and that the material, although at present used only for rough construction, could be safely applied as a building stone. Although the present quarries have been opened quite recently along the same streams upon which these are situated, and within a short distance of them, quarries have been in operation for more than twenty years.

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a Report of the Geological Survey of Ohio, Vol. II, Part i, p. 672.

HELDERBERG.—The Helderberg formation is exposed in a narrow strip (*a*) upon the boundaries of Highland and Ross counties, and indeed more stone is taken from the quarries at Greenfield than from any others in the Helderberg formation of Ohio. The stone is regular in its bedding, and, therefore, curbings and crossings of excellent quality are easily extracted. In the Cincinnati market it is largely employed for these purposes. Slabs 3 or 4 inches thick, with a superficial area of 4 feet, can be obtained with surfaces as smooth and regular as if sawed. These stones can be used for door-steps and like purposes without any dressing. The courses are never heavy, seldom exceeding 14 inches, and usually ranging between 4 and 8 inches in thickness. The stone is exceedingly strong, 2-inch cubes having been found to stand a pressure of over 50,000 pounds. The quarries produce no waste material, and their spalls are saved to be burned into lime of fair quality. Perpetual kilns are set upon the edge of the Greenfield quarries, the floors of which are kept clean and free from accumulations of refuse of any kind, and the lime produced is similar to that obtained from the Niagara formations, but it possesses in some degree hydraulic properties which make it especially adaptable for outside work.

The stone produced is drab in color when first raised, but upon exposure it generally acquires a yellowish-brown shade. It is ordinarily used only for the rougher purposes of construction and for flaggings and curbings, but, by proper selection and skillful dressing, stone can be obtained from the quarries that produce a good architectural effect. Without such an exercise of taste and judgment, the stone does not appear well, owing to its monotonous gray color, which contrasts unpleasantly with the white lines of mortar. On the other hand, its regular bedding renders it peculiarly suitable for ordinary purposes, as it can be laid upon its even bed surfaces easily, and therefore can be worked with facility and economy. The stone finds its principal market in Cincinnati.

It will be noticed that of the large quarries which supply the Cincinnati market but one is in Highland county. The other is situated in the town of Greenfield, in Ross county. In the Highland County quarry one-twentieth of the profit results from the sale of lime, but in the Ross County quarry more than one-half is burned.

In the Ross County quarry the section shows 42 feet of stone disposed in layers, all of which are available. The quarry is capped by 10 feet of drift material, which constitutes all of the stripping. The Highland County quarry shows 35 feet of stone of a like character overlaid by 6 feet of drift.

The stone in the main is non-fossiliferous, but upon the surfaces of a few layers there are found the forms of the *Leperdita alta*, which is a characteristic fossil of the Helderberg formation. A layer of concretions from 1 inch to 3 inches in diameter is found in the upper part of the section, and short cylindrical columns which fall out, leaving cylindrical cavities in the stone 3 or 4 inches in diameter, occur in considerable numbers, and which are supposed to be due to the effects of pressure.

Nodules of zinc-blende are not uncommon in the Greenfield stone, and the fossil corals are sometimes composed of silica, which also is distributed through some of the stone in bands that separate the layers.

In composition the stone is nearly a typical dolomite, as is indicated by the following analysis: (*b*)

	Per cent.
Calcium carbonate	53.67
Magnesium carbonate	42.42
Alumina and iron	-----
Sesquioxide	1.30
Calcium and magnesium silicates	1.44
Silica	1.00
Total	99.83

When examined under the microscope the whole stone shows the characteristic crystalline granular structure of the Helderberg formation. There are streaks of iron oxide and carbonaceous matter which proceed in regular wavy lines through the sections, and these bituminous substances are what give to the stone the strong fetid odor which is produced by striking or cutting it. The quality of the lime produced is another evidence that magnesian limestones may be converted into lime of excellent quality.

Quarry operations have been carried on at Greenfield since the first settlement of the country to satisfy the local demand, but in recent times the business has been greatly enlarged for the more distant markets along the line of the railroads, and especially for the Cincinnati demand. The supply of stone is practically inexhaustible.

In the southern and western part of Champaign county the Helderberg or Water-lime rocks have been quarried in numerous places; formerly a quarry at Salem supplied most of the local demand, and the building and flagging stones used in Urbana were obtained there until the sandstone of Berea superseded them. The stone obtained in the neighborhood of Urbana is of indifferent quality for building purposes, but here it is found in a drift-covered region in an area which for 25 or 30 miles in each direction is devoid of stone. Only about 14 feet of the upper strata have been much quarried. The floor has been sunk to a greater depth, and the stone from the lower courses is proving itself to be a valuable building stone for rougher work. There is no so-called cutting stone in the quarry,

a *Geological Survey of Ohio*, Report of Progress in 1870, p. 255: "Geology of Highland County," by Professor Edward Orton.
b *Report of Progress of Geological Survey of Ohio*, 1870, p. 287.

and the accompanying section will give an idea of the method in which the strata of the Helderberg are arranged at this point. It will be noticed that there is much greater diversity as regards stratification than is shown in the Greenfield quarries.

The specimen sent to the National Museum is a light drab stone, somewhat streaked with red. Its material is of the same character as that of the other Helderberg stones—that is, a dolomite with a fine, crystalline, microscopic structure, and which emits a bituminous odor when struck with a hammer, although the odor is not so strong as in the case of some other Helderberg rocks.

Allen county is almost entirely covered by limestones of the Water-lime or Helderberg formation, (*a*) and all of the quarries that have been considered worthy of note extract stone from these beds that is used for the more ordinary building purposes and for foundations and underpinnings. The upper beds of the Niagara formation occur in the southeastern corner of the county, and a few quarries were once opened in those rocks, but the building material that was extracted was inferior, and the production of quicklime from them was not profitable.

Although the building stone obtained from the Helderberg is, as a rule, not of excellent quality, still, as it is the only accessible material, it is of much value.

The stone quarried directly in Lima is an inferior building stone, and is seldom used for foundations above ground, but is in demand for the underground portions of foundations. The quarry is worked more to obtain stone for macadamizing than for any other purpose. It occurs in thin layers, and a block 6 inches thick is seldom obtained. This thinly-bedded character renders it applicable as a flagging stone; the bedding, however, is uneven.

The material obtained from this quarry is a dark gray dolomite, which is quite porous in its character; it dissolves in hot acid with very little residue, and the solution is found to contain only traces of iron oxide, which the microscope proves to exist in the state of pyrites. The polishing of a face upon this stone renders its fossiliferous character very prominent, which is not common in the rocks of this formation. The stone is very bituminous and gives forth a foul odor when struck with the hammer.

A quarry 4 miles north of Lima is said to produce some material of a much better quality. It is situated near the Dayton and Michigan railroad, but a side track could not be constructed to it without considerable expense on account of the heavy grading that would be necessary. Some of the courses are over 1 foot thick, and some from 4 to 6 inches thick have been used for sidewalk paving in front of the Lima machine works, where it gives indication of both strength and durability. The following is a section of the strata in the quarry:

	Feet.
Soil	3
Building stone for ordinary foundations	3
Dark gray paving stone	1½
Blue shaly material	—
Blue-stone	—

There is no natural drainage below the paving stone, and for this reason the underlying blue-stone has not been extensively quarried. According to the testimony of all builders and contractors the stone in the bottom of this quarry is the best building material found within a radius of at least 30 miles. The shaly rock which overlies the blue-stone forms good material for the macadamizing of roads. The material above the paving stone, which is used for foundations, occurs in thin beds which are never more than 3 inches in thickness.

The specimen which was sent from this quarry was taken from the lower or "blue-stone" layers; it has a dark gray color, finely banded with yet darker lines, and much more compact than most of the stones sent from the quarries in the Helderberg. Indeed, no pores or cavities were found in it, and its texture was such that it admitted of a fair polish, as indeed do most of the Helderberg limestones. The stone from this quarry is a dolomite, but on being dissolved in hot acid quite a large residue of argillaceous character is left undissolved, and it contains bituminous substances which impart to it the character of a fetid limestone. It contains little or no iron.

A quarry is situated 5½ miles northeast of Lima, and the following section indicates its character and the uses to which the stone is applied:

Stripping	feet	5
Road stone	do	3
Gray building stones	do	3
Two courses of blue-stone	inches	6
Blue clay	do	½
Gray building stone	do	—

As in the case of the preceding quarry, the thickness of the stratum of the gray building stone is as yet undetermined. It occurs in courses from 3 to 6 inches thick. The upper 3 feet of stone, which is used for the purpose of macadamizing, is extracted with neither profit nor loss. The material is a more or less porous dolomite of a gray color, mottled and streaked with black, which is due to the arrangement of the bituminous substances contained in the stone. Of the two specimens sent to the National Museum, one was polished upon a surface parallel with the stratification, and this treatment developed a beautiful structure, due to the presence of

a *Geological Survey of Ohio*, Vol. II, Part i, p. 397: Report on the "Geology of Allen County", by N. H. Winchell.

a fossil bryozoan, which filled the layer that was cut. Thus the presence of a fossil in abundance was demonstrated although the rough stone gave no indication of a fossiliferous character. This stone and the one previously described from Lima are the only stones of a fossiliferous character which were sent to the Museum, and which were obtained from the Helderberg formation.

These stones are thus most markedly contrasted with those from the Niagara, which are almost all fossiliferous, as is indicated by microscopic examination, which very often renders the forms evident when they are invisible to the naked eye.

In the eastern part of the township of Bluffton the quarries are better adapted to supplying flagging than building stone, since the thickness of the strata usually varies from 1 inch to 3 inches. When properly laid down these slabs make a very durable paving material for sidewalks, cellar bottoms, etc. They are very hard, but break quite easily into any required shape. The stone is dark-colored and of the same character as those previously described. Its color is imparted to it by bituminous substances, and the dark streaks with which it is filled are very irregular, so that a pattern not at all unattractive to the eye is developed upon the smooth or polished surfaces of the blocks, and when dressed in the usual way and laid with white mortar they make a beautiful wall for smaller buildings. Such large blocks have been moved as to insure the possibility of obtaining blocks as large as might be desired.

Although the quarries described have been recently opened, the stone has been quarried in the immediate neighborhood for fifteen years.

Scott's Crossing is situated 4 miles east of Delphos, on the Pittsburgh, Fort Wayne, and Chicago railroad. A quarry at this place produced a drab-colored limestone, which occurs in courses from 3 to 11 inches thick, and which serves very well for foundations. Samples which have been in walls for over fifty years show no signs of decay. The quarry is situated in the bed of the Auglaize river, and is not worked early in the spring nor late in the fall, when the water is high. A slight dam is built about the quarry, which is washed out every winter, and in addition heavy rains in the summer frequently destroy the works. No more permanent dam is built, since the site of the quarry is often changed, and no excavation has been made in the vicinity to exceed 6 feet in depth. The material is mostly used in the vicinity for bridge abutments and at Delphos for foundations for buildings. It has been sent, to a limited extent, into Mercer county, over the Toledo, Delphos, and Birmingham railroad, to localities where the Piqua stone is not so readily sent. Ten inches of coarse sand, gravel, and other river deposits cover the stone, and about 18 inches of the cap-rock is used upon the public highways. This is one of the best building stones quarried in Allen county for the purposes to which it is applied.

Van Wert county is covered in its northwestern part by the Niagara beds. The Helderberg limestone underlies the rest of the county, but only a few exposures of the rock of either kind are known, as the whole region is mostly covered by drift. (*a*) The county is entirely agricultural, and the stones where quarried furnish materials that are used only for foundations in that neighborhood or burned for lime. The lime-kilns at Straughn have caused the most extensive quarrying operations, and the Helderberg stones there extracted are said to burn easily and cheaply to a beautiful white lime. The Van Wert quarry, which is the only one reported as producing any considerable amount of building material, also produces quicklime; and during the last census year the value of the lime produced was about equal to that of the building stone. The Van Wert stone is a light gray dolomite, which is found in courses from 3 to 7 inches thick. The material thus far has given evidence of being a good building stone. Openings have been made in the limestone at several other points in the county; for example, on the Little Auglaize, in the northeastern part of the county, a stone very much like the Bluffton limestone has been quarried to a small extent for the Delphos market. In the northwestern part of the county some building stone is said to have been obtained in much thicker courses than in any other part.

A very light gray limestone has been quarried at Charloe, on the Auglaize river, in Paulding county, which belongs to the Corniferous formation. This Paulding limestone is a soft stone which occurs in courses about 3 feet thick. It has been sawed, and was used in the foundation of the court-house and also in that of the Russel House at Defiance, where it has suffered from the action of moisture and frost. As other specimens of the same stone do not show this disintegration, its defective character is very likely due to the circumstance that it was quarried too late in the season. A blue limestone is also quarried about 5 miles farther down the river from Charloe, which occurs in courses from 6 to 18 inches thick, and has been used for the construction of locks on the Miami and Erie canal. It is not durable when exposed to atmospheric action, and the quarries have been abandoned. The demand for the material has been destroyed by the introduction of the White House stone from the north and the Piqua stone from the south.

Tiffin is situated exactly upon the boundary between the Niagara and the Helderberg rocks, in Seneca county, and its quarries, although producing only Helderberg rocks, show at some times at their bases exposures of the underlying Niagara limestones. These quarries are located on the eastern side of the ridge known as the Cincinnati axis, and the characteristics of the rocks are much the same as those in the quarries on the western side of the anticlinal in the Helderberg formation; but the stones at Tiffin are more massive, and are therefore more suitable

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a *Report of the Geological Survey of Ohio*, Vol. II, Part i, p. 314: "Geology of Van Wert County," by N. H. Winchell.

for heavy construction. The courses are often 26 inches in thickness, and the stones produced are used largely for foundations and bridge work. The product of quicklime from these quarries is also large.

The stone is light drab in color; it is bituminous, and gives forth a strong odor when hammered, but this characteristic is not so marked as in the dark-colored varieties. The principal market for all three of the quarries situated in Tiffin is furnished by the immediate neighborhood. Beside the quarries in the table there are several smaller ones which are worked in the vicinity of the town, and which produce the same kind of material in less amount.

A short distance west of Fremont several quarries have been opened in the strata of the Water-lime or Helderberg formation.

The only quarry at this point of sufficient importance on account of its production of building stone is situated one mile to the west of Fremont, and in this the value of the lime which was produced from the quarry during the census year was ten times that of the building stone. The strata suitable for building purposes are from 1 foot to 10 feet in thickness, and the material which does not make an excellent quicklime is comparatively small. As a building stone the material is superior to much of that used in counties to the southwest, although not equal to the Sandusky and Marblehead limestones. It is of a light drab color, full of small cavities, and works very easily, and some of it is soft and pure enough to be sawed. The stripping is sold for macadamizing. It presents the usual microscopic characteristics of the Helderberg rocks, and it dissolves in hot acid, leaving a very slight residue. The qualitative analysis indicates that it is composed of remarkably pure dolomite.

CORNIFEROUS.—Quite a variety of stone is found in the neighborhood of Columbus, for although Franklin county is flat it has a number of geological formations within its limits. To the east lie the Waverly sandstones and the Huron shale, but the limestones of the Corniferous, which lie to the west of Columbus, are by far the most important from an economic standpoint. Thick and heavy layers of stone exist among the strata. From the different layers material suitable for the most diverse uses can be obtained, good quicklime can be made, and being in part a very pure carbonate of lime the stone is desirable as a flux for smelting iron ores. Of late it has been very extensively applied to the latter purpose, especially in the Hocking Valley region. The quarries are all situated a few miles to the west of Columbus, and have been operated for a long time. Some which have been the most important, for instance the state quarries, from which the material for the state-house and for the walls of the state-prison was extracted, are no longer worked, but all of the quarries mentioned in these tables are immediately about the old quarries and extract the same material. While the state-house was in process of construction, and stone of the best quality was in demand, the Corniferous limestone was worked to a greater depth than it is at present, for the finest quality of stone is found in the lower layers. At present the production of building stone is subordinate to the production of lime and flux.

The Columbus limestone is dense, compact, and strong. There are 12 feet of the upper courses in the present quarries that average 93 per cent. of carbonate of lime, and frequently the percentage rises to 95 or 96, while, on the other hand, there are localities where the Corniferous limestone becomes nearly a typical dolomite, as at Bellefontaine. The stone is fossiliferous, but the fossils are very firmly cemented and do not appear to weather out; in some cases, indeed, the fossil appears to be firmer than its surrounding stone. In microscopic structure the stone bears the appearance of a fragmental stone, being composed almost entirely of fragments of fossils. In the finer ground mass very perfect little rhombohedrons of dolomite are developed, which in number are apparently disproportionate to the amount of magnesia contained in the stone. Many of the fossils have apparently retained their primitive condition, but others have been dissolved away and the forms filled with crystalline calcite; and this will perhaps explain the different behavior of the fossils in weathering. The stone is somewhat bituminous in character, as evinced by the odor emitted when struck. Its gray color is pleasing to the eye; it works easily, and will even assume a good polish.

Dynamite is used as an explosive to a large extent, any desired number of charges being exploded simultaneously by means of electricity.

Although the common stone for foundations and underpinnings used in Columbus is obtained from the quarries, still, during the census year, no great amount of building stone was extracted, and no important structures were built from the material. The quarries can at any time be operated much more extensively, and will produce a superior quality of stone for fine construction.

In the eastern half of Logan county a large island of Corniferous limestone occurs, the center of which is covered with shales, but all around the edges small quarries have been opened for the purpose of obtaining stone both for building purposes and for lime. (*a*)

At the present time the only quarries of special importance that are located in this district are those which are situated a short distance to the northwest of Bellefontaine, and the material which they produce is used chiefly for rough work. Although capable of producing excellent building material, the more important stone structures in the neighborhood have been built of materials brought from a greater distance. The quarry operations are carried on in a quite primitive manner, and at present the lower strata in one quarry are inaccessible, since no means of

a *Report of the Geological Survey of Ohio*, Vol. III, Part i, p. 482: "Geology of Logan County", by Franklin C. Hill.

drainage have been supplied, and the quarry is filled with water to a depth of from 12 to 15 feet. The top layers of the stone are being extracted, although the lower layers are best suited for purposes of construction.

The quarry of Angel, Miller & Co., situated a half mile west of Bellefontaine, exhibits the following section:

Drift	feet	5
Cellar stone	do	10
Heavy hard stone	do	5
Honey-combed porous stone	inches	9
Heavy soft stone	feet	5

Occasionally some lime is burned at this quarry, although its amount is small and its quality inferior.

The material that is at present produced by these quarries is a typical dolomite, and in microscopic structure consists of a perfect mass of sharply defined large rhombohedral crystals of dolomite cemented together by a mass of minute little crystals of the same form and composition. In many places the crystals are only attached at their corners, leaving angular interspaces, and this accounts for the avidity with which water is absorbed by this stone. The fossiliferous character, if any originally existed, has been entirely obliterated. In color it is light gray, and it works easily and safely. Its microscopic structure is illustrated upon the plate at the end of the chapter.

The first quarry in Marion county was opened in 1825 in what is known as the Marion limestone. Ten acres only are considered as belonging to the quarry. It is situated in the southeastern part of the town of Marion, and is the farthest south of any quarry in the neighborhood producing good building stone. A gray stone occurs about 12 or 14 feet below the surface, and is probably underlaid by blue-stone, but as the gray is considered the best the lower courses have not been opened.

Other quarries are located in the northeastern part of the town which extract material for building and quicklime. The largest quarries are, however, operated on the Columbus and Toledo railroad, one mile north of Marion. The stone is considered very strong and durable. The average thickness of the rocks extracted is not more than 8 inches, although blocks 12 and even 15 inches thick are sometimes obtained. There is no difficulty in extracting blocks of any required dimensions in the bed for all ordinary purposes of construction. The stone is easily quarried, being lifted with bars and broken with sledges, no blasting operations being necessary except to make an opening in the floor of the quarry for deeper workings.

The material is chiefly used for foundations and bridge work, and was largely employed in the construction of the depots and shops of the Columbus and Hocking Valley railroad. It is commonly called blue limestone, although the color differs at different horizons, and the layers also vary in texture and hardness, each layer, however, being homogeneous. The stone is usually quite fine in grain and rather hard. The following may be regarded as a typical section representing this and all other quarries in the neighborhood of Marion:

	Feet.
Soil	1 to 4
Weathered rock	1 to 4
Blue-stone	1 to 6
Gray-stone	4
Blue-stone	

The overlying blue-stone is found in blocks from the exterior of which a gray color penetrates to a variable depth from the natural joints. It is liable to contain flinty nodules, from which the underlying gray-stone is almost entirely free. The blue-stone in the bottom of the quarry is free from this gray covering; but the intermediate stone, which is all gray, is considered the best material.

In these quarries the gray-stone is found near the top, but in the other quarries reported from this township, being about 1½ miles to the southeast of these, and in the direction of the dip of the strata, this gray layer is not struck until a depth of from 12 to 16 feet from the surface is obtained. A very large amount of the cap-rock has been used for macadamizing streets and for ballast on the Columbus and Toledo railroad. The quarries in this township furnish the greater part of the stone used in the northern part of Union county and in quite a large portion of Hardin county.

The material quarried at Marion is dolomite, containing some calcite. When microscopically examined it is found to consist of a multitude of perfect little rhombohedral crystals, each one of which contains a little black bituminous substance accumulated in its center, and all are cemented together by the calcite, which, although crystalline, does not assume a definite outline. The rock, when treated with cold and dilute acid, effervesces for a while, and the residue when examined is found to consist of a multitude of perfect and beautiful little rhombohedrons. The Marion stone has been selected for representation in the plate of microscopic sections, and some further remarks concerning its chemical composition and structure will be found in the general remarks that close this chapter.

At Owen's station, in the southern part of the county, there is a quarry in the Corniferous limestone from which over 9,000 tons of lime and broken stone were shipped during the census year.

Six miles northeast of Marion, in the township of Grand Rapids, the same limestone is worked quite extensively. A ridge occurs at this point in which a number of quarries are located.

Crawford county is well supplied with building material. The limestones are quite well adapted for construction of foundations, but they are not at the present time extensively quarried owing to a number of causes. There are no great demands for stone in this agricultural region, and the home resources are thrown into competition with the Berea grit, which is quite extensively quarried at Leesville, in the southeastern part of the county. In Holmes township, about 6 miles northwest of Bucyrus, and near the Ohio Central railroad, three quarries are at present worked in the Corniferous limestone. The material has much the appearance of the Marion limestone, but, while it may be of the same quality, the courses are generally thinner and not so well bedded.

In Lykins township the same limestone is also quarried to some extent. The material from all these quarries has been used for bridge building and for foundations, but it is more and more displaced by the Leesville sandstone, especially for bridge-building purposes.

A large quantity of quicklime has been produced here which has been shipped from Nevada, in Wyandot county, by the Pittsburgh, Fort Wayne, and Chicago railroad.

For building purposes the limestone which is quarried from the Corniferous formation at Bloomville, Seneca county, has a higher reputation than the Helderberg limestones, and indeed it is said that these quarries produce one of the best limestones in northwestern Ohio. The material has been quite extensively used in Tiffin for many years for trimmings and stone fronts, and also for general building purposes in Mansfield and in the surrounding country. Good material for flagging, bridges, and foundations is quarried, and a slab 25 feet square might be obtained. It has already displaced in a measure at Mansfield the sandstones which are quarried in that vicinity.

The specimens sent to the museum are of an attractive gray color and are highly fossiliferous. Some fossils have apparently been entirely removed at some period and their places subsequently supplied with a clear crystalline calcite, and some of the fossil forms are therefore strikingly apparent upon polishing the surface of the stone.

Under the microscope the stone is found to consist of a grand aggregate of fossil fragments, among which here and there the rhombohedron crystals of dolomite are developed in much perfection. The number of these rhombohedral crystals is, as usual, proportionate to the amount of magnesia in the rock, which in this case is about 16 per cent.

The limestone industry in and about Sandusky is one of the most extensive in the state. This is partly due to the abundant and excellent supply of building stone furnished by the Corniferous strata of this region, and partly to the facilities for transportation by water and by rail. The city of Sandusky is founded upon a ledge of limestone, and excavation of any kind necessitates quarrying operations. In early days the stone thus extracted was the cheapest building material accessible, and came to be used very extensively. As a result the use of stone is more general there than in any other Ohio town.

At Sandusky the upper layers of the Corniferous formation are composed of a blue limestone of a thickness from 20 to 25 feet. This is underlaid by the white Sandusky limestone, which is found in thicker courses, cuts easier, and is capable of making a better lime; but at Sandusky this stratum, which is also from 20 to 25 feet in thickness, lies beneath the level of the lake, and is not readily accessible. The dip of the strata is, however, away from the water, and consequently this layer of white limestone is brought to the surface at Marblehead and on Kelley's island, as is shown in a number of quarries. The largest quarries are situated at these points. Sandusky itself, owing to the circumstances mentioned, possesses quite a large number of quarries, and the city itself constitutes in fact a great limestone quarry covered with but a very shallow layer of soil or earth. These city quarries have been worked very largely for home and foreign supply, not less than 12 acres having been excavated to a depth of 8 feet. The Sandusky blue limestone is found in layers of convenient thickness, and the range work furnished by it presents an attractive appearance. The courses vary between 4 and 10 inches in thickness, and the material is used largely for flaggings, although not very well adapted for this purpose. It is laid in slabs from 4 to 8 feet square, which are not very smooth or regular until they become polished by wear, and then they are dangerously smooth. For construction purposes the stone has proven very durable, and the best foundations can be secured at small expense if made from this stone. It is also used for macadamizing the streets, and recently it has been found that a foundation of the Sandusky blue limestone can be advantageously overlaid by a thin coat of the white limestone which binds and cements the road-bed.

All of the quarries which in the tables are indicated as existing in the corporate limits of Sandusky are essentially one, as they produce the same material, and only in a single case has a quarry been sunk to the level of the underlying white limestone. About one hundred and eighty houses in the city have been constructed of this stone. The specimens sent to the National Museum from various quarries are identical in their minutes structures. They are bluish-gray in color, compact, and present a fine appearance, however dressed. Although they effervesce rapidly in acid, they are quite magnesian, and under the microscope they are seen to consist of fossil fragments, among which a multitude of little rhombohedral crystals are developed. In the center of each one of these rhombohedrons is a black spot, which, upon close examination, is found to consist of pyrites. Sometimes, instead of a single spot, there is a large number of dust-like particles, which give to the stone a very marked and characteristic appearance. These are so numerous that it can scarcely be doubted that they impart the characteristic color to the stone. That they are situated, however, in the exact center of compact crystalline material cannot but have an influence in protecting them from disintegration, and there is no evidence that the presence of this ingredient has proved deleterious to the stone.

The white underlying limestone is what is called a cutting stone, and can be raised in blocks as large as can be handled. It is more highly fossiliferous to the unaided eye than the blue limestone, but under a microscope it is less so, and there is a much larger number of the rhombohedral crystals which correspond to its more magnesian character.

At point Marblehead the limestone quarries are all located in a terrace lying a few rods from the beach, where the thickness of the formation quarried is from 15 to 25 feet. Already 20 acres, as estimated, have been excavated to this depth.

These quarries are among the most famous of northern Ohio, and their location directly on the shores of lake Erie, and the heavy stones that some of them produce, have led to very large use of the stone, especially in the government works along the line of the great lakes. Latterly they are losing their place as building stones to some extent, but the production of lime has increased. Some quarries have been worked for at least fifty years. In these quarries the lower 6 or 8 feet are cemented into one solid sheet from which the large dimension stones for which the location is famous are extracted. It is from these quarries that a large part of the heavy stone used in the Sault Ste. Marie canal, in the northern light-houses, and in other government works has been derived. Many of the most important public and private structures in the region of the great lake were built of the Marblehead stone. The Detroit and the Cleveland water-works, the light-houses at Spectacle reef, Marblehead (built over fifty years ago), and Stanard's Rock, lake Superior, were all wholly or partly built of this material. It is particularly valuable in situations where it is exposed to the action of water or frost, as is shown by the condition of the old locks of the Sault Ste. Marie Falls canal and the light-houses in exposed situations.

The material from these quarries, like that at Sandusky, is a magnesian limestone, which contains beautifully-preserved fossils; the centers of the little rhombohedral crystals that characterize all of the Sandusky limestone are free from the grains of pyrites which characterize the blue Sandusky layers, and the difference in the color of the two stones is to be attributed to this circumstance.

The following analysis, made by Mr. J. Lang Cassels, represents the composition of the limestone from these quarries:

	Per cent.
Calcium carbonate	83.20
Magnesian carbonate	15.83
Silica	0.15
Organic matter	0.02
Moisture	0.80
Total	100.00

The proprietors claim that they could easily extract a block of stone equal in size to the Egyptian obelisk recently introduced into this country, its extraction being simply a matter of expense.

The block-stone proves to be a source of excellent lime, which has long been used, but which of late has been more abundantly produced. All of the waste material is devoted to this purpose, and nothing remains in the quarries except flint nodules. The modern kilns of the best construction are attached to some of the quarries, and 300 or 400 barrels per day are turned out from one single quarry. Part of the thin stone goes to lake Superior for furnace flux, where it is highly esteemed, and a large trade in the lime has been built up at Duluth and in the northwest, and the best stone of the quarries is now being burned. Much of the stone is shipped to other points to be burned, and all along the lakes are kilns which are supplied from Marblehead and Kelley's island. The Michigan Insane Hospital building at Pontiac and the government breakwaters at Erie were constructed of the Sandusky stone.

At White House, in Lucas county, the same lower beds of the Corniferous are worked, and this is the only quarry which is operated to any extent on the Toledo, Wabash, and Western railroad between Toledo and Wabash. Some of the material is shipped to Toledo, as there is a demand for it in the winter, when, on account of the ice, the stone quarried near Sandusky cannot be shipped to Toledo by water.

Near Defiance there is some stone quarried from the beds on the Miami river, and the same is true at Antwerp. The quarry at White House was not extensively worked until 1879, when the railroad track was laid into it. The cap-rock has been used for ballast on the railroad, so that the stripping is accomplished without expense.

The weathered rock which is used for ballast is from 2 to 8 feet in depth, and this is underlaid by 6 feet of gray-stone in courses of from 6 to 10 inches in thickness, 6 feet of blue-stone in courses from 6 to 18 inches in thickness, and one course of gray-stone 1 foot 10 inches in thickness. The bottom course is nearly uniform in thickness and is used for heavy bridge work. The blue-stone is not of a decided blue color, like that of the Upper Corniferous at Sandusky, but is a kind of grayish-blue.

Napoleon and Defiance, Ohio, and Fort Wayne, Indiana, furnish the principal markets for this stone.

In the townships along the Muskingum the sandstone, which is situated below the coal, affords an excellent building stone and is extensively quarried. The Waverly sandstone also occurs in the western portion of the county. The limestones which also occur in the county are, upon the whole, of rather inferior quality for purposes of construction, and would scarcely be worked if the lime which can be made from them was not of good quality and demanded for construction in the neighborhood.

Sub-Carboniferous.—A quarry situated at Newtonville, about 8 miles west from Zanesville, is the only one in Ohio from which limestones of sub-Carboniferous age are raised for building purposes. There are several large quarries in other exposures of this same horizon in southern Ohio that are worked exclusively for furnace flux and for lime-burning. The Newtonville stone is a beautiful material, very fine grained, quite even in color, and of great strength. It is very compact, highly fossiliferous, of light gray color, and has thus far shown no ill effects from exposure to the weather. The Muskingum County court-house, at Zanesville, one of the finest in the state, is built from this stone, and it has also been much used for caps, sills, columns, etc., and although the production at present is small, it may at any time be increased with a demand for the material; but at the present time most of the product is burned. A thickness of about 10 feet of stone is quarried, that being the depth to which natural drainage extends. Several feet more of the best of the stone lie below this level, and the thickness of the layers increases with the depth; upon the top there are only very thin beds, while at a depth of 10 feet the beds are 16 or 18 inches in thickness. The material is nearly a pure carbonate of lime, containing only traces of iron and magnesia. In its microscopic structure it appears to be quite highly fossiliferous and very compact, containing only small traces of iron pyrites, the oxidation of which imparts the faint yellow color which the stone generally possesses.

Carboniferous.—A quarter of a mile southwest of Zanesville, near the Muskingum river, a quarry has been opened in the limestone of the Lower Coal Measures, from which some material has been extracted which has been used chiefly for caps, sills, and top courses of foundations. The main product of this quarry is burned into lime. It is not used for the ruder purposes of construction, as it is too expensive. The ledge from which this stone is taken is a solid mass of a bluish color, and about 3 feet in thickness. The stripping which overlies the 3 feet of stone is 25 feet thick. The material is a compact, earthy limestone of a very dark color, containing considerable protoxide of iron and very little magnesia. It is very highly fossiliferous and difficult to work, and is called by the stone-cutters hard and plucky.

The outcrops of this stone are found abundantly in the neighborhood of Zanesville, and the material is quite extensively used for macadamizing streets. The national road for some distance west of Zanesville is constructed of it.

There is quite a large number of quarries situated in the outcrops of Carboniferous limestone in southeastern Ohio, the products from which are used as fluxes and for burning, but the two quarries which have been mentioned in Muskingum county are the only ones which are of any consequence as producing materials of construction. The Carboniferous limestones of this area are hard to work and do not possess the highest requisites of a good building stone, but these quarries are capable at any time of producing material for building, and in fact does so under special circumstances. Although these quarries are worthy of consideration in connection with their ability to produce building stones, still the industry is so insignificant that it has not been considered important to tabulate the products of any of them.

To recapitulate: The line drawn nearly through the center of the state from Erie county on the north through Adams county on the south will form the boundary between the area to the east, in which the chief quarrying industry is devoted to the extraction of sandstones, and the western area, in which the only quarrying industry is devoted to the extraction of limestones.

The geological formations in the limestone area follow one another in a quite regular order, the oldest being situated in the southwestern corner, and the youngest in the eastern part of the state; and the character of the stone is entirely dependent upon this geological arrangement, as regards both the character and the quality of the material.

A considerable quantity of stone is extracted from the Cincinnati group, but, as already indicated, this is chiefly owing to the circumstance that the material is in the neighborhood of the large city of Cincinnati. In quality the material is surpassed by the stone from other formations. A narrow band of Clinton limestone surrounds the area of the Cincinnati group, but at the present time this formation furnishes no building stones.

The Niagara or Cliff formation, which succeeds, is one of the great building-stone formations of the state, and in numerous places most excellent and durable materials are obtained; but even the subdivisions of this group determine largely the character of the stones extracted. The lowest or the Dayton formation produces at all points a hard, compact, light stone, while the Springfield division produces a less compact, more easily worked stone, and the top beds are almost universally converted into quicklime.

The Helderberg or Water-lime rocks, which cover a large area, are almost without exception bituminous dolomites, but in character vary from dark to light and from compact to open or vesicular. The Corniferous limestones are most extensively quarried in and about Sandusky, and furnish one of the finest materials obtained in the state, while all of the overlying formations are almost devoid of building-stone quarries. As regards composition, the stones from these various formations vary from almost typical limestones to almost typical dolomites, and there seem to be no rules which will enable one to decide upon the quality or durability of the stone from its composition. Experience also demonstrates that the composition, as regards the proportion of lime and magnesia, does not determine the value of the stone as material for the production of quicklime. It would therefore appear that the value of the stone is more largely dependent upon its accessory constituents and its microscopic structure.

There is a progressive increase in the amount of magnesia from the Lower Silurian limestones to the Corniferous The Cincinnati limestones of the Lower Silurian contain from 1 to 5 per cent. of magnesian carbonate, while the Clinton limestones of the Upper Silurian contain on an average about 12 per cent. The Dayton limestone of the Niagara period contains about the same amount, while the upper divisions of the Niagara and the Helderberg formations are made up mainly of nearly typical dolomites. As regards composition the next following Corniferous limestones are very variable. At Bellefontaine the stone is a dolomite, and at Columbus it is as good a limestone, containing on an average 93 to 95 per cent. of carbonate of lime, and the Hocking Valley furnaces are largely using it for a flux.

In structure there is less diversity in the Ohio limestone than in those of some of the other states, since the oolitic and concretionary forms do not appear; but all other types are found, and therefore the greatest diversity exists in the ease with which stones may be worked. There are the open, porous varieties, and the varieties which once were open and porous, but which have been again partially consolidated by the filling of the pores; others in which the pores have been entirely filled; and other varieties in which large crystals have developed themselves in a ground mass, giving to the stone a porphyritic aspect. There are the compact fossiliferous stones and the compact non-fossiliferous stones. As regards colors, they vary from very light to very dark, but all possess the drab, gray, or yellowish tints which are characteristic of what are called limestones.

In microscopic structure the limestones of Ohio can all be classified according to certain types of structure which are found to be correlated with composition. It may be at first remarked that the microscope indicates that the stones are all highly crystalline. A crystal is a body which possesses a definite internal molecular structure, and if it is further assumed that the external crystalline form is a property of crystals, then many Ohio limestones are more crystalline in their structure than are the so-called highly-crystalline marbles; for in a great many cases the very well developed crystals with external planes are developed in the mass of the stone, and in other cases the stone is entirely composed of such crystals with the form characteristic of the species of the mineral which composes it. In no case has there been found in any Ohio limestone anything which could be called in any correct sense of the word uncrystalline; and, indeed, in the light of the microscopic study, any distinction which can uniformly distinguish a limestone from a dolomite is very difficult to find. The progressive increase in the amount of magnesia which is contained in stones is indicated in the microscopic structure by the development of little rhombohedral crystals the sections of which appear quite conspicuous with their sharply-defined edges.

INDIANA.

[Compiled mainly from notes of Professor Orton.]

The rocks of the Cincinnati epoch of the Lower Silurian period occupy a small area in the southeastern part of the state, but no quarry rock is developed in this formation. Its western limit is roughly defined by a line drawn from Winchester, Randolph county, to Madison, Jefferson county.

The rocks of the Niagara epoch of the Upper Silurian period occupy a more extensive territory north and west of this line. This formation furnishes stone for foundations, underpinnings, and bridge work in nearly every county which it occupies. In a few localities the stone is suitable for the better architectural purposes, and in some places an excellent flag-stone is produced. The Helderberg formation has not been identified in Indiana. The approximate northern and western limits of the Upper Silurian formation are marked by a line drawn from Fort Wayne to Logansport, and thence to the eastern extremity of Clark county.

The Devonian formation occupies a narrow belt to the west of the Silurian. It has a meager development, its entire thickness being only about 200 feet, and it furnishes little building stone. The line between this and the sub-Carboniferous formation may be roughly drawn from the northwest corner of Benton county to the northwest corner of Clinton county, and thence to the southern extremity of Clark county.

As to production of stone, the sub-Carboniferous is the most important formation in the state. It furnishes the famous "Bedford limestone," and also some valuable sandstones, which are, however, mostly noted for their adaptability to the manufacture of grindstones and whetstones.

The Coal Measures occupy the southwestern part of the state, and the dividing line between this and the sub-Carboniferous formation is nearly that from the southern extremity of Perry county to a point about 5 miles southwest of the northeast corner of Warren county, and from there west to the state line.

The coarse sandstone, commonly known as the "conglomerate", at the base of this formation is found in a region on all sides of which for many miles little sandstone suitable for heavy masonry is available, and also near large districts entirely destitute of building stones; but as yet no large quarry industries have been developed in this formation.

The northern portion of the state beyond the line drawn across it through Fort Wayne and Monticello is deeply covered with drift material. The granitic bowlders found quite abundantly on the surface in some localities furnish the only local supplies of stone in this extensive district. It is in this region that a considerable market is found for the sandstones quarried at Stony Point, Michigan, and Berea and Amherst, Ohio, and for the limestone quarried in the Bedford district in southern Indiana, and in the Joliet district of Illinois.

LIMESTONE.

The localities north of Indianapolis where limestone is quarried for building stone, with a few exceptions, deserve but a passing notice. At Wabash quite an important flagging stone is obtained at the quarries of Messrs. Bridges & Seot, Hubbard & Smith, Philip Hipskin, and William J. Ford; important because it is the best stone for sidewalk pavements to be obtained for many miles around. It occurs in layers from 1 inch to 7 inches in thickness, those from 2 to 5 inches thick being most commonly used for flagging, and the heavier courses for foundations and bridge work. The joints run quite regularly, and occur far enough apart to allow the largest required slabs to be obtained. The surface of the natural slabs is, however, rather too rough to allow the stone to be classed with the best of flag-stones. The quarry of Messrs. Moellering & Paul is in a different stratum of the Niagara limestone; the beds vary in thickness from 3 to 15 inches, and the stone is shipped to Fort Wayne, where it is used for foundations and underpinnings. The quarry of Messrs. Little & Shoemaker is in a thin, irregularly-bedded limestone, commonly called "shell-rock". It is easily worked, and is cut through by the Wabash and Pacific railroad, which furnishes direct transportation for the quarry product to Fort Wayne, where such stone is in demand for ordinary foundations.

The quarries in Adams, Wells, Howard, Grant, Blackford, and Delaware counties furnish stone for light bridge work and for foundations.

The most valuable deposits of limestone that have been quarried for building purposes in northern Indiana are in Cass and Madison counties.

The quarries of Messrs. J. E. Burns and August Gleitz are located about 3 miles west of Logansport, Cass county, in the south bank of the Wabash river, and in a stratum of compact, though easily-worked, uniformly-colored limestone, in layers from 4 inches to 4 feet thick. These quarries have furnished the stone for the superstructures of some fine church buildings and for quite a large number of dwellings, stores, shops, etc., in Logansport. This stone presents a very pleasant appearance in a building when dressed rock-face. The stone from the quarry of Messrs. Lux & Lux, at Logansport, is used for foundations.

The Anderson, Madison county, quarries are located in an evenly-bedded limestone which works quite well under the chisel. This stone lies in beds from 4 to 12 inches in thickness, and is used in the town of Anderson for flagging, foundations, caps, sills, etc. It is rather beautiful and quite durable.

There is a number of localities in northern Indiana, south of the drift-covered region, where limestone is quarried for the manufacture of quicklime. A large amount of lime of excellent quality is burned annually at Huntington, and considerable amounts are burned at Peru and Delphi.

In the Upper Silurian or Niagara formation there are quarries of considerable importance in the southern part of the state, but by far the most valuable building stone of the state is obtained from a stratum of limestone in the sub-Carboniferous formation. This limestone is supposed to belong in the geological scale to the Saint Louis group of the sub-Carboniferous period. It occurs in massive beds of almost pure limestone, varying in different localities from an ordinary gray to an almost pure white color, and having a granular or oolitic structure. It is known by Indiana geologists as the "oolitic limestone", and is commonly known in the trade as Bedford stone and Indiana stone. A piece of the stone dressed in the shape of a flat bar rings like iron when struck, and it is very elastic, strong, and durable. It does not take a fine polish, but its adaptability to carved work is well shown in the elaborate carving in the mansion of Mr. William K. Vanderbilt, built of this material, on Fifth avenue, New York city.

In the Greencastle quarries the stone has a light gray or drab color, and is susceptible of receiving quite a high polish. This stone differs considerably from the sub-Carboniferous limestone in the Ellettsville, Stinesville, Bedford, and Salem quarries; it is harder, less granular, takes a higher polish, and occurs in thinner beds. This stone is used for the construction of cellar walls, for bridge work, blast-furnace flux, and lime-burning.

The quarries at Okalla, Putnam county, furnish material for bridge construction and for lime. The stone differs little from that quarried at Greencastle. At the Putnamville quarry the stone is heavily bedded, highly siliceous, quite hard, of a light gray color, and receives but a slight polish. It has a very compact, fine, granular structure. This stone is employed in all kinds of building, principally in the cities of La Fayette, Terre Haute, and Crawfordsville.

The quarries at Longwood, Fayette county, furnish stone for bridge work, cellar walls, steps, and some flagging. The material finds its principal markets at Connersville and Rushville. The specimens forwarded to the National Museum represent a buff variety and a drab mottled with buff. Both varieties take a medium polish, and from the latter tombstones have been made. The quarries near Laurel, in Fayette and Franklin counties, furnish stone for foundations, bridge work, and flagging to the country along the line of railroad from Cincinnati, Ohio, to Muncie, Indiana. This stone has quite a beautiful drab color, a compact structure, and is strong and durable. It works well under the chisel and takes a medium polish.

The New Point, Greensburg, and Saint Paul quarries, in Decatur and Shelby counties, furnish stone for general purposes of construction and for flagging. The material finds its principal markets at Cincinnati, Ohio, and at Indianapolis, Terre Haute, and La Fayette, Indiana. A section at New Point quarry exhibits 2½ feet of drift; 3 feet of thinly-bedded rock, used for rubble and lime; and below this 4 feet of cutting stone. It is estimated that the value of the lime sold annually from this quarry is about one-third of that of its entire product.

The specimen forwarded to represent the material from this quarry contains numerous crystals of pyrites, varying in size from the smallest that can be seen with the naked eye up to half an inch in diameter. The stone works well, but does not take a good polish.

At the Greensburg quarry the stone is more crystalline and is susceptible of being quite highly polished. It is rather hard and slightly plucky. It is used for all building purposes, and the thinly-bedded stone in the upper portion of the quarry is used to some extent for flagging and for railroad ballast. A section of the quarry exhibits 6 feet of drift material, 7 feet of thinly-bedded stone, and 9 feet of cutting stone.

At the Saint Paul quarries the stone is quite highly crystalline, works well, and takes a medium polish. It is used for all building purposes and for flagging. Mr. J. L. Scanlan manufactures lime, and it is estimated that the value of lime burned is about two-thirds that of the entire product of his quarry. The material which is burned is the thinly-bedded rock occuring above the cutting stone. A section of the quarry shows 4 feet of drift, 10 feet of lime-rock, and 10 feet of cutting stone.

A section of Mr. W. W. Lowe's quarry shows 1 foot of drift, 5 feet of thin stone, and 20 feet of cutting stone.

The quarry of Mr. G. W. McNeely, 2 miles west of Saint Paul and in Shelby county, is worked in 6 feet of thinly-bedded stone, and furnishes foundation stone and flagging to the neighborhood. The stone from these quarries may be equal in beauty and durability and even superior in strength to the oolitic limestone, but it is not so extensively employed, especially for the better kinds of architectural uses, because it is harder to quarry and to dress, and cannot be obtained so readily in large-sized blocks. It has been chiefly used for foundations and bridge abutments, and the thin, evenly-bedded layers are extensively used for sidewalk paving.

The oolitic limestone is quite extensively quarried in Monroe county, and the Ellettsville stone is used for all building purposes in Chicago, Saint Louis, Indianapolis, and also in many of the smaller cities and towns in Indiana and Illinois. The following are some of the buildings in which examples of Ellettsville stone may be seen: Indiana state-house, Marion County court-house, and the Vance block, at Indianapolis; the custom-house and post-office, Evansville; Knox County court-house, Vincennes; Dearborn County court-house, Lawrenceburg; Posey County court-house, Mount Vernon; Clark County court-house, Jeffersonville; Bartholomew County court-house, Columbus; Johnson County court-house, Franklin; Asbury university, Greencastle; Wabash college, Crawfordsville—all in Indiana; and the state capitol, Springfield, Illinois.

A section of the quarry of Messrs. John Mathews & Sons shows first 3 feet of clay, then 7 feet of worthless rock, called "bastard" limestone, and, below this, 18 feet of limestone in one bed, which has, however, several "cone-in-cone" seams. This stratum has not been worked to the bottom in this quarry.

There are 2 feet of clay and 6 feet of bastard limestone over the building stone in the quarry of Messrs. Perry Brothers. The bed of building stone has been worked to a depth of 34 feet, divided into five layers by cone-in-cone seams. The stone in the top and bottom layers, respectively 8 and 6 feet thick, is quite hard, and is used in the construction of bridges. The intervening 20 feet consist of two layers, each 5 feet thick, and one layer at the bottom 10 feet thick. All the stone in these three layers is easily worked.

The disintegration of the fossil fragments, mostly coral, of which this stone is largely made up, has gone to such an extent in the Ellettsville stone that the fragments are very small, and the interstices between them have been so completely filled as to give the stone quite a compact structure. The representative specimen from the Stinesville quarries shows a much coarser and a more open structure, the fossil fragments being much larger and the interstices between them being less perfectly filled; however, the material is about as widely distributed, though somewhat less extensively, and is used for similar purposes.

The last-mentioned quarries are located near each other. The one at the lowest level has 28 feet of limestone exposed, with a small honey-comb seam about 6 feet from the top. The two other quarries have about 30 feet of limestone exposed, with the honey-comb seam coming in at a depth of about 12 feet.

The entire section of the Saint Louis group is exposed at the quarry of Mr. B. Schweitzer, in Owen county, but the oolitic limestone is not well developed here. About 70 feet of limestone, varying, at different heights, in color, texture, and composition, are worked; and from 4 to 10 feet of the lower portion of this is a white limestone, which is burned. The lime product represents about one-fourth of the entire quarry product in value.

The building stone occurs in layers from 2 to 14 inches in thickness, being mostly a very fine grained and compact material, with a conchoidal fracture. It is not suitable for cutting; but, being evenly bedded, is well adapted for the construction of foundations, for which the blocks are easily squared up. The stone finds its principal markets at Indianapolis, Terre Haute, Vincennes, and Evansville, Indiana.

Bedford, Lawrence county, furnishes the "Indiana limestone", famous over a large portion of our country, known as "Bedford stone" in some markets. As is shown in the tables, most of the Bedford quarries now worked have been quite recently opened. The stone has only within a few years come into extensive use, though it has been quarried and used in a small way for twenty-five or more years. At the present time it is one of the stones most extensively employed for architectural purposes in the city of Chicago. The fossil fragments of which the stone is composed are quite uniform in size, of about that of an ordinary grain of sand, and the interstices between them are well filled, giving a uniform texture and firm structure. The appearance of the stone, when dressed in any manner applicable to limestones, is good. The qualities of beauty, strength, durability, and cheapness due to accessibility and ease of working possessed by the Bedford stone, tend to secure for it a very prominent place among the building stones of our country. The following are some of the buildings in which Bedford stone was used: Residences of Mr. W. H. Vanderbilt, Mr. I. Sherwood, and Mr. Cornelius J. Vanderbilt, Fifth avenue; residence of Mr. William H. De Forest, Fifty-seventh street; the Smith building, Cortland street; Appleby flats, corner Seventh avenue and Fifty-eighth street; Bridge building, Fourteenth street; flats, Eighty-fourth street and Eleventh avenue; and rectory, Fifty-first street—all in New York city; Cotton Exchange building, New Orleans, Louisiana; new city hall, Chicago; state capitol, Springfield; McLean County court-house, Bloomington; Peoria County court-house, Peoria; and county court-house, Olney—all in Illinois; new state-house and United States custom-house, Indianapolis; Grant County court-house, Marion; Lawrence County court-house, Bedford; county court-house, Shoals; Floyd County court-house, New Albany; Music hall, New Albany; Posey County court-house, Mount Vernon; United States custom-house and approaches, Evansville—all in Indiana; and United States custom-house and Jefferson County court-house, Louisville, Kentucky. In Louisville, Chicago, Saint Louis, Evansville, and Indianapolis there are scores of buildings the fronts of which are built of Bedford stone.

At some of the quarries there are from 4 to 5 feet of worthless rock on top; below this the solid bed of oolitic limestone has been worked to a depth of 40 feet, and the bottom of the bed is not yet reached. The amount of stripping varies in different localities. In some places there are but a few feet of clay on top of the oolitic limestone, while in other places the stripping consists of 12 or more feet of bastard limestone.

At the Lawrenceburg quarry, in the southeastern part of Lawrence county, and at the Fort Ritner quarry, near the line between Lawrence and Jackson counties, the oolitic limestone has not been so extensively quarried as at the Bedford quarries; the material, however, is of good quality. At Lawrenceburg the oolitic limestone has been worked to a depth of but 14 feet. From this quarry the material goes principally to Cincinnati and to Saint Louis.

At Fort Ritner only 10 feet of the limestone have been worked. The material was used in the construction of the court-house at Brownstown and the cathedral at Vincennes, Indiana.

The quarries in Jennings county are in the Niagara limestone of the Upper Silurian period, and the stone produced is quite like that from the same formation in Decatur county, which has already been described. Sections in these quarries show from 3 to 5 feet of drift material, and below this from 8 to 30 feet of quarry stone in evenly-bedded layers from 2 to 36 inches in thickness. The thinly-bedded layers are used quite extensively at Indianapolis and other cities for paving sidewalks. With these stones, when used for sidewalk paving and in rough masonry, nothing is necessary in the way of dressing beyond breaking the blocks into rectangular shape. The heavier layers are used extensively for the construction of foundations and bridge abutments, for which purpose this stone is well adapted on account of its strength, durability, and cheapness, due to the fact that little dressing is necessary for this kind of work on account of the evenness of the layers and the smoothness of the bed surfaces.

The specimen from the North Vernon quarries has a dark drab color, and that from the Oakdale quarry a light drab or gray color. The former represents what is locally known as the North Vernon "blue limestone", which was used in the construction of the Ohio River bridge of the Cincinnati Southern railroad. The strata occur near the surface of quite an extensive area along the lines of the Ohio and Mississippi railroad and its Louisville branch and the Jeffersonville, Madison, and Indianapolis railroad.

The quarries worked at Osgood, Ripley county, are also in the Niagara limestone, and the principal use made of the product is for flagging and curb stones. The material finds its principal markets at Cincinnati, and at Covington, Kentucky. At these quarries there are from 2½ to 5 feet of drift on top, and below this from 10 to 12 feet of quarry rock. The representative specimens of these stones forwarded to the National Museum contain a considerable amount of pyrites in the crystalline form. The stone is less applicable for cut work than for sidewalk paving, curb stones, foundations, etc.

Near Salem, in Washington county, the oolitic limestone has quite a valuable development. Under about 5 feet of cap-rock a solid stratum of limestone 30 feet in thickness occurs. Six feet of the lower portion of this, however, is not used on account of its being too hard. The remainder of the stratum is quarried for all kinds of building purposes, and the material finds its principal markets at Louisville, Kentucky, and New Albany, Indiana.

Samples of this material may be seen in the court-house at New Albany, and in the Galt house and city hall at Louisville, Kentucky. In color, texture, and ease of working this stone differs little from that quarried at Bedford.

At the New Albany quarries, in Floyd county, the oolitic limestone is somewhat harder and less valuable for architectural purposes. It is principally used for foundations and street pavements at New Albany. Only 9 feet of limestone is quarried, and the cap-rock is about 25 feet in depth—16 feet of clay and 9 feet of worthless sand-rock. This depth of cap-rock of course increases the expense of quarrying to a considerable degree, but the quarries can be worked with profit so far as the material may be in demand at the New Albany market for the above-specified purposes, no other material so suitable for the same uses being so near at hand.

ILLINOIS.

By Professor Allan D. Conover, *Special Agent.*

The state of Illinois embraces rocks representing most of the epochs of the Silurian, Devonian, and Carboniferous ages, and including most of their varieties in texture. Over the greater part of its area these rocks have been but little disturbed, and occur with beds approximately horizontal or inclined at a small angle to the horizon. In a few localities, however, very considerable disturbances of the normal relation of the strata have taken place, usually within rather restricted areas, and have been accompanied in some places by marked changes in the physical characteristics of the rocks, which have affected very considerably their value as building material.

The surface of the state is almost everywhere covered by a variable depth (at places but a few feet, at others much over 100 and possibly over 200 feet) of the looser deposits of the Tertiary and the Quaternary ages. Owing perhaps partly to the nature of its rock formation, but most largely in all probability to these subsequent deposits, a very large portion of the state presents a very level or slightly-undulating prairie surface, within the limits of which are but few rock exposures. This is true of the whole central and eastern part of the state, the larger portion of its territory.

Skirting this great area on all sides except the east is a country of very different character, though the change is gradual—a valley country with very marked water-courses, which cut through the beds of clay and sand to and into the rock formations below. Throughout the greater part of this area the rocks immediately underlying are Silurian, Devonian, or sub-Carboniferous, all of which furnish excellent building materials, and but few localities of considerable area are found where at least a fair building material cannot be easily obtained.

SILURIAN.

Lower Magnesian.—The oldest of the Silurian rocks occuring in the state, the Lower Magnesian or Calciferous, is found in two small areas in the central northern part of the state, one lying principally in Ogle county and the other mostly in La Salle county. Its beds furnish a dolomitic limestone, utilized in the manufacture of cement, but is only fitted for the most ordinary of building purposes, and is nowhere systematically quarried.

Saint Peter sandstone.—The Saint Peter sandstone, occurring closely associated with the Lower Magnesian limestone in these localities, is a coarse-grained sandstone of various shades of dark-yellow or buff to reddish-brown, its grains not often sufficiently cemented to form a good building rock. In a few places in Lee county it is hard enough to quarry, and small quantities of it have been and are yet occasionally used. In La Salle county the lower 4 feet of the bed furnish an excellent and durable rough building material, which was formerly considerably used for heavy masonry, but is now very little quarried.

Trenton group.—In its northern area the Trenton group has two very distinctly marked subdivisions—the Trenton limestone and the Galena limestone.

The Trenton limestone in this southward extension from its southwestern Wisconsin area presents here very similar characteristics. It is nearly everywhere a rather thinly-bedded, close-textured, often semi-crystalline, hard, gray or light drab-colored rock, easily blocked into quite square and regular shapes, and furnishing a very excellent and durable, occasionally somewhat ornamental, building material.

It is found and quarried in small amounts in numerous places along the valley of Fever river, in Jo Daviess county, and there furnishes a good ordinary building stone only. In the eastern part of Stephenson county it is quarried in a few places to a slight extent, but is everywhere so deeply covered by clay and shales as to render quarrying it very expensive, while farther east, in Winnebago county, it occurs in numerous places, and furnishes a good ordinary building stone, easily quarried out and shaped. In this locality some of the dark blue and drab colored beds fade very rapidly upon exposure, finally reaching to a light buff color, as in the same beds in Wisconsin, near by.

In western Boone county these beds furnish the only building stone of value obtainable within the county, and are extensively quarried in the vicinity of Beaver creek, where they furnish more than usually heavy beds of a rather rough but durable stone well fitted for ordinary and heavy masonry.

In the vicinity of Mount Morris and of Polo, in Ogle county, these beds furnish an excellent and handsome building material which has been used quite largely in building at those places.

At Dixon the stone is thinly bedded, but has been largely quarried and used in the construction of the mills at that place.

To the south of these places throughout the remainder of this area, and also in the detached area closely adjoining it, the Trenton limestone beds are thin and irregular, and nowhere furnish building material of value. Wherever these beds occur quarries are so easily opened and worked that large numbers of them are found, each worked to a slight extent, but rarely furnishing regular employment at one spot for any considerable length of time to more than one or two men.

The upper subdivision of this group, the Galena limestone, occurs in these northern areas of the Trenton group in considerable thickness, in all between 200 and 300 feet. It everywhere presents very constant physical characteristics, and is a rather coarse and rough-textured stone, occurring in heavy, sometimes massive beds to over 5 feet in thickness; is rather hard to work, and hardens gradually upon exposure, forming a very excellent, durable material for all purposes except for fine ornamental work. Its color is a rather rich, warm buff tint, which deepens somewhat upon exposure, and when well worked it presents a very handsome appearance.

In Jo Daviess county there are numerous quarries, though none largely worked. Near Freeport, in Stephenson county, and within the city, are large quarries presenting solid walls of rock from 60 to 90 feet high, in which the upper beds are very thin, but those below are very massive. Large quantities of stone from these quarries have been used in this city, and numerous very handsome buildings and residences have been constructed of it. Near Rockford, in Winnebago county, it has also been quarried and very largely used in that city, particularly in the construction of residences. At Harlem and at Cherry Valley, in the same county, there are also large quarries, the stone from which is extensively used for heavy masonry, such as bridge work, for which it is found to be a most excellent material.

In Ogle county there are numerous outcrops, and the stone has been considerably used for heavy masonry, but there are no quarries largely developed. In Lee county the formation is finely exposed all along the Rock River valley, and has been quarried extensively at Big Springs and at Lee Centre, while at numerous points along the valley small quarries have been opened. At Dixon it has been considerably quarried, and was used with success for the piers of the large bridge erected there across Rock river. Where found in Whiteside county it presents the same characteristics, but is generally difficult to quarry because it is nearly everywhere deeply covered up.

The Trenton group is found within the state at four other points along the Mississippi river to the southward, but these subdivisions seem there to be less distinctly marked and have not been recognized and traced.

In Calhoun county the rocks of the Trenton group form the axis of an anticlinal running east and west, and are largely exposed on both the Mississippi River and the Illinois River sides of the county. On the Mississippi River side at about the middle of the county they form the base of the river bluffs, and rise southward till at Cap Au Gris, in Lincoln county, Missouri, they form the whole body of the bluff, exposing a total thickness of from 300 to 400 feet. At this point the lower beds of the series are quite heavily-bedded, compact, hard, grayish dolomitic limestone of great endurance, nearly, if not quite, equal in value to the limestone of the famous Grafton quarries in the Niagara limestone on the river, just below. These beds could be readily quarried and the stone lowered directly into barges in the river. A vast quantity of this stone can be readily and cheaply obtained.

On the Illinois River side of the county these rocks have numerous exposures, and are quarried in various places to a limited extent.

In Jersey county, where this axis crosses the Illinois river, the upper beds of this group are elevated above the river 40 or 50 feet. The rock is thinly-bedded, with shaly partings, and probably of little value as a building materia

In Monroe county the Trenton limestones are again found forming the base of the river bluff at Salt Lick point. They occur here in very heavy beds as thick as 6 and 7 feet, and are coarse-grained, quite even-textured, and of light color. From these same beds upon the Missouri side were obtained the great blocks for the columns of the Saint Louis court-house.

Farther south, in Alexander county, these rocks appear for the last time in this state and cross the Mississippi river in such a way as to form the rapids known as the Grand Chain. They rise on the Illinois side to a height of 75 feet or more and occur in very heavy beds—a light gray, fine, even-textured stone, some of the layers of which receive a high polish and would make an excellent and handsome ornamental stone. The same beds have been largely quarried at Cape Girardeau, in Missouri, just opposite, and the stone is known as the Cape Girardeau marble.

While in each of the last-named localities these beds are capable of furnishing quite cheaply vast quantities of building material, they have never, so far as I could learn, been worked to any extent.

Cincinnati group.—The rocks of the Cincinnati group, which immediately overlie those of the Trenton, consist mainly of more or less hardened clays, their composition in places varied by the addition of a considerable percentage of carbonate of lime. They furnish nowhere except in one locality any reliable building material, but are quarried in some places where their exceptional hardness renders them usable, and where other building stone is very scarce. In Boone county, where there is but one quarry (in Galena limestone, at Beaver creek) of limestone, a quarry has been opened in these shales just southeast of Belvidere, from which most of the building material for ordinary purposes used in that city has been obtained. In some buildings these stones have been exposed for nearly thirty years without showing much signs of injury. Very good flag-stones are also obtained from this quarry.

In the vicinity of Sterling, in Whiteside county, there are two considerable quarries in this formation which are especially notable. The rock is here a very compact, hard stone, and one quarry has been worked to a depth of about 30 feet. The upper beds are quite thin and can be taken out in very large slabs, which make very excellent flag-stones. The lower beds are of moderate thickness with a compact, argillaceous limestone, furnishing an excellent building material, and have been quite largely quarried. Samples of this stone were tested by the United States authorities at Rock Island, and showed a strength to resist crushing varying from 7,000 to 10,000 pounds per square inch; in specimens 2 inches square and 4 inches high, a strength nearly equal to that of similar specimens from the Joliet and Lemont quarries. That this quality of stone has a very limited extent, however, in these beds the small quarries and other exposures within a limit of 2 miles show very conclusively. In Hopkins township, east of Sterling, is another similar quarry, where almost, if not quite, as good stone has been quarried considerably. A much less thickness of the strata furnishing good building stone is exposed here. In these quarry stones the addition of a considerable percentage of the carbonates of lime and magnesia has made the shales impure magnesian limestones and given them locally strength, durability, and reliability. At all other points where they are quarried, however, though they may in places appear to yield durable stone, they are liable to furnish occasional stones which, upon exposure, will rapidly disintegrate, and they are extremely unlikely to furnish anywhere any stone which will have more than a small local value, or be the basis of any regular industry.

NIAGARA GROUP.—The limestones of the Niagara group show in no place a thickness of more than about 100 feet, but are the surface stone over a very large area in the extreme northeastern, northwestern, and western part of the state. Nearly everywhere when exposed they furnish at least a good ordinary building stone, while in very many localities the stone quarried from them is of unusual excellence and applicable to almost all of the uses for which stone is required for building purposes. Their principal area of occurrence, in point of territory covered, lies in the extreme northeastern part of the state, where they extend from the northern boundary along the lake shore, and as far south as the central part of Iroquois county, in a band whose varying width averages about 40 miles.

In Jo Daviess, Carroll, Whiteside, and Rock Island counties are two very irregular areas of considerable extent. Farther south, in Pike county, and in Calhoun and Jersey counties, are two small areas, the latter of considerable importance, while in Alexander county, at almost the extreme southern point of the state, they occur again in a narrow area extending two-thirds the length of the county from near its northern boundary along or closely adjoining the Mississippi river.

In the first-mentioned area they are almost everywhere quite deeply covered with deposits of bowlder drift and clays, except where rivers or streams of some considerable magnitude have cut through these coverings. This is especially true of the extreme northeastern counties, McHenry and Lake, where the covering is very deep, and where those exposures which do occur or have been made show the rock to be too flinty and thinly-bedded to be of any value. To the southward, especially as they approach the southwestern limit of the area, the main valleys of the Fox and Illinois rivers show numerous exposures of the rock, most of which are capable of furnishing an excellent building material. The most important of these are found extending along the Illinois river from 2 miles above Lemont to a few miles below Joliet in an almost continuous line. The exposures of value for building stone are almost entirely confined to the left or south side of the valley, except at and below Joliet.

At Lemont the stone quarries lie on both sides of the Illinois and Lake Michigan canal, which here skirts along the valley above the base of the hills on the left bank of the river, though principally on the southwest. The beds are quarried to their lower limits through a variable thickness of from 12 to 40 feet. The stone here is uniformly a very fine grained, homogeneous, light drab limestone, occurring in beds from 6 to 24 and some times 30 inches in thickness. The beds are divided vertically by seams occurring at somewhat irregular intervals of from 12 to 50 feet, and continue with quite smooth faces for long distances, and also by a second set running nearly at right angles with the first, but only continuous between main joints and occurring at very irregular intervals. This structure renders the rock very easily quarried and obtainable in blocks of almost any required lateral dimensions.

The stone is easily worked into required shapes and takes a fine, smooth finish, which can hardly be called a polish. At the works of the Singer & Talcott Company large quantities of the stone are planed by machines closely resembling those used in planing surfaces of iron. This forms a very rapid and cheap method of finishing flagging stones and preparing stones which are to receive a smooth finish for the polishing-bed. Very large quantities of flagging stone are gotten out by this company, which for the past few years has supplied nearly, if not quite, nine-tenths of the stone for that purpose put down in Chicago, as well as large quantities for other places. The finer and more homogeneous varieties can also be very readily shaped into any of the forms which lathes are capable of turning out, such as balustrade work, and a great deal of this sort of ornamental stone-work is made here. The stone can also be readily carved in bas-relief, but is not sufficiently tough for high relief work. Its color is a bluish-gray to nearly white, and that quarried in this immediate vicinity seems to contain less iron oxide than that quarried lower down, at and below Joliet, and does not tarnish so much.

Quarrying has hitherto been largely done under very light stripping, but most of the future developments of these quarries must necessarily be done under very heavy stripping of clay and medium-sized gravel. This is here all done by hand. The stone here is injured by exposure to the frost while containing its natural moisture. This is a cause of either a considerable annual expense in making earth protection, or annual loss in destruction of stone, except in a few of the quarries so fortunately situated that they can be flooded during the winter season.

The principal market for the stone quarried here is the city of Chicago, but large quantities of the stone are also shipped in every direction to points throughout northern Illinois and the adjoining states of Michigan, Indiana, Iowa, and Wisconsin. These quarries extend for nearly 4 miles below Lemont, where a gap occurs, to just below Lockport, from which point a line of closely-adjoining quarries extends to below Joliet. The finer varieties of this stone do not seem well fitted for heavy masonry in damp situations. Fine clay seams abound, which are invisible when the stone is first quarried, and when it is used under ordinary circumstances generally do not develop at all, but in such situations as expose the stone to heavy moving loads, or to alternate moisture and dryness accompanied by frost, they are soon developed and often render the stone worthless. Even the purest and best of the stone, especially in cities where much soft coal is burned, becomes somewhat tarnished to a light yellowish tint after long exposure, but does not become of a strong buff color.

The quarries of the Joliet group extend from about a mile below the village of Lockport to about the same distance below Joliet. The total thickness of Niagara strata exposed here is apparently much greater than at Lemont, and two fairly distinguishable varieties of the stone are quarried. That quarried at the lower beds, in the vicinity of the penitentiary, on the right bank of the river, and just below the city closely adjoining the river, is generally a rougher, more irregularly-textured stone, occurring in beds as much as 24 inches thick, and is now chiefly used for ordinary and heavy masonry, and very little for ornamental purposes. This stone, upon exposure, becomes tarnished to a very decided and sometimes a quite deep buff tint, which is not a handsome color for face or ornamental stone. It appears, however, to be especially well suited to the purposes mentioned above.

In the quarries back from the river, at higher levels, the stone is generally a fine-grained, much more homogeneous rock, much of it quite equal in this respect to the best of that quarried at Lemont, and it occurs near the bottom of the quarries, as now worked, in beds often from 3 to 4 feet in thickness, and is obtainable in large blocks. Most of it appears to weather-stain rather more than the Lemont stone, but to be otherwise exactly like it. It is very largely used as a building and an ornamental stone, and large quantities of it are shipped by rail to points throughout northern and central Illinois, and to every one of the adjoining states. The value of the stone quarried at these two localities is probably fully equal to that of all the other stone quarried in the state.

Along the Fox River valley, from Elgin to Aurora, there are occasional exposures of the Niagara limestone, some of which are considerably quarried. In all of them, however, there is a heavy covering of drift, which renders the quarrying quite expensive.

At Batavia there are extensive quarries. The drift covering necessary to be removed is from 20 to 40 feet deep, almost entirely sand and medium-sized gravel. There are three large quarries on each side of the river whose products are all entirely similar. The stone is rather rougher, coarser, and more irregular in texture than that at Joliet and Lemont, and is more compact and difficult to work. A few of the beds furnish stone fit for ornamental work in fairly large sizes. The expense of quarrying has been very greatly increased by the heavier stripping required.

At Aurora there is also a very large quarry of the same excellent and durable stone, the product of which is mainly used for rough foundation and heavy masonry.

There are also quarries of some value at Thornton, on the Illinois Central railroad, and at Blue Island, on the Chicago, Rock Island, and Pacific railroad. There is also within the city limits of Chicago a quarry in the limestone of this formation, which is there impregnated with organic matter that gives the stone a dark and dingy tint upon exposure, and soon imparts to it an appearance of great age. It was used in the construction of one of the principal church buildings in the city, but it was most largely quarried for lime and ordinary wall stone.

At Kankakee, Kankakee county, there are two large quarries. The stone quarried there is a compact, coarse, somewhat irregularly-textured dolomitic limestone containing rather numerous small cavities and sand-pits, but it is a strong and durable building material, especially valuable for resisting and enduring under very unfavorable circumstances when exposed to dampness and frost, and has very considerable strength. It has been largely used as face-stone in building work, but contains numerous crystals of pyrites which decompose and stain the stone dark yellow in patches, badly marring its appearance. Large quantities of the stone are used in bridge work along the lines of railroad passing through this place.

In the area of Niagara limestone lying in the northwestern part of the state, in Whiteside and Jo Daviess counties, are numerous exposures, and the beds furnish everywhere a rough-textured, heavily-bedded, durable stone, excellent for all kinds of ordinary heavy masonry, but they are nowhere extensively quarried. Farther south, in northern Rock Island county, these beds, when found, are softer and excellent for lime-burning, but furnish no first-rate building material.

In Pike county the Niagara rocks form the base of the Mississippi River bluffs for a considerable distance. They are here of somewhat rough-textured, compact, buff-colored limestone of great durability, a building material for ordinary and heavy masonry quite equal to the best Joliet or Grafton stone. The same stone is also found high up on the river bluffs in southern Calhoun county, and also all along the Illinois and Mississippi River fronts of Jersey county to just below Grafton, and everywhere presents precisely the same physical characteristics.

At Grafton the stone is very extensively quarried, principally for the Saint Louis market, but considerable quantities of it are also shipped to other river points, the river having been, to the present time, the only channel for transportation available. The stone quarried here is of very great strength and durability.

The rocks of this group also occur in the river bluffs of Union and Alexander counties, in the extreme southern part of the state. Like the Trenton beds which they overlie, they are there mottled, semi-crystalline rocks, occurring in very heavy beds, the stone taking a fine polish and capable of yielding a very handsome ornamental stone, as well as a thoroughly reliable and handsome building material. They are not, as far as I could learn, yet worked.

DEVONIAN.

The Devonian age is represented in Illinois by a series of shales and limestone, of small total thickness, varying from 10 to over 100 feet. The exposures of these rocks are not numerous and are of very limited extent. In Calhoun county they include about 10 feet of a coarse, gray limestone, useful and slightly used as a building material. In Jackson, Union, and Alexander counties some of the beds might be utilized for the same purpose.

In Jackson county there are beds in the Devonian series at Bald Hill and at Back Bone which are very hard ande ven-textured and take a fine polish. They are of variegated color also, and have been worked to some extent. Other beds in the same series also furnish excellent rough building material.

CARBONIFEROUS.

The rocks of the Carboniferous age underlie the greater part of Illinois. They form a series of very great thickness in their greatest development, probably over 2,500 feet, and are of very great importance not only because of the mineral wealth, especially of coal, but also because of the vast, almost unlimited, quantities of most excellent building stone they are capable of supplying, and very cheaply, at great numbers of points over the state. This is especially and particularly true of the lower division of the group, the sub-Carboniferous limestone, so called, which furnishes a maximum thickness of limestones, sandstones, and shales; principally limestones of over 1,500 feet, in the southern part of the state, which gradually thins out to less than 1,000 feet total average, toward the northern limit of their exposure. A very large proportion of these beds furnish excellent building stones wherever found.

The most northerly exposures of these beds occur in southern Mercer county, and from here they extend southward in an area of very variable width from 5 to 30 miles or more, always along or close to the Mississippi river, and nearly the whole length of the state to southern Jackson county, where they swing to the eastward and cross the state, through Union, Johnson, and Pope counties to Hardin county, at whose easternmost limit they cross the Ohio river into Kentucky. They form the whole or the greater part of the Mississippi River bluffs throughout the entire distance from Mercer to Jackson county, with the exception of the limited localities already described, where the river front is occupied by older rocks. Five main subdivisions of the rocks of this group were made by the Illinois geologists and traced throughout most of the area.

KINDERHOOK GROUP.—The Kinderhook group, the lowest and least important of the series, has at its greatest development a thickness of less than 200 feet, which in places includes limestone strata of no great thickness available for building stone, but which are not always a reliable material, and nowhere extensively quarried.

BURLINGTON LIMESTONE.—The Burlington limestone, next in the series, occurs in beds whose variable thickness amounts in many places to over 200 feet; it is a very pure carbonate of lime, highly fossiliferous, and for almost its total thickness is an excellent building material.

In Henderson county it outcrops along the river bluffs through the whole length of the county. It is a fairly even textured light blue or yellowish-gray, moderately thick-bedded stone, but little affected by weather. The beds have been quite largely worked in the eastern part of the county, and also at Sagetown, where a very extensive quarry furnishes a large quantity of material, principally used in railroad constructions. The stone for the piers of the Mississippi River bridge at Burlington was taken from this quarry and has stood the exposure and abrasion with great success, and seems also to have been discolored little or none.

It forms no part of the surface of Hancock county, but in Adams county is again exposed along the whole line of river bluffs, from Quincy to the southern line of the county, having everywhere about 40 feet in thickness of moderately heavy beds of excellent but rather rough-textured building stone. At Quincy, within the city, a thickness of about 100 feet of this limestone is quarried, and is most of it available for building stone; an excellent and durable material, but not a fine ornamental stone. Some few of the layers contain pyrites and become badly discolored upon exposure.

Throughout the whole river front of Pike county, both on the west and on the east, these beds form a continuous outcrop, including, as in Adams county, about 40 feet in thickness of beds available as building material. The stóne is here often found in beds from 2 to 4 feet thick, and is, wherever free from flints, an excellent building and dimension stone. Numerous exposures are also found along the creeks in the northern part of the county.

In the vicinity of Jersey landing, Jersey county, it forms the entire river bluff, and is a nearly white, somewhat uneven-textured, medium-bedded limestone, containing occasional seams and flints, and furnishing a very good building stone for rubble and ordinary cut-stone masonry. It is very little quarried now.

KEOKUK GROUP.—The Keokuk group, next in succession, consists chiefly of limestones. Its rocks extend in Illinois from central Henderson county along nearly the whole band of sub-Carboniferous rocks to Hardin county. Only the middle beds of this formation furnish good building material, and in these there are a number of noteworthy quarries. Their extreme thickness is about 70 feet, and the rock is an even-textured, light gray colored, easily-dressed stone, which does not discolor or show any signs of disintegrating upon exposure. In most places its beds are separated by clay seams sometimes of several inches thickness, the beds themselves varying from 6 inches to 3 feet.

In eastern Henderson county these beds are exposed in numerous places, especially in the vicinity of Biggsville, and there furnish only an ordinary building stone in blocks of very moderate dimensions.

In Hancock county these beds form the base of the river bluffs for a long distance, and have been extensively quarried in a number of places. Near Nauvoo large quarries were at one time worked, and furnished the material of the once famous Mormon temple at that place. Stone from these quarries was used also in the construction of the United States court-house and post-office buildings at Galena and at Dubuque. South of here about 4 miles the Tallant Stone and Marble Company has opened a considerable quarry in the same beds, and furnishes a rather coarse, uniform-textured, white, and very light gray limestone, which is easily cut, sawed, and shaped, and does not tarnish upon exposure. Some of the beds furnish stone which can be polished, and in places some of the beds contain much cherty material, while others are entirely free from it. Very large blocks are easily obtained. The same beds have also been much quarried at Hamilton and Niota in the same county.

The analysis of this stone (*Illinois Geological Report*, Vol. I, p. 99), specimen from Nauvoo quarry, gives:

	Per cent.
Carbonate of lime	82.48
Alumina and iron	2.10
Insoluble matters	12.50
Water and loss	2.92
Total	100.00

Throughout Adams county where these beds are found they furnish, when free from flints, a stone precisely similar to that at Nauvoo. They outcrop in very many places throughout the northern and northeastern part of the county.

In Pike county the beds of this group, which rest directly upon the Burlington beds, furnish an excellent building material very like that of those beds. They outcrop, especially in the vicinity of Griggsville, where the beds are unusually free from flints. In Jersey county, though there are numerous exposures, they furnish no excellent building material on account of the number of flints they carry. In Hardin county a heavily-bedded limestone, in layers from 1 foot to 3 feet thick, outcrops along the Ohio River bluffs, but is not quarried for building material.

Saint Louis group.—The beds of the Saint Louis group furnish a very large amount of building stones of considerable variety in texture and properties. In Hancock county the lowest beds of the series are of a somewhat arenaceous magnesian limestone, generally of a light yellow or buff color, darkening upon exposure. The stone cuts readily and can be obtained in quite large blocks, and possesses very great durability in the most trying situations. Large quarries in these beds were opened and extensively worked just at the head of the Keokuk rapids, on the Illinois side, and furnished nearly all of the riprap for lining the government canal around those rapids, beside considerable of the cut stone used in the locks, where it has resisted very successfully. These quarries have been abandoned for several years, however. This stone readily breaks into blocks for the better class of rubble, very square and of convenient sizes.

Below Warsaw these beds attain a very great thickness, and are quarried considerably in a good many localities. They nearly everywhere contain minute crystals of pyrites, which decompose upon exposure and discolor the stone. There are also numerous exposures upon the creeks in the eastern part of the county. These same beds are also found in the northern and northwestern part of Adams county, where the rock is of the same character. In Pike county they are only found in the extreme northern and northeastern part, and where occurring furnish the same brown magnesian limestone, a most excellent and durable building material.

In Calhoun county they form a continuous exposure along the river bluffs, and are everywhere a rather thinly-bedded and hard but very durable building rock, and would furnish an almost inexhaustible supply.

In Jersey county the principal exposures occur along the Piasa; and on the Mississippi river, just south of the Piasa, at its mouth, in Madison county, are also large exposures. The beds here are nearly true dolomites, are often found with very heavy layers, and furnish a very excellent heavy wall stone. Some of the upper beds at this last locality take a fine polish, and could be used as an ornamental stone; they also furnish excellent flags.

The bluffs at Alton present a thickness of over a hundred feet of these beds, the whole of which is quarried for lime and building stone. The middle and lower beds furnish some excellent hard, even, close-textured rock, in every respect good building material. The brecciated beds found here have been largely used for rough, heavy masonry, but observation shows them unreliable for that purpose, gradually becoming separated into irregular fragments.

In Saint Clair county a total thickness of about 200 feet of these beds is exposed, nearly all of good building material and available. Some of the thinner beds furnish an excellent flagging, while the heavier beds contain a light gray, compact stone, excellent for every variety of mason work. They form the river bluffs through most of the southern part of the county. In Madison county the beds exposed are also dolomitic to some extent; at places pure dolomites (specimens analyzed at the Smithsonian Institution, Washington, proved to be calcareous dolomites). They furnish everywhere an excellent material for building purposes. Occasionally the stone is sufficiently hard and compact to take a fine polish.

In Monroe county the rocks of this formation are pretty well distributed over nearly the whole of the county. They are extensively quarried at Columbia and at Waterloo. In the vicinity of the latter place the rocks quarried are especially suitable for cut-stone work of every variety. They are of a bluish-gray color, sometimes nearly white.

In the vicinity of Columbia there is exposed in the lower division of these beds about 20 feet in thickness of heavily-bedded, light gray, granular limestone entirely free from flints, splitting easily and furnishing blocks of any required size. There are also in the lower division of these beds heavily-bedded buff limestones which make most excellent heavy wall-stone. These are exposed in about 100 feet thickness at and in the vicinity of Salt Lick point, on the Mississippi river.

In Randolph county they also occur in the northwestern part of the county 200 feet thick and in beds similar to those in Monroe county.

In Jackson county these beds furnish some good building material.

In Union county, in the vicinity of Jonesboro', are numerous quarries, not now much worked, of massive, granular, nearly white limestone, an excellent building stone for ordinary situations; they are of fine appearance and obtainable in large blocks, but are said not to resist when exposed to frost in damp places.

In Johnson and Pope counties also these beds would furnish excellent building material in large quantities, but they are nowhere worked. At Roseclair, in Hardin county, large quarries were worked for many years in the beds of this formation, and are yet worked, though not on so large a scale.

Oolitic beds occur in the bluffs just below the village, and are somewhat quarried. They furnish a very hard, fine stone which takes a high polish, has a dark bluish-gray color, and is a very durable and handsome stone. Large blocks are readily obtainable. Places for several large quarries conveniently located on the river can readily be found here.

Chester group.—The beds of the Chester group expose a thickness in places of over 600 feet of alternating limestones, sandstones, and shales, capable of furnishing large quantities of fine building material. One of the sandstone beds of this group is found capping the bluffs at Alton, where it is a clear, white, pure siliceous sandstone, fine-grained, perfectly homogeneous, and occurring in massive beds from which very large stones might be obtained. It shows no tendency to discolor upon exposure. It is little quarried, and not at all for ornamental purposes, for which it appears very suitable.

In Saint Clair county the lower sandstone of the group furnishes a durable stone, buff or brown in color, easily quarried and cut, hardening upon exposure, and obtainable in blocks of any required size possible to be handled. Overlying this is a thinly-bedded limestone of the same group available for common wall masonry.

In Monroe county the lowest sandstone of the group shows in a thickness of 60 or 75 feet, generally evenly-bedded and uniform-textured, but occasionally concretionary. This outcrops in numerous places in the southeastern part of the county. Some of the limestones of the group outcrop here also, and furnish good rough building stone.

In Randolph county, where this series finds its greatest development, the lower limestone of the series is 150 feet thick. It is all fit for ordinary building stone, while some of the beds also furnish excellent dimension stone for cut work. Some of the upper limestone beds of the series also furnish excellent material for cut-stone work.

The Penitentiary quarry at Chester is worked in these beds, and much riprap, rough building material, great quantities of paving blocks, and considerable cut stone of fine appearance are obtained.

The lower sandstone of the group is here precisely similar in characteristics to the same beds in Monroe county, but is here more than 100 feet in thickness. It has been somewhat quarried just above Chester, where it can be made to furnish blocks of great size. It is a stone of great strength and durability, and presents a uniform and good appearance, its color, however, being somewhat against it.

The other sandstones of the Chester series furnish a fine-grained, soft, even-textured, buff and brownish colored stone which cuts with great ease when first quarried, but hardens upon exposure and changes color very slightly. It is a rather handsome building material. The southern Illinois penitentiary is built largely of these sandstones, and presents a fine appearance.

In Jackson county, where they occur, the limestones of this group are generally too siliceous and too hard to work, and usually furnish stone only for ordinary building purposes. The sandstones, however, can furnish large quantities of excellent building material. They are soft, fine-grained, harden on exposure, are durable, and usually of dark brown or strong yellow color.

In Union county, when not too argillaceous, the limestones furnish good building material. At Cobden there is a very heavily-bedded, compact, dark blue, very hard limestone, very difficult to cut, but which would make a most excellent bridge and culvert material, and has been somewhat used for that purpose.

In Johnson county the sandstones of this group occur in easily workable position in numerous places, and would furnish excellent flagging and dimension stone. Some good building material is also obtainable from the limestones.

In Pope county, while some few of the sandstone exposures furnish a fine building material, most of the outcrops show the stone to be too hard and uneven. Where exposed near the Ohio river the limestones of this group furnish excellent building stone for the finer classes of work.

In Hardin county some of the sandstones are very refractory and are used for furnace linings. They furnish also some good flagging and some fair building material.

The Coal Measures underlie the greater part of Illinois, probably three-fourths of its territory; the greater portion of the territory is deeply covered with the more recent clay deposits, and exposures are rather scarce. In the southern part of the area there is, however, a less depth of these deposits, and more numerous exposures, many of which furnish building material of some sort. Their rocks comprise here, as elsewhere, alternate beds of sandstones, shales, limestones, and conglomerates. Most of the sandstones are coarse and irregular in texture, and generally disintegrate upon exposure. In the southern part of the state there are, however, many places where they are hard, fine, and tolerably durable, and in many localities furnish excellent flagging and good building material. The limestones of the series are generally rough-textured, thin-bedded, and shaly, and in but few places furnish a material fit for ordinary use. In comparison with the sub-Carboniferous beds, these, however, will furnish but a small total amount of really excellent material.

The points where beds in this formation have been worked are few in number, and of little importance generally.

Between Cobden and Mahanda, on the line of the Illinois Central railroad, and adjoining the track, is a small quarry in a medium-bedded limestone, which might be very greatly enlarged. The beds are regular and even, and the stone appears to be quite durable.

Three miles south of Carbondale, on both sides of the little creek through whose valley the railroad runs, are exposures of a reddish sandstone of considerable value for building material. It is a medium-grained, even-textured stone, fresh fracture, dark red, weathering to a purplish-gray tint, easily quarried, but becoming quite hard upon exposure. At the top of the eastern bluff a large quarry was once worked but is now abandoned. The convenient outcrop could supply a great quantity of the material. The bed seems to be about 14 feet thick, and would easily furnish sawed stone 4 by 10 by 40 feet in one piece. The stone for the State Normal School building, a very handsome structure, was obtained at this quarry. On the west side, opposite, are excellent exposures of the same rock, forming a similar ledge low down on the bluff. The beds lying above this ledge are thin and hard, and furnish a fair flagging, which is quarried in moderate quantities at this place.

At Xenia, Clay county, there is a small thickness of drab-colored, fine-grained, even-textured sandstone exposed in a creek valley for 2 or 3 miles, furnishing a fair building and ornamental stone, and is quarried and shipped in moderate quantities. There are also said to be sandstone exposures along Crooked creek, in the same county, of considerable value for building purposes.

At Carlyle, Clinton county, are small quarries in a rough-textured, durable limestone; and on Shoal creek, a few miles west of Carlyle, limestone strata of fair quality for both ordinary and cut-stone work are found outcropping in a number of places, and are quarried in a small way.

In Greene county are beds of sandstone which would furnish considerable quantities of fair building stone, and there are numerous other exposures of like character. In no place, however, are there any beds which are likely to prove of more than local importance.

In the northern part of this area the covering of the rock formations is so deep and the country so level that large districts are without rock exposures, and depend entirely for their supply upon the means of transportation. The county, however, is crossed in every direction by railroads. While the resources of the state within herself are sufficient many times over, it is quite likely that much of the building stone for the state, especially in some portions of it, will be brought from Ohio and Indiana, because of its great excellence and proximity to the market.

Nearly all the northern, western, and southern counties have ordinary building stone in great abundance and well distributed.

Increased facilities for transportation have been rapidly extended throughout many of the counties richest in this particular commodity, which have hitherto had no railroads, and this must undoubtedly result in the development of considerable industries in quarrying and shipping of these materials to the less favored districts.

I have to acknowledge my great obligation to the Illinois geological reports for facts about much of the territory having no present quarrying industries, which could not be visited, and for other facts gleaned from that report and incorporated herein.

MICHIGAN.

By Professor Allan D. Conover, *Special Agent.*

The state of Michigan contains rocks representing a larger range of geological formations than those of any of the adjoining states, but within her limits their lithological character and mode of occurrence, as also those of the later and looser deposits, are such that there are comparatively few points where the quarrying of stone for building purposes is ever likely to become an important industry, but at some of these it is of very considerable importance.

The Archæan rocks occur only in the northern and northwestern parts of the northern peninsula, and have not as yet furnished any building stone. The Huronian subdivision, however, carries beds of very considerable thickness of slates of very great value as roofing material. These have unusual development in the vicinity of Huron bay, on the coast of lake Superior, and were during the last decade opened and worked at a number of points, all in the same vicinity, in township 51, range 31. Several stock companies were formed, with large capital, each owning large tracts of land in this township, and some work was done in developing quarries, but the difficulties of transportation and shipment and small market for their product led to their temporary abandonment and the failure of the companies owning them. These beds furnish slate very readily cleavable, generally of black color, but also occurring in places of green, purple, and gray colors, in vast quantities, and so far as their exposures and the limited trial given them go to show, of very considerable enduring power, and they bid fair to be of very considerable value as the development of this and the adjoining states creates more market for material of the kind. Besides these deposits I do not know that these rocks furnish any material now used in building, or any whose character, so far as known, renders them likely to be quarried for that purpose even to supply local demand.

Beds of limestone, altered to marble, occur associated with the granitic rocks of the Laurentian, which furnish very numerous handsome specimens, but do not, I believe, occur anywhere, as yet discovered, where large blocks of material of homogeneous character can be obtained in quantity. It is quite possible that the granitic beds may some time furnish valuable building material of that class, and also that the quartzites which occur in large quantities and are easily reached may also furnish valuable paving material where the location of outcrops of the suitable quality occurs conveniently to cheap transportation facilities; but as yet nothing of that sort has been developed.

The Potsdam sandstone is likely to furnish the largest quantity and the best of the building material found within the state. Its occurrence is mainly in the northern part of the Upper Peninsula, where very numerous exposures occur, especially along the lake shore. The lower beds of this formation furnish a rather coarse grained, homogeneous, siliceous sandstone, rather soft when first quarried, and easily hewn, but hardening on exposure. Its color is generally reddish, or some shade of reddish-brown, and, when uniform, renders it a very handsome material for outside and ornamental work. It often occurs of mottled-white or yellowish-white and red-brown colors. These parts of the stone are usually rejected, though some buildings have been built of them at Marquette and also in Chicago, and present a rather handsome, picturesque appearance. They seem to be equally durable with the rest. The stone usually occurs in approximately horizontal but usually very uneven beds, and is always readily obtainable in large masses. In most places where quarried the stone carries occasional, sometimes numerous, pockets of clay of very various sizes, which considerably affect its value by causing much waste and rendering the stone unreliable. Where free from these, however, the stone is a durable and reliable one, and always commands a high price and a considerable market in all the large lake cities.

It was, during 1880, only quarried regularly at one quarry, which is within the city of Marquette. Numerous attempts to quarry elsewhere have usually failed, principally from the difficulty of obtaining a safe harbor at the quarry spot. This difficulty is very likely, however, to be overcome, so that quarries will be opened in numerous places. These beds occur especially in the vicinity of Marquette, in many places along the lake shore, west of Keweenaw point, and also near the eastern end of the coast of lake Superior along the lower valley of the Laughing Whitefish river and the country around it. In this latter locality the stone is very hard, compact, reddish, or speckled, is heavily-bedded, readily splits to required thicknesses, and is especially suitable for heavy masonry, but, because of its hardness, not well suited for an ornamental building stone. It is found underlying a very large territory and is easily obtainable almost everywhere.

The Calciferous group occurs in the Upper Peninsula only where it extends in a very narrow band from a point some distance northwest of Menominee, northeastward, swinging to the east, to the extreme eastern end of the peninsula. It exposes an extreme thickness of about 100 feet of calcareous sand-rock of very variable character, the more calcareous beds of which sometimes furnish good building material in rather thin beds and blocks of moderate size. They are, however, nowhere regularly worked as yet, the country they underlie being still entirely a wilderness.

The Trenton group is represented on the Upper Peninsula by beds of perhaps 100 feet greatest thickness of thinly-bedded shaly limestones, which have nowhere been discovered of such character as to furnish a first-rate building material. At places it is thick enough and sufficiently even bedded to quarry out in good shape, is of compact or crystalline structure, but everywhere yet worked contains too many irregular argillaceous seams to render it a safe and reliable building material. It also extends in a narrow band from west to east, through nearly the whole extent of the peninsula, just south of and adjacent to the band of Calciferous rocks. It is crossed by all of the important streams flowing into lake Michigan, and, in most cases, forms upon them falls or rapids of considerable extent, so that exposures are very numerous. To the southward lie the Niagara beds, in a similar but wider band, which covers most of the southern part of the Upper Peninsula, extending from Big Bay de Noquette eastward to the limit of the state. They furnish usually a hard, compact limestone, often in very heavy beds, but generally containing so many seams of argillaceous material as to render them liable to split and crack under the action of frost. Some of the beds are free from these seams. Most of the region where these beds occur is a wilderness, and the beds are, moreover, heavily covered with drift, except where the streams have cut their way through. A few quarries have been opened and worked to a limited extent.

The beds of the Hudson River shale, lying in a narrow band of country between the last-mentioned formation, are everywhere too soft and too easily affected by weather to be of value as a source of building material, and can never be expected to supply material fit even for ordinary purposes.

The Helderberg group furnishes limestones of considerable hardness in places, but everywhere occurring in a brecciated condition which renders them unfit for building material.

In the rocks of the Onondaga Salt group there are on the Upper Peninsula some beds of fair gypsum, and quarries were formerly worked in them near Point aux Chênes, but were long ago abandoned. This completes the list of the rock formations of the Upper Peninsula.

Passing southward through the Lower Peninsula, we cross successively the beds of the later formation to the basin filled by the Coal Measures, which cover a disk-like area in the southern-central part, around which the earlier formations occur in concentric rings.

The rocks of the Helderberg group occur on the Lower Peninsula at its northern extremity and upon the adjacent islands, and everywhere furnish impure limestones of some value for lime, but so brecciated as to be entirely unfit for any building purposes, except the lightest and most ordinary cellar masonry. They occupy also a small area in the southeastern course of the Lower Peninsula, and there furnish beds of some considerable value. At Trenton, near Detroit, in Monroe county, is a very extensive quarry in these beds. They furnish a somewhat impure limestone, occurring in beds from 1 inch to 12 inches thick, from which no large stone can be obtained owing to numerous dry seams which occur throughout the mass. The heavier beds only are utilized for building material, and are close, compact, and rather fine grained, sufficiently hard to take a fair polish, but fit only for ordinary rubble work, while blocks selected with the greatest of care furnish material fairly fitted for such ornamental work as caps, sills, etc. Very little of the material, however, is utilized for such purposes.

Upon Macon creek, in the valley, are a number of small quarries in the beds of this formation which expose a total thickness of about 8 feet of beds 6 inches to 2 feet in thickness, and a much more compact, gray, crystalline limestone of considerable strength, and very free from the dry seams found in the rock at Trenton. The beds in the valley are covered only by from 2 to 6 feet of loose earth and can be very easily quarried. They furnish excellent material for all ordinary mason work and for very good-appearing cut-stone work, though somewhat difficult to hew. Some of the upper beds in this locality are also brecciated.

A sandstone bed of small thickness also occurs among the beds of this age which in places contains a considerable proportion of calcareous cement, and is a firm, compact rock obtainable in fair-sized blocks, nearly pure white, and to all appearances a fair and quite handsome building material. This bed was seen at the surface on Fritz Rath's farm, near Raisinville. There are also in the limestones a number of small quarries along the valley of Raisin river and Plum creek which furnish good building material. The most important of these are at Monroe.

There are in the southern part of the Lower Peninsula no beds representing the Hamilton period, but in the northern part they occur in great thickness and form the surface rock over a very considerable area adjoining that of the Helderberg group, and extending across the whole width of the state. They consist of alternate beds of limestones and shales, some of the former furnishing fair building material, quarries in which are worked at Alpena and vicinity. The stone obtained is very hard, compact, and durable, but is obtainable only in moderate-sized blocks. It is well suited for all ordinary plain ornamental stone-work, but has a rather dull, light drab color, rendering it not very attractive for the latter. It appears every way a durable and reliable stone. It is not obtainable anywhere in large quantities, but in numerous places supplies the local demand for common building stone. Where it outcrops along the shore of lake Michigan it can be quarried in several places and loaded directly upon barges in the lake.

The black shales, next in order in the geological series, furnish no material for construction.

The Waverly group, next succeeding, is by far the most important of the series in the Lower Peninsula, and furnishes a large proportion of the good building material obtained. The rocks of the group consist of alternate sandstones and shales; the sandstones, which furnish the building material, vary considerably in texture and composition, but furnish in many localities valuable building stone.

Along the south shore of Saginaw bay from Point aux Barques southwest there are numerous exposures of the sandstones of this group. At the point itself a thickness of about 16 feet of these strata is exposed, which would furnish excellent building material.

At Grindstone City, just southeast, are other exposures which are extensively worked for grindstones, for which they furnish excellent material. Some of the stone has been used for building purposes, but it has more value for its present use.

There are numerous exposures elsewhere, especially in Jackson and Hillsdale counties, very few of which have been much worked of late years. The increase of railroad facilities has greatly increased the use of the superior Ohio stones. The most notable quarry in the formation is that at Stony point, in Jackson county, where a thickness of about 40 feet of fine-grained, buff-colored sandstone, very soft and easily dressed, but hardening upon exposure and retaining its color well, is quarried under very heavy clay stripping, and blocks of any required dimensions are easily obtained.

Beds of the same formation are also exposed at and near Jonesville, Hillsdale, Osseo, Moscow, Homer, and Condit station, in the same region, and on Black river, near Holland, Ottawa county, farther northwest. There are, however, no very important quarries, and at only a few of these places can really good stone be obtained.

The Carboniferous limestone at the base of the Coal Measures has a comparatively small development in this state, and nowhere furnishes building material of much importance. There are quarries in these beds at and near Bellevue, Eaton county, and north of Jackson, at the junction of Grand and Portage rivers. At these places the beds furnish pure, light-colored limestones in beds of moderate thickness, a very fair building material for ordinary uses. These beds also occur on some of the islands on the east side of Saginaw bay, and furnish an excellent building material for foundation walls.

The sandstones of the Coal Measures sometimes furnish very good building material. The most noteworthy quarry in these beds is that near Ionia, Ionia county, where a bed of dark red and mottled yellow or white and red stones occur in horizontal position in layers of moderate thickness, and furnish an easily-quarried, medium-grained, easily-cut, and hardening sandstone in blocks of considerable size, and a very handsome building material. The beds from the lower part of the quarry are of an even brown color; those near the top are mottled. This stone has been much used in the vicinity both for ornamental and heavy masonry purposes, and has proved itself well suited to all classes of building construction. A very handsome church edifice has also been built of the brownstone at Detroit. Beds of these sandstones are also found at Jackson, where they are somewhat quarried, and near Lansing, at Grand Ledge, and at Flushing, near Flint, but they are nowhere regularly worked, nor do they furnish any very desirable material.

The resources of the southern peninsula in building stone are comparatively very limited, except in such ordinary grades of the material as are necessary for house-foundation purposes, and even for that purpose stone is frequently lacking in very large districts. This is in part compensated for by the numerous railways which traverse the state, the close proximity of the numerous excellent building stones of Ohio, and the cheap lake transportation by which the resources of the Upper Peninsula can be reached.

WISCONSIN.

By Professor Allan D. Conover, *Special Agent.*

SILURIAN.

The great bed of Silurian rocks which almost completely encircles the Archæan area of northern central Wisconsin had previous to the census year furnished practically all of the building stone quarried within the state. Every one of the grand divisions of the belt furnishes in one or more localities material fit for ordinary building purposes, though stone suitable for the finer class of work is as yet quarried at but few places. Within the Silurian area, to which the more thickly-settled portions of the state pretty closely correspond, except where a very deep covering of glacial drift exists, there are but few regions where rock fit for the most ordinary building purposes cannot be obtained everywhere within a few miles, and almost every large town or city has within its limits, or near by, quarries of sufficient capacity to supply its own most pressing needs for that sort of building material; but there were previous to 1880 no localities (except at Bass island in the Lake Superior region) where building stone had been quarried in any quantity for export beyond the state, (*a*) and but few where it had been quarried for other than a local market. There are indeed but few places where the Silurian formations yield large quantities of easily-obtainable stone of such character as to be in very general demand. The Niagara group furnishes several of these places in the vicinity of Milwaukee; the Trenton group (Galena limestone), a number along the Lower Fox river and Duck creek, in Outagamie and Brown counties; the Saint Peter sandstone, a barely possible one at Red Rock, near Darlington, La Fayette county; the Lower Magnesian but one, at the Prairie du Chien quarries and in their immediate vicinity, Crawford county; and the Potsdam sandstone, in the Apostle islands, and possibly along the coast of Bayfield and Douglas counties.

Potsdam.—The main body of Potsdam sandstone in southern Wisconsin is made of a medium-grained, somewhat rounded, siliceous sand, the particles cemented together either by a fine siliceous powder of the grains themselves, or by a coating of carbonaceous or ferruginous cement. Where the first is the cementing material the stone is exceedingly friable and useless as a building material, but where the cementing material is either of the other two, the rock is generally of a compact and durable character and furnishes some excellent building stones. Sections of this formation in different parts of the state show a varying thickness, reaching as much as 700 feet in the central southern part. Of this the middle and by far the greater part is loose friable stone, much of it easily separated into sand by light blows. Exceptions to this occur in numerous places where the sandstone was deposited close

a A temporary exception to this statement occurred during a period of about two years after the Chicago fire, when such building stone was sent into Chicago from a number of quarries in southeastern Wisconsin.

to the Archæan area, as at the Stevens Point quarries, and those near Grand Rapids, at which last place the stone is a very valuable one, and is referred by Professor Irving to the middle portion of the Potsdam. Another exception of like character occurs along the quartzite ranges of the Baraboo region, where many facts go to show the probability of two separate sandstones laid down at different periods.

Wherever, along the quartzite ranges of that region, the sandstone is found resting immediately upon the quartzite it furnishes a medium-grained, compact, massive sandstone of great durability, which can be quarried in very large blocks, is of uniform texture throughout, free from flaws, and of colors from light straw and nearly white through various shades of light pink, the varying colors being due mainly to changes in the cementing material. The two large quarries in this sandstone at Ableman's have furnished a very large amount of stone for bridge and culvert purposes along the line of the Chicago and Northwestern railroad. The hardness of the stone and consequent difficulty of dressing have so far prevented its use for general building purposes. There is a large number of localities throughout the same region where this stone occurs, and it everywhere presents the same character, and has in many places been quarried to the extent of a few cords.

The upper beds of the Potsdam also furnish in the southern part of the state two layers—one of sandstone underlaid by the other, an impure dolomitic limestone—which immediately underlie the Lower Magnesian limestone, and occur everywhere just below the base of that formation wherever the latter is exposed in the half circle in which it comes to the surface. These beds have been given the name of Madison sandstone and Mendota limestone.

The Madison beds, wherever they occur, are rarely less than 35 feet thick, often more, and furnish frequently a slightly calcareous sandstone, which is generally a very good building stone, although never occurring in layers of a thickness suited for large ornamental stone. It is of various shades, from yellow to a light dull brown, and has been much quarried wherever found, because of the ease with which it can be shaped into appropriate forms. It gradually hardens and changes upon exposure to a rather dull yellowish-brown, and has been quite extensively used at Madison and in the surrounding country, and in many villages in the region where it occurs.

The Mendota limestone is equally persistent in occurrence throughout the same area, and includes a total thickness of from 20 to 45 feet in different localities. It furnishes a stone varying from nearly white through all shades of yellow to dull brown, is quite regularly bedded, occurring in layers up to 5 feet in thickness, and is more extensively quarried than the Madison sandstone, since it can also be burned for lime, of which it furnishes a very fair quality. Wherever it occurs it furnishes valuable building material, especially for heavy work.

The Potsdam sandstone of the region of lake Superior is of a character somewhat distinct from that in southern Wisconsin. Its rock where exposed in Wisconsin is composed of siliceous grains, medium to somewhat coarse, held together by a cement usually either ferruginous or argillaceous in its character, and is generally stained from yellow to deep brown by the ferruginous matter. It furnishes a very handsome building stone, and is quarried in masses of almost any required size. The chief difficulty with the stone as a fine building material arises from the fact that it contains, wherever yet quarried, numerous clay pockets which are liable to badly pit the finished surface. They are likely to be found anywhere in the stone when it is worked, and where ornamental relief work is being done the nearly-completed piece is often entirely spoiled by opening into one of these pockets, or the completed piece is badly defaced by the subsequent breaking away of a thin skin of sandstone and the dropping out of the clay. The difficulties which arise in this way can, of course, be partly overcome by having all the cutting, shaping, and finishing done at the quarries, thus saving the cost of transportation of useless pieces. This characteristic of the stone has proved a great drawback to its general use. Many exposures from which the stone could be readily quarried and shipped directly upon vessels are found on the islands of the Apostle group, and some are found along the coast of Bayfield and Douglas counties.

At Bass island (Apostle islands) a large quarry was opened in this sandstone, and was extensively worked during the first three or four years of the last decade. Quite heavy stripping of clay is required, and below this there is exposed a quarry face of 26 feet of good stone; below this the stone is inferior. In this depth there are three layers which in places unite. The joints are inclined about 60° and are spaced about 50 feet apart. Between these and within the beds the stone is uniform in texture and color, and without seams or cracks. It is of very much the same grade as the Marquette stone, but free from its vexatious variations of color. The quarry has been abandoned for several years, and was not worked during the census year.

Lower Magnesian.—The Lower Magnesian limestone forms the surface stone over a very large semicircular band everywhere skirting the wide Potsdam belt. Its beds consist largely of a quite siliceous dolomitic limestone, sometimes nearly pure, the siliceous or arenaceous material sometimes predominating. In a great many localities it furnishes a rather rough and irregularly but heavily bedded limestone, a good material for heavy masonry, and it is quarried in a large number of places, though nowhere very extensively. In a few localities a very excellent building stone has been quarried from it, usually from its lower or lowest beds. The most noteworthy of the places are the southern part of the town of Westport, Dane county, just west of Bridgeport, near Prairie du Chien, Crawford county, and at the summit of the Mississippi River bluffs, in the vicinity of La Crosse, La Crosse county, and northward to a point across the river from Winona, Minnesota. In the town of Westport, Dane county, is a number of quarries of considerable size, not much worked during the census year, which were nearly all opened for the purpose of supplying stone for the Insane Hospital building located in that township. They were opened in the lowest beds of the Lower Magnesian, just above its beds of separation from the Potsdam. The Venhusen quarry has supplied the greater part of the stone for the hospital building, a heavily-bedded, compact, hard limestone of rather fine but slightly uneven texture, in color varying from very light straw to light buff when dressed, and having occasional small sand-pits. This stone does not discolor upon exposure, and its chisel marks remain after more than 20 years apparently as sharp and definite as when the stone was first built into the wall. This quarry is a very difficult one to work because of very heavy stripping.

O'Malley's quarry, $1\frac{1}{2}$ miles northwest and not far from the horizon, furnishes a whiter, clearer stone. A considerable thickness of good rubble stone is succeeded by some heavy beds, 28 inches thick, which were quarried for the face stone of the United States court-house and post-office at Madison. This is a hard, somewhat arenaceous, white, uniform-textured stone, which an exposure of over ten years in that building has only turned to a very delicate straw color. It was somewhat hard to dress, retains its chisel marks unchanged, and shows no tendency to scale off on the dressed surface.

[The trimmings of the post-office water-table caps, sills, joints, etc., are of selected stone from one of the Joliet, Illinois, quarries, and have scaled off in large thin scales, entirely defacing the tool marks.]

This stone is by far the handsomest stone quarried in southern Wisconsin, except at Waukesha, in the vicinity of Milwaukee.

There are several smaller quarries in these beds and numerous places in the locality where quarries equally good could probably be opened. The Chicago and Northwestern railway traverses the town, and is not farther than a mile from these quarries.

At the Bridgeport quarries, near Prairie du Chien, the Lower Magnesian limestone is also quarried quite extensively in Marsden's quarry. The beds quarried cannot be many feet above the base of the formations. They have a ledge near the crest of the river bluffs, just west of the village, which is there perhaps 80 feet above the river, and dips gradually westward, coming to the level of the river valley before it opens upon the Mississippi river. Numerous quarries have been opened in this ledge and large quantities of stone removed, but all the quarries except Marsden's have been abandoned, and an examination of them indicates that probably none of them could be worked profitably, except for an unusually favorable market. One or two places remain where good quarries could probably be opened.

The stone quarried from the heavier and more regular beds is a nearly white, somewhat creamy-tinted limestone, which does not iron-stain or change much upon exposure, except to take a slightly gray dust-colored hue. It dresses rather easily, and seems to harden somewhat on exposure. It is on the whole an excellent stone for all building purposes where a very fine finish is not required. This and the adjacent quarries furnished the stone for the state capitol, and from this quarry the stone for the extension of that building, now in process of construction, is taken. Large quantities of dimension stone are also now being shipped from here to Minneapolis, Minnesota, and much stone furnished for bridge work upon the Prairie du Chien and River divisions of the Chicago, Milwaukee, and Saint Paul railway.

On the bluffs next the river valley, and near their summit, in the region around La Crosse, there outcrops and is quarried a limestone (lower beds of Lower Magnesian) the lower beds of which yield a clear, creamy-white tinted stone, very fine-grained and of quite uniform texture, which makes a very handsome ornamental building stone. At some places it is pitted with occasional sand-holes, but at others stone of considerable size can be obtained free from these imperfections. It can be very readily worked into different shapes and even carved in fine figures in considerable relief.

There are doubtless many other localities where these lower beds of this formation yield equally good stones with those here described, but no other extensive quarries have, so far as I have been able to learn, been opened in them

SAINT PETER SANDSTONE.—The Saint Peter sandstone consists almost everywhere of somewhat rounded siliceous grains, sometimes entirely uncemented, forming beds of very pure sand, and sometimes cemented to a quite hard and durable stone, which is everywhere, however, where I have seen it exposed, very much cut up by irregular seams or joints, themselves filled with arenaceous material dividing the rock into angular fragments. The material of these seams, however, sometimes cements the fragments well together. The rock has some slight use as a building stone in the town of Portland, Jefferson county, and in the southwestern part of the state, but only for cellar-wall purposes.

At Red Rock, in the valley of the Pecatonica, in southern Iowa county, near Darlington, there is a remarkable exposure of this rock, which appears to have been an upheaval.

In the north side of this exposure a large quarry was opened in 1872 by William T. Henry, of Mineral Point, which was worked only one season. The stone was shipped to Chicago, but the heavy freight charges prevented the business from paying, and the quarry has remained unworked since. Better freight rates can now be had to Chicago and Milwaukee. Some of the stone has been sent to Chicago for trial, and if it meets with favor there the quarry is likely to be opened on a large scale. The stone can be obtained in blocks as large as 6 foot cubes, apparently without flaws. It is, however, much cut up by the fine, irregular seams alluded to above, and it seems doubtful whether the desirable deep tint of brown is the color of more than a small portion. The stone in the railroad cut approaches a brick-red in color, and this grades to a deeper color, nearly brown at the quarry spot, beyond which it gradually passes into a grayish-pink. It is in general appearance much the handsomest building stone found in that part of the state, but some considerable stripping of worthless stone will be required should the quarry be extensively worked.

Trenton group.—The Trenton group in Wisconsin contains two rather distinct divisions—the Trenton limestone and the Galena limestone.

The Trenton limestone or blue and buff beds furnish, wherever they occur in the southwestern part of the state, in what is called the Lead region, an excellent and durable building stone, but not often a handsome one. The buff beds, the lower, occur in layers from 6 inches to 2 feet, and sometimes thicker, and furnish a rather coarse, hard, somewhat unevenly-textured stone which is not difficult either to quarry or to shape and work. Its color, owing to uneven leaching, is usually, or at least often, blue at the center of the layer, but a decided buff for some inches from the bedding-planes, while often stone taken from near the natural surface is leached throughout to a buff color. The blue beds in that region usually furnish a very thinly-bedded, hard, dark grayish-blue to dark drab, fine-grained, often fossiliferous stone of pretty uniform texture, rarely occurring in layers thicker than 10 or 12 inches and not obtainable in very large blocks. At some places these beds remain unchanged by leaching, at others the leaching affects their color almost as much as it does the buff beds. They furnish very hard, durable stones, which are very hard to dress, but take a very fine, soft-feeling polish, and often, because of the fossils included, present a very handsome appearance. These beds have been considerably worked at many points in the Lead region, as at Mineral Point, Darlington, Mifflin, Platteville, Highland, etc. There are, so far as I could learn, no quarries now worked on a sufficient scale, or enough distinguished in former working from hundreds of others, to warrant a special report.

In the adjoining parts of Saint Croix and Pierce counties there is a considerable area where the bluffs are everywhere capped by the Trenton limestone, often only the buff beds; and this is quarried in a number of places, notably at Gibson's quarry, near Hudson, and in Walker's quarry, at River Falls. They present here almost exactly the same physical characteristics as in southwestern Wisconsin, and furnish an excellent and durable though not a handsome building stone. Owing to their position close to the surface the beds are more generally leached to a solid buff color.

In the southeastern and eastern portions of the state the blue and buff beds present very little marked difference in texture and physical characteristics, the heavier and more regular beds being still characteristic of the lower beds or buff, and that being much the more profitable portion of the formation for quarrying. The blue beds generally furnish little or no material fit for other than the commonest masonry, while deep quarrying into the buff (away from the originally-exposed surface) often develops a bluish graystone of rather rough, uneven texture, but suitable for a fair quality of the ordinary ornamental building stone. The quarries in these beds in the eastern and southeastern parts of the state, upon which special report has been made, are those at Beloit, at Janesville, and at Neenah and Menasha. Along the line of its outcrop, as it passes from the northeastern part of the state southwest and then bends to the westward and southwestward, and also where it outcrops in the Lead region, are very arenaceous small quarries.

The upper bed of the Trenton group, the Galena limestone, is the surface formation over a large area in the Lead region and extends in quite a wide band southeastward into Illinois, then bends to the northward nearly parallel with lake Michigan, and at a distance of from 25 to 50 miles inland to and across the state line into northern Michigan.

In the central and eastern part of the Lead region the stone of this formation is everywhere of the same brown or yellow color, often much iron-stained, and also somewhat rotten and honey-combed throughout with large cavities often an inch or more in diameter, almost everywhere unfit for any building purpose, though sometimes compact enough for rough cellar-wall work, and is occasionally used for that purpose.

There are several horizons, however, at which, when it is exposed, it furnishes an excellent, heavily-bedded, rather coarse-textured, strong and durable building stone, well fitted for ordinary and heavy masonry. These beds outcrop at Cassville and along the Mississippi River bluffs in western Grant county, and in numerous other places in that part of the Lead region.

In the southeastern part of the state for some 60 miles north of the state line the Galena limestone has the same physical characteristics as distinguish it in the central part of the Lead region.

At Watertown, however, beds of sufficient firmness and freedom from honey-combing are found to furnish a fair building material. From here northward the stone gradually undergoes a change, mainly through the addition of argillaceous material, which very materially affects for the better its appearance and usefulness as a building stone.

At Waupun a large quarry was once worked in this formation, which furnished an excellent coursing stone.

At Oshkosh are two large quarries which furnish a dark drab stone of considerable hardness and durability, but which dresses with much difficulty, and has been little used heretofore for facing or for ornamental purposes.

Northward from here there are no noteworthy quarries in this formation until we reach the rapids in the Fox river at Kaukauna, where large quarries have been opened and great quantities of unusually large dimension stone taken out. Here is opportunity for opening many extensive quarries in stone of a most excellent character for all mason work, except that requiring the very finest of finish.

Many of the government locks on the Fox river have been built with this stone and others are to be built.

The stone is a medium-textured, light drab or gray limestone, and occurs in beds from 6 to 30 inches thick, from any one of which it can be split in almost any required size, and it can be quarried for dimension material almost if not quite as cheaply as for rubble.

The quarries at Duck creek, on the Chicago and Northwestern railway, near Green Bay, are in exactly similar rock, and have furnished the railway with large quantities of a most excellent stone for bridge purposes.

NIAGARA GROUP.—The Cincinnati shales, *i. e.*, limestones, furnish no building stone. The only Upper Silurian formation in Wisconsin furnishing any building stone is the Niagara limestone. This formation is the surface rock in a strip of country 30 to 50 miles wide along the shore of lake Michigan. There are four well recognized subdivisions of the formation, which maintain the characteristics with considerable persistency throughout the whole country where the formation is exposed: 1. Guelph beds; 2. Racine beds; 3. Waukesha beds; 4. Mayville beds.

The lower of these, the Mayville beds, forming the surface rock in the country adjoining that immediately underlaid by the Galena limestone, contain some beds which furnish stones fit for ordinary building purposes, but no especially noteworthy quarries. In the upper part of these beds there is, in some places in Fond du Lac county and the counties immediately adjoining, a very pure calcareous sandstone, whose occurrence has been mentioned in the reports upon the quarries in the vicinity of Fond du Lac. It is a pinkish-gray stone of varying compactness, which cuts with very great ease and seems to harden some upon exposure. It would be a valuable building stone but for the fact that no spot has yet been found yielding a large quantity of stone of even a tolerably uniform character, or from which pieces of large size could be taken out.

The Waukesha beds throughout Waukesha county furnish a hard, compact, very light drab, sometimes nearly white dolomitic limestone, which yields an excellent, fine-appearing, and durable building stone suitable for all grades of construction. It is quite a hard stone to cut and finish, but presents a handsome appearance when dressed. The typical occurrence of these beds is in very thin sheets, from 1 inch to 6 inches thick, very well fitted for flagging, but these often unite to form much heavier ones, furnishing stones of almost any ordinarily required size. The quarry of the Hadfields, at Waukesha, is the largest and most worked, and sends considerable quantities of stone to Milwaukee and many other Wisconsin towns. In the quarries owned by these gentlemen the typical Waukesha beds yield flagging stones and heavily-bedded building stone. Throughout the country where these beds occur are numerous excellent quarry spots awaiting development. South of this point there is a considerable quarry, 2 miles from Genesee station, which furnishes some stone rather easier to work and somewhat freer from slight defects than the Waukesha.

Northward also from Waukesha these beds have been worked at a number of places and furnish fine flagging material especially. In the country to the northward where these beds emerge from under their intermediate heavy drift covering their stratigraphical equivalent presents three very well-marked divisions, the first only of which furnishes any considerable amount of valuable building stone. This division, called Byron beds, from having its most marked exposures in the town of Byron, Fond du Lac county, forms in that county what is called "the ridge" and "the ledge", a considerable rise of ground, with an abrupt and rocky western face, which runs southward, swinging somewhat westwardly, just east of Fond du Lac, and which is quarried at numerous places near that city, as, notably, at Eden and Oak Centre, and at Sylvester, in Green county. Here good building stone—a compact, medium to fine textured and quite homogeneous limestone—is obtained for ordinary and ornamental purposes, though somewhat hard to shape, and fine flagging stone of any required thickness between 1 inch and 8 inches. Many quarries have been opened in the ledge, but only a minute fraction of the easily-quarriable stone has been as yet uncovered. These beds pass to the east of lake Winnebago, through Calumet county, where they occur in places as a very pure white and sometimes handsomely-mottled stone, which is locally called marble, and can be polished fairly well, presenting a handsome appearance and being well fitted for ornamental building stone. The two upper divisions furnish very little material fit even for ordinary building purposes.

The Racine beds, which rest upon the Waukesha beds at the south and the upper coal beds at the north, are the surface rock along and parallel to lake Michigan, from the state line on the south to the extreme end of Door county on the north, attaining in places a width of 30 miles. They are beds of quite pure dolomitic limestone, and present a great variety of texture and structure, from a porous, granular, and irregularly-bedded to a fine, compact, homogeneous, and evenly-bedded rock. They are very extensively quarried, and furnish most excellent common and fine building material at a great many points, notably at Milwaukee, Cedarburg, Grafton, Sheboygan, and Manitowoc. The Racine quarries in these beds have furnished large quantities of ordinary building stone and stone for lime, but very little material well fitted for ornamental and the finer classes of stones. The Milwaukee quarries furnish every grade of building material and almost any necessary size, and are remarkable for the great depth of excellent building stone which their working has developed.

The Guelph beds, forming the uppermost series of the Niagara group, have pretty much the same general physical characteristics as the Racine beds upon which they rest. In a number of places they furnish excellent building stones, similar to those of the Racine beds. They skirt the shore of lake Michigan as far north as Kewaunee county, and are somewhat quarried at Cedarburg and Grafton, and at Sheboygan.

The Niagara group as a whole furnishes by far the largest number of extensive quarries of any formation in the state, and almost the only ones, except the few in the Archæan, in which the depth of excellent stone is more than a few feet, and which therefore warrant the expenditure of large sums of money in removing the covering. For this reason the number of places in this formation where quarries can be profitably worked is very large.

None of these quarries as yet opened are in convenient proximity to the lake, so that the development of these, as well as of all those valuable Archæan quarries inland, will depend upon transportation facilities furnished by railroad companies.

ARCHÆAN.

The vast area in northern central Wisconsin which is underlaid by the Archæan rocks is almost everywhere covered with an irregular but heavy covering of glacial drift, and there are large areas where rock exposures are very rare. A large part of the stones of this formation are of a character unfit for building or ornamental purposes. Several localities have, however, been pointed out by Professor R. D. Irving in his report upon the geology of central Wisconsin (*Wisconsin Geological Report*, Vol. II) as likely to furnish valuable building and ornamental rocks.

At Little Bull falls, on the Wisconsin river at Mosinee, Marathon county, are large rock exposures of a greenish-gray mottled syenite, much of which would furnish a handsome and excellent building and ornamental stone, and which could be quarried with great ease. A very similar rock is found on the Eau Claire river, at the crossing of the Stevens Point and Wausau road, but is here coarser than that variety of the Little Bull Falls syenite which is best fitted for building purposes.

A short distance west of Wausau, in the southeast quarter of section 21, township 29, range 7 east, is a small granite quarry owned by Mr. Kolter, on which a special report has been made. The stone has some considerable local value. The ridge upon which this quarry is located extends 3 or 4 miles. A rock very similar to this is also found on the south side of the valley of Little Rib river, on the southeast quarter of section 29 in the same township, but it is not exposed.

At the falls of Rib river there is found a heavily-bedded greenish syenite, which breaks readily into rectangular blocks.

In the valley of the Wisconsin river, around Grand Rapids, Wood county, there are numerous exposures, natural and artificial, of reddish granites, some of which could be easily quarried for building stone, but most of them show a decided tendency to decompose upon exposure. At Grand Rapids there is exposed in the bed of the river, at low water, a deep red, handsome granite, which would probably have considerable value as a building stone, and could be quarried quite readily during times of low water. The amount of quarriable rock is not, however, very great.

In the valley of Yellow river are some exposures which merit special attention.

In Hemlock creek, at the crossing of the wagon-road from Grand Rapids to Dexterville, is a fine-grained, flesh-colored granite, which, though showing some tendency to weather and even to stain, would furnish a very handsome, readily-dressed rock.

On Yellow river, at Big Bull falls, on sections 15 and 16, township 24, range 3 east, are large exposures of a medium-grained red granite extending along the bed and banks for a quarter of a mile. It is an unusually fine stone, taking a handsome polish. Polished specimens were exhibited in the Wisconsin collection at the centennial exhibition at Philadelphia, where they were regarded as among the finest of the polished granites exhibited.

On section 3, township 22, range 3 east, 3 miles north of Dexterville, there is in the bed of the river a greenish-gray quartz-porphyry similar in texture to those of the isolated Archæan patches in the southern part of the state.

At Black River Falls there is in the bed and along the bank of the river a continuous and large exposure of medium-grained pinkish granite. There are several spots where extensive quarries could be opened. The Chicago, Milwaukee, Saint Paul, and Ohio railroad crosses the river at the town, and convenient facilities for loading and transporting the granite could probably be arranged for. Specimens of this rock were taken.

On Black river, in the stream, about 1 mile above Black River station, is a ledge 25 feet high and 150 feet long of fine-grained, dark reddish granite.

Above the mouth of its east fork there are exposures and ledges of red granite as far as to French's mill, in section 25, township 23, range 3 west. At the mill the exposures are large; the stone is reddish, fine-grained, and uniform-textured, and would make a handsome building material.

Three-quarters of a mile west of Neillsville, where the wagon-road crosses Black river, on southwest quarter of section 15, township 24, range 2 west, is a fine grained, light pinkish, slightly gneissoid and very quartzose granite, hard and compact, and which appears to be a very fine ornamental granite.

The gneissoid and red granites of Black and Yellow rivers resemble one another closely and appear to be directly continuous with one another underneath the sandstone, which nearly everywhere between the two rivers is the surface rock. Occasionally the crystalline rocks come to the surface in the interval, and are then of the same character as in the rivers, as for instance on O'Neill's creek, in section 1?2, in township 24, range 1 west, Clark county, where red granite is exposed; and on a high bluff in the northeastern part of township 23, range 2 east, whose upper portions are reported to be of red granite, with sandstone layers at lower levels. (*a*)

These notes show quite conclusively that there is in the southern and southwestern parts of the main Archæan area of central Wisconsin and its branches a large number of localities where are found granitic and syenitic rocks of excellent quality for building and ornamental purposes, in many of which the rock can be readily quarried, and it seems probable that in course of time these stones will find their way into the market.

Beside the main Archæan area there are in the southern central part of the state a number of small patches or islands of granite, quartz-porphyry, and quartzite projecting through the overlying Silurian rocks. Previous to the census year no regular quarrying had been done in these rocks, but at the close of that year a great demand arose in Chicago for paving stones of a durable character, which led to the opening and working for that purpose of several quarries in these outlines, which happened to lie near the means of transportation to that city.

Owing to their nearness to the thickly-settled portions and great cities of Wisconsin and Illinois, and to means of transportation, these small areas all seem likely to sooner or later become important centers of the quarrying industry.

At the present time the most important quarry of these areas is that at Montello, where a medium-grained, dark, rather dull pink granite is quarried. It was first opened chiefly to obtain paving stones for Chicago, but has from the first furnished considerable quantities of building and ornamental granite. The stone takes a fine polish, but owing to its small grain and the even distribution of the constituent minerals its appearance is not as showy or handsome as that of many other granites. It is a very durable and reliable stone, having also apparently great strength. The extent of quarriable rock is very great.

The quarry near the village of Waterloo, Jefferson county, in an outline of nearly white quartzite, is perhaps next in importance. It furnishes as yet only paving stones and macadam material. The paving blocks are split more smoothly and regularly than any others I have seen in Chicago from the east or from Wisconsin. They appear harder and likely to be more durable than those from the Montello quarry. An attempt is being made to get this stone out in large blocks adapted for building and ornamental purposes.

A quarry has been opened in the Moundville quartzite-porphyry, which also is worked only for paving blocks, all of which have as yet been sent to Chicago. Monroe street, from State street to Wabash avenue, in that city, has been paved with it. The stone is very hard and well suited for that purpose, and blocks out easily though somewhat roughly into pieces of requisite size. The stone takes a very handsome polish and is very dark, almost black, when so finished.

Some 5 or 6 miles from Portage, at the east end of the ranges, a quantity of jasper has been taken out, and some citizens of Portage are experimenting with it to learn its value. The pieces taken have been handsomely polished and present the appearance of beautifully-grained dark mahogany. I have been unable to learn whether the locality yields large quantities of this stone, and whether it can be obtained in blocks of considerable size, but I judge from reports that the only difficulty anticipated by the owners is that of properly shaping the pieces taken out.

The following description includes fuller statements as to some localities already named:

On the line of the Wisconsin Valley railroad, between Centralia and Junction City, are several deep cuttings, which expose usually crumbling and partially-decomposed laminated gneissic rocks. The exposures are very poor and the rock is generally out of position. About 3½ miles north of Centralia is a cutting 400 feet long, through a rather fine grained, granular-textured, pinkish granite. This rock consists of brownish, translucent, granular, glassy quartz largely predominating; pinkish bright-lustered feldspar, and fine black mica sparsely but uniformly scattered. It would dress readily, but shows some tendency to weather and iron stain.

At Little Bull falls, on the Wisconsin river at Mosinee, Sec. 29, T. 27, R. 7 E., Marathon county, are quite large rock exposures. The river here is divided into two widely-separated channels by a high, rocky island about a quarter of a mile in width. On its northeast end this island is itself cut by several smaller channels, dry at low water, which show high walls of bare rock. Most of the water of the river passes through the easternmost channel, which in one place, for a distance of 130 feet, is a gorge only 35 feet wide. The main fall of the river was formerly in this gorge, but has lately been moved down stream by a dam erected below. The rocks of the various exposures at this place are all closely allied and may be designated by the general term of syenite. They are all characterized by the presence of much greenish-black amphibole and white striated feldspar, the quartz, though present, being always subordinate. Two general kinds were noted. The prevailing rock is a moderately-coarse grained, highly-crystalline syenite, with a greenish-gray mottled appearance, and without any sign of parallel arrangement of the various ingredients, which are uniformly intermingled. On a weathered surface this rock appears greenish to white, the latter color being due to a kaolinization of the feldspar. On a fresh fracture the two main ingredients are readily perceptible to the naked eye. The hornblende is usually of a bright-lustered,

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greenish-black color; the feldspar facets are commonly white, translucent, and beautifully striated, as can readily be seen with an ordinary lens. More rarely pinkish feldspar occurs. That variety of this rock which has a medium degree of coarseness presents a very handsome appearance on a dressed surface, and, since it shows no tendency to iron-stain or decompose, might make a valuable building stone. The second variety found here is very much finer in grain, and of a dark greenish-gray color, showing the crystalline texture only under the lens, and then not plainly. It is evidently merely a phase of the coarser rock. It occurs both in small embedded patches and in large, distinct outcrops. According to the microscopic examination these finer kinds, while having the same ingredients as the coarser, show a larger proportion of hornblende, and may be designated as "hornblende rock". Chlorite appears to occur in all, more especially in the finer kinds, as an accessory.

On the Eau Claire river, at the crossing of the Stevens Point and Wausau road, Sec. 7, T. 28, R. 8 E., there is a fall over coarse pinkish syenite resembling that on the Wisconsin river near the Mosinee hills, and also the prevailing syenite at Big Bull falls, a short distance northward.

On the upper Eau Claire, in Sec. 4, T. 29, R. 10 E., are exposures of a very coarse, rough-textured, feldspathic granite, consisting of pink, cleavable feldspar, very large-flaked black mica, and gray quartz.

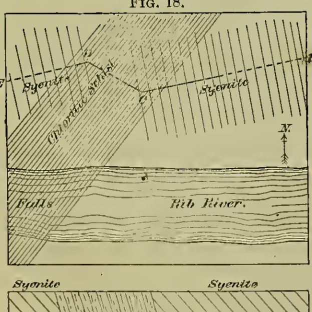
Westward from Wausau, in T. 29, R. 7 E., a number of outcrops occur. Near its south line this town is traversed by Rib river. In Secs. 21, 22, 27, and 28 there is high ground trending north and south, which rises from 200 to 300 feet above the Wisconsin at Wausau. In the S. E. quarter of Sec. 21, on the south slope of part of this ridge, a peculiar, fine-grained feldspathic rock is exposed and is quarried to some extent on Mr. Kolter's land. This rock has a brownish-pink color, the least weathered portions showing a grayish tinge; it is rather fine grained, and has a marked granular texture, looking almost like a mechanical rock. The most abundant ingredient is a pinkish feldspar in cleavable fragments up to one-twentieth of an inch across. With this is much granular brownish quartz, and a little blackish mica in fine flakes, making the rock a granite. No arrangement of the minerals in parallel lines is perceptible. In the quarry the rock is seen to be nearly horizontal, dipping not more than 10° in a due south direction. A total thickness of about 3 feet was seen. Large thin slabs, from 2 to 4 inches thick, splitting off parallel to the bedding, can be obtained.

Near Single's mill, in the north part of the S. E. quarter of Sec. 29, in the same township, and on the edge of a part of the same high ground, are exposures of a whitish, slaty, granular quartzite, in places iron-stained. Under the magnifying glass this rock is seen to be made up of rounded grains of glassy quartz, and some few places were noted where the variety with granular texture grades into a non-granular, glassy quartz. Scales of silvery mica occur on the surfaces of laminæ. The bedding structure is distinct, and shows a strike of N. 75° E. and dip of 56° S. E.

About half a mile from this place, and on the south side of the valley of Little Rib river, S. E. quarter of Sec. 29, the northeast face of the ridge shows quartzite in large exposures. The rock here is glassy, translucent, and occasionally iron-stained, resembling that of Rib hill. The bedding is obscure. On the slope of the hill below, the roots of the trees of a heavy windfall have upturned numerous fragments of a brownish-pink, granular-textured feldspathic rock, similar to that at Kolter's quarry in Sec. 21. Half a mile northeast on the north face of the same elevation, N. E. quarter of S. E. quarter of Sec. 30, a high ledge shows the same feldspathic rock, striking N. 80° E. and dipping 50° N. W.

At the falls of Rib river, S. E. quarter of Sec. 28, T. 29, R. 5 E., are large exposures of greenish chloritic schist and syenite. On the south side of the river, at a point near the lower left-hand corner of Fig. 18, is a rocky point about 15 feet high, showing heavily but distinctly bedded greenish syenite, dipping 20° E. and striking N. 8° W. The uppermost layer, about 3 feet thick, is moderately-coarse grained, mottled green and gray, weathering white. To the lens it shows much grayish quartz, green amphibole, and white altered feldspar, the last least abundant, though coarsest of the three. In some specimens greenish chlorite accompanies the hornblende. The next layer below, 4 feet thick, is a very much finer grained, almost aphanitic, greenish-gray rock, containing apparently a good deal of chlorite. The weathered surface is white, with numerous green, epidote-colored blotches. Microscopic examination shows that the ingredients of this fine-grained rock are the same as those of the coarser one above, but that the amphibole and feldspar are both more altered. This rock breaks out very readily into rectangular blocks, the planes of easiest cleavage lying at right angles to the bedding. The lowest layer, 3 feet thick, is again of coarse variety like that of the uppermost bed.

FIG. 18.

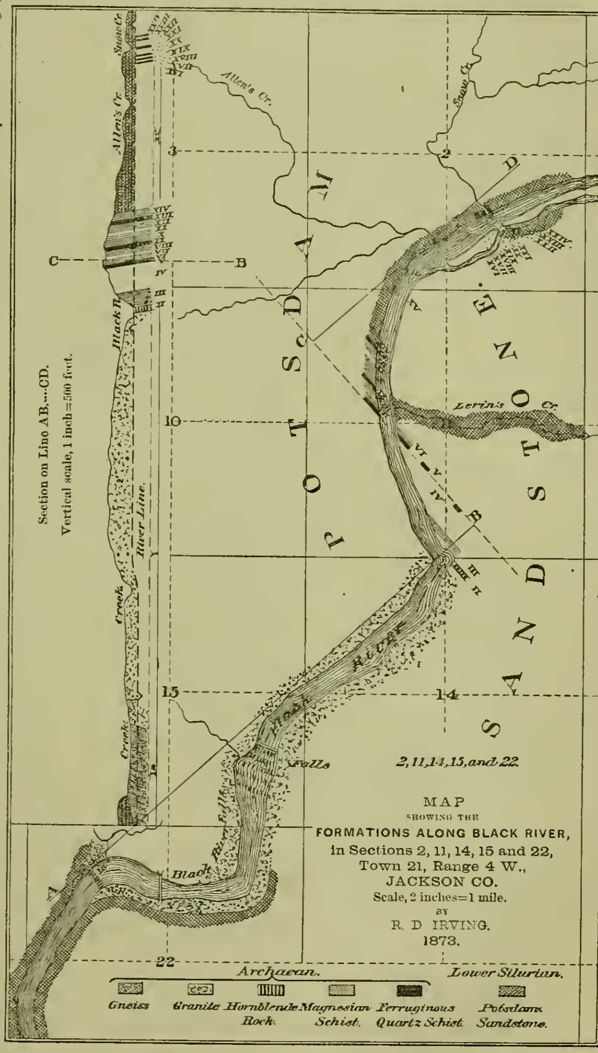


Section on the line BCDE.

ROCK OCCURRENCES AT THE FALLS OF RIB RIVER.
Scale, 1 inch=50 feet.

At Hemlock creek, at the crossing of the wagon road from Grand Rapids to Dexterville, in the N. E. quarter of the S. E. quarter of Sec. 5, T. 22, R. 4 E., are ledges of rather fine grained, flesh-colored, gneissoid granite. Translucent, wine-colored quartz, and pinkish orthoclase, in small brilliant facets, make up most of the rock; the mica is sparse, in fine, green-black flakes, which have a distinct linear arrangement. This rock is a handsome one, and would probably dress well, though showing some tendency to weather and iron stain. The bedding directions appear to show a strike of N. 60° E. and a dip of 70° S. E.

On Yellow river itself, the southernmost Archæan exposure is to be seen about 2 miles north of Dexterville, in the N. half of Sec. 14, T. 22, R. 3 E. The rock here is medium-grained, pinkish, quartzose, gneissoid granite composed chiefly of limpid quartz and orthoclase feldspar, the former the most abundant. Mica is present in fine black scales arranged in parallel lines. The strike appears to be N. 55° W. and the dip 60° S. W. Near the top of the river bank, which rises directly from the granite, thinly-bedded, friable, horizontal sandstone is exposed.



On Sec. 3, T. 22, R. 3 E., 3 miles north of Dexterville, there are large flat ledges of gneiss in the bed of the river, bounded on the north by quartz-porphyry. The gneiss is very fine grained, laminated, dark gray to black in color, and consists of a black mineral (mica, hornblende, or both), in small brilliant flakes; and whitish quartz and feldspar. Its weathered surface is earthy and of a dirty white color, but shows the fine lamination even more distinctly than the interior. The quartz-porphyry consists of a light greenish-gray, aphanitic matrix, having the peculiar flaky appearance that is characteristic of the quartz-porphyries of the various isolated Archæan patches of Wisconsin, in which are embedded somewhat sparsely scattered facets of pinkish orthoclase feldspar up to one-sixteenth of an inch in diameter. It is a very tough, compact, rock, and is worn by the running water into smoothed and polished surfaces. This porphyry appears to penetrate the adjacent laminated rock in a very irregular manner. In one place a mass of the gneissoid rock some 50 feet in diameter is nearly surrounded by the porphyry, the lines of junction between the two being very sharp, and rendered especially noticeable by the different appearances of their weathered surfaces. The lines of junction are not curved, but straight, bearing respectively N. 70° W., W. 20° E., and N. 70° W., the first and last upon opposite sides of the inclosed mass. The strike of the gneiss is N. 25° W., its dip 60° N. E. The porphyry is from 20 to 30 paces wide, and appears to be bounded on the north by the same gneiss as before, with the same bedding. Beyond, porphyry comes in again.

At Big Bull falls, 9 miles north of Pitt's mill, on Secs. 15 and 16, T. 24, R. 3 E., large exposures of medium-grained, highly feldspathic, red granite extend along the bed and in the banks of Yellow river for a quarter of a mile. This granite has a base of cleavable reddish orthoclase, throughout which is quite uniformly distributed hyaline, occasionally smoky, and quartz in irregularly-shaped patches from one thirty-second to one-quarter of an inch in diameter. Mica is present, but is very fine and sparse. For the whole length of the exposure this rock is nearly uniform, and without any tendency to kaolinize. Its peculiar texture, composition, and color combine to make it a very valuable and unusually handsome building granite. Polished specimens of the rock attracted great attention at the Philadelphia exposition, where it was regarded by experts as among the finest of the many polished granites exhibited.

On Sec. 7, T. 24, R. 3 E., another exposure of a similar red granite was noted. Above this point Yellow river is reported without exposures.

BLACK RIVER VALLEY.—The first exposures of crystalline rocks met with in ascending Black river are found a short distance below the town of Black River Falls, T. 21, R. 4 W., in Jackson county. From here they occur in the bed and on the sides of the stream, with only occasional interruptions, as far north as town 28, in Clark county. For the greater part of this distance they are concealed away from the river by overlying horizontal sandstone, through which, however, they occasionally rise in knobby projections. In some of the branch streams also the sandstone is cut through and the crystalline rocks exposed. Along the river the rock ledges in few places only rise to any considerable height above the water.

Granite: Medium-grained pinkish, consisting of a nearly uniform admixture of pinkish orthoclase, in facets up to one-sixteenth of an inch, and fine-grained, translucent quartz. Some mica is present, in fine scales, showing sometimes a slightly stringy arrangement. This granite is exposed from a short distance above the wagon bridge as far north as the north line of Sec. 14, the river in this distance passing through a gorge whose walls sometimes reach a height of 80 feet. In the large exposures at the falls the parallel grain of the gneiss below is almost entirely lost, being only occasionally indicated in an obscure arrangement of the mica. The rock here is traversed by several sets of joints, mostly somewhat irregular, those showing the greatest irregularity trending N. 80° E. and dipping 72° S. E., but having no corresponding structure in the rock. The granite shows the same general character above as at the falls, occasionally—as in the railroad cut on the west side of the river, just above the falls—showing a darker kind than usual from a greater quantity of fine dark mica. In this cut there are to be seen two sets of planes equally marked, one set trending N. W. and dipping N. E., the other trending N. E. and dipping N. W. A distinct stringy arrangement of the mica was noted parallel to the former set. Near the north line of Sec. 15 the granite exposures cease suddenly on the east side of the river, while they continue some distance farther on the west side—a fact to be explained by the northwest strike of the succeeding slaty rocks.

In the river one mile above Black River station on the Green Bay, Winona, and Saint Paul railroad, a ledge 150 feet long and 25 feet high is seen of fine-grained, dark reddish granite, consisting of a rather uniform and close admixture of reddish orthoclase, in fine glittering facets, reddish-brown, translucent quartz, some colorless quartz, and a little, sparsely scattered, fine black mica. Half a mile farther up stream, fine-grained red and gray banded quartzose gneiss is exposed. The gray bands consist of fine-grained, glassy quartz, fine black mica, and white feldspar; the red of brown and red translucent quartz mingled with a little orthoclase. From here to the mouth of the East fork the bed of Black river shows numerous small ledges, 3 to 4 feet high, of contorted gneiss and reddish granite.

Above the mouth of the East fork, which is on Sec. 36, T. 23, R. 3 W., exposures of red granite are seen as far as French's mill, on Sec. 25. The wagon-road, which for half a mile below the mill follows the west bank of the river, has, on the east side, ledges of red granite and on the west a ridge 30 to 40 feet high composed of horizontal, coarse-grained, quartzose, cross-laminated sandstone. In one place the exact junction of the two formations is to be seen. At the mill the granite exposures are especially large, both on the west bank and on a large island in the stream. Two kinds of the granite occur, both presenting a prevailing pinkish weathering: (1) a rather fine-grained, very uniform-textured, dark reddish kind; and (2) a medium-grained, uniform-textured, pinkish-gray quartzose kind, containing colorless, glassy, and pink translucent quartz, pink orthoclase, and fine black brilliant mica. Both kinds appear like handsome building or ornamental granites. No definite bedding structure is to be seen.

Three-quarters of a mile west of Neillsville, at the crossing of Black river, on the S. W. quarter of Sec. 15, T. 24, R. 2 W., fine-grained, light pinkish, slightly gneissoid, and very quartzose granite is exposed, with a vertical dip and E. W. strike. This rock is very hard and compact, and appears to be a fine ornamental granite.

The gneissoid and red granites of Black and Yellow rivers resemble each other very closely, and appear to be directly continuous with each other underneath the sandstone, which nearly everywhere between the two rivers is the surface rock. Occasionally the crystalline rocks come to the surface in the interval, and are then of the same character as on the rivers; as, for instance, on O'Neil's creek, in Secs. 1 and 2, T. 24, R. 1 W., Clark county, where red granite is exposed; and on a high bluff in the N. E. part of T. 23, R. 2 E., whose upper portions are reported to be of red granite with sandstone layers at lower levels.

The amount of these reddish ornamental granites of extraordinarily fine quality occurring on Yellow and Black rivers and in the intervening country appears to be very great.

The following table indicates the location, size, nature, etc., of the various Archæan outcrops in the Silurian area of the state:

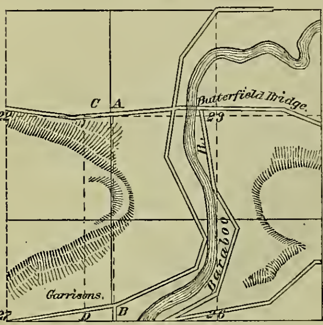
ARCHÆAN OUTCROPS WITHIN THE SILURIAN AREA.

No. on the Fig. page 238.	Name of outcrop.	Location.				Approximate area.	Height of bluff.	Nature of rock.	Distance from main Archæan.
		Sec.	T.	R.	County.				
							Feet.		
I	Baraboo bluffs				Sauk and Columbia.	75 square miles	100 to 700	Quartzite, quartz-porphyry, clay-schists, and quartz-schists.	60
II	Lake mills	24, 25	8	13 E	Jefferson	20 acres	Low.	Quartzite	90
III	Portland	33, 36	9	13 E	Dodge	1/16 square mile	50 to 75	Quartzite	84
IV	Necedah	19 24	18 18	4 E 3 E	Juneau	1/8 square mile	175	Quartzite	28
V	South bluff	21, 22, 23, 25	21	2 E	Wood	3 square miles	200+	Quartzite?	10
VI	North bluff	1	21	2 E	Wood	1/2 square mile	200+	Quartzite?	6
VII	Observatory hill	7	14	10 E	Marquette	1/8 square mile	250	Quartz-porphyry	48
VIII	Moundville	5, 8	14	9 E	Marquette	1/16 square mile	40	Quartz-porphyry	48
IX	Marcellon	7	13	10 E	Columbia	1/16 square mile	75	Quartz-porphyry	52
X	Marquette	34, 35 2	15 14	11 E 11 E	Green Lake	1½ square miles	75	Quartz-porphyry	50
XI	Pine bluff	36	15	13 E	Green Lake	1/3 square mile	100	Quartz-porphyry	54
XII	Pine bluff	2	17	11 E	Green Lake	1/20 square mile	100	Quartz-porphyry	30
XIII	Berlin	2, 3	17	13 E	Green Lake	1/4 square mile	50 to 75	Quartz-porphyry	30
XIV	Montello	9	15	10 E	Marquette	1/16 square mile	40	Granite	42
XV	Spring lake	27	18	11 E	Waushara	1/3 square mile	50	Granite	27
XVI	Marion	12, 13 7, 18	18 18	11 E 12 E	Waushara	1/8 square mile	50	Granite	26
XVII	Waupaca	31	22	12 E	Waupaca	1/8 square mile	100	Granite, etc	
XVIII	Mukwa	25, 26	22	14 E	Waupaca	1/8 square mile	70	Granite	
XIX	Iron mound:								
	No. 1	31	22	3 W	Jackson	1/16 to 1/4 square mile	75 to 200	Ferruginous quartz-schist	
	No. 2	1	21	4 W					
	No. 3	12	21	4 W					
	No. 4	17, 20	21	3 W					
	No. 5	14, 15	21	3 W					

Baraboo bluffs.—On the northernmost portions of the northern of the Baraboo ranges at the lower narrows of the Baraboo river, T. 12, R. 7 E., and also for a short distance to the westward, a great thickness of quartz-porphyry is to be observed. This porphyry resembles that of the several small porphyry areas of the adjoining portions of Columbia, Marquette, and Green Lake counties, and proves at once that we must regard these areas as part of the same formation as that which appears in the Baraboo ranges.

On Secs. 23 and 26, T. 12, R. 7 E., Sauk county, the Baraboo river passes the north quartzite range in a gorge known as the lower narrows of the Baraboo. The passage is nearly half a mile in width, the level bottom extending to the foot of the cliffs on either side. The cliffs rise 400 feet above the river, and show finely the great beds of quartzite and associated strata. The gorge is much wider than needed by the small stream that now occupies it, and may, as already suggested, have been at one time used by the Wisconsin, as the valley of Devil's lake seems to have been. It is unlike the latter valley in having been, in part at least, formed first before the Potsdam period, as indicated by the way in which horizontal sandstone and conglomerate ledges occur around the heads of steep ravines that extend down the cliff toward the main gorge.

FIG. 29.



MAP OF THE LOWER NARROWS OF THE BARABOO.
Scale, $1\frac{1}{2}$ inches = 1 mile.

Beginning with the north end we find, forming the north face of the range, in bold northward-sloping ledges, quartz-porphyry about 600 feet in width. This porphyry is for the most part dull red to pinkish on the weathered surface, which is a good deal altered, often iron-stained, and has generally a whitish undercrust. The least altered specimens show a brownish-pink matrix, through which are scattered, very thickly, large facets, up to one-eighth of an inch in diameter, of bright red cleavable feldspar, and, more sparsely, minute facets of a white kind. In nearly all specimens a few small greenish-black blotches, apparently composed of fine mica scales, occur, as also small iron-stained cavities, which often show linings of minute quartz-crystals. The porphyry is very distinctly bedded, showing an E. W. strike, and a dip of 58° to 60° N. Toward its lowest portions, and higher up on the bluff, it becomes gradually more slaty in character, the feldspar facets, though very numerous, becoming at the same time less well defined, and the surfaces of the laminæ becoming covered with a soft, greasy mineral. This finally changes to a distinct schist, [a] about 80 feet wide, containing a large proportion of the soft mineral, and allied to the greasy quartz-schists occurring at Devil's lake, but without transverse cleavage. Continuing the ascent of the bluff southward quartzite is seen lying immediately underneath the schist and forming the body of the ridge to the foot of its southern slope. At first this quartzite is much veined and seamed with reticulating veins of white quartz, in which fine specular iron is occasionally to be seen.

Marcellon.—On Sec. 7, in the town of Marcellon, Columbia county, on each side of the road in the south half of the section, are two low, rounded hills, 40 to 60 feet in height, of quartz-porphyry. The rock exposures are large and are much rounded and weather-worn, being separated into numerous bowlder-like masses by wide-open, earth-filled joints. The weathered surfaces have a prevailing pinkish tinge, giving the idea that the rock is largely composed of pink feldspar. On obtaining a fresh fracture, however, only a very few, sparsely scattered, minute feldspar faces are to be seen, the mass of the rock being composed of a brownish to blackish compact matrix. Two general varieties occur, one presenting a light brownish color, showing a tendency to flake off in fragments that are translucent on the edges, and containing no distinguishable feldspar crystals, the other having a dark gray to black matrix, in which are to be seen a few distinct crystals of feldspar and numerous copper-colored points of iron-sesquioxide. The rock has nearly the hardness of quartz, and fuses only with the greatest difficulty. A more siliceous character as compared with other quartz-porphyries of the state is thus indicated, and the indication is borne out by the content of silica—76.98 per cent.—as shown by analysis. We have evidently, in this case, a porphyry which, in its large contents of silica and in the sparseness of its feldspar crystals, approaches the true felsites (petrosilex hälleflinta). Quite a distinct and uniform set of bedding joints occurs, the strike being N. 32° E., the dip 65° to 75° N. W. Numerous cross joints traverse the rock, and, on weathered portions, cause it to fly into smooth-faced, angular fragments at the least blow of the hammer. The surrounding country is occupied by the Potsdam sandstone, which is exposed at many points.

Observatory Hill.—Six miles north of the Marcellon outcrop, in the S. E. quarter of Sec. 7, in the town of Buffalo, Marquette county, a knob of quartz-porphyry rises 250 feet above the general level and 490 feet above lake Michigan. On the flanks of the hill and up to a vertical distance above the base of 125 feet are horizontal sandstone ledges; above, to the top, are nearly continuous outcrops of porphyry, with a not very plain N. 32° E. strike and 60° N. W. dip. These bedding directions are the same as on the Marcellon outcrop.

Moundville.—On the edge of the Fox River marsh, at the head of lake Buffalo, on the line between Secs. 8 and 5, T. 14, R. 9 E., Moundville, Marquette county, are three low, rounded outcrops of quartz-porphyry. These are 5 miles, in a direction 10° N. of W., from Observatory hill, which is the nearest Archæan outcrop. No other rock shows in the neighborhood, the country being heavily drift-covered. The largest outcrop is on the east end of a low bluff 35 feet high and several hundred feet in length. There are quite marked appearances here of the same N. E. strike and N. 60° dip as seen at Observatory hill and in Marcellon. The rock has a dark brown matrix, resembling in this regard the Marcellon porphyry, from which it differs, however, in showing throughout traces of crystalline structure, and quite thickly scattered large brown feldspar surfaces. A few crystals are white and translucent. The weathered surface is often a bright pink color. Mr. Wright's microscopic examination shows that fine magnetite particles are abundant. Their existence is not rendered evident even by the use of the ordinary lens. The silica content is 72.76 per cent.

[a] This schist is probably non-magnesian, like the schists of Devil's lake, ordinarily called talcose.

Seneca (*Pine Bluff, R.* 11 *E.*).—A rounded elliptical knob of quartz-porphyry, 100 feet high, one-eighth of a mile long, and a quarter of a mile wide, lies on the north side of the White River marsh, in Sec. 2, T. 17, R. 11 E., Seneca, Green Lake county. The greatest extension of the hill is in an east and west direction. It is largely rocky, but there are no abrupt rock ledges, the exposures being almost entirely surfaces conforming to the general contour of the hill, and on a level with the surrounding sod. In places the slopes of the hill are covered with angular fragments apparently split off by frost. This is a peculiarity not noticed upon any of the other porphyry outcrops, and appears to be due to the large content of comparatively coarse cleavable feldspar. The hill is only about 2 miles south from the granite hills of Spring lake, in T. 18, R. 11 E., Waushara county. The surrounding country is marshy and drift-covered, and shows no outcrop of horizontal rocks. The loose fragments are many of them smoothed on one side, and some surfaces are most beautifully striated. Owing to the broken condition of the outcrop, no definite bedding planes were made out, though weathered specimens brought away show distinct traces of lamination.

This porphyry in its least weathered portions shows a light gray to whitish fine-grained matrix, in which, with the lens, can be seen what appear to be angular grains of quartz. The glassy feldspar crystals are also abundant. The weathered surface is brownish, with a kaolinized undercrust. Nearly all of the rock shows signs of weathering. The silica content is 76.39 per cent.

Marquette and Berlin.—The large outcrops of quartz-porphyry in Secs. 34 and 35, T. 15, R. 11 E., and Secs. 2 and 3, T. 14, R. 11 E., near the village of Marquette, Green Lake county, were originally regarded as within the central Wisconsin district, of which, however, by subsequent agreement, the Fox river was made the southern boundary. They will, therefore, be described by Professor Chamberlin, in whose district is also the outcrop at the city of Berlin, Green Lake county. As the writer has examined both localities carefully, he may be permitted to allude to the nature of the rock of each, for the sake of comparison. In the Marquette outcrops the prevailing rock noticed has a black, compact, flinty matrix, which is streaked with white non-continuous lines. These lines are for the most part very prominent, and are frequently much contorted, the whole rock having a very evident parallel grain. The feldspar crystals are minute and sparse. The silica content is 70.29 per cent. less than that of any other of the Wisconsin porphyries. The general course of the contorted laminæ points to the same N. E. direction of strike as is observed on the Marcellon, Observatory Hill, and Moundville outcrops.

The Berlin rock has a dark bluish-gray matrix, much streaked with white, and having a peculiar fine, granular, quartz-like texture as seen under the lens. The feldspar crystals are small, grayish to brownish, and rather numerous. The lamination is very fine and distinct, and often contorted, and the silica content 74.37 per cent.

Montello.—In the village of Montello, on the west side of Sec. 9, T. 15, R. 10 E., Marquette county, is an elliptical-shaped, rounded mound of pink granite, about a third of a mile in length and 40 feet high. Over most of the hill the rock is quite uniform in a fresh fracture, though presenting a weathered surface from bright pink to dull grayish-pink in color. The weathering is very slight, however, and the rock shows almost no tendency to decompose. It has a medium grain, close texture, is of a bright pinkish color, and without sign of arrangement of the ingredients in lines. These are: Rath er large flaked, pinkish, cleavable feldspar, predominating; somewhat granular, fine, pinkish, translucent quartz, abundant; and greenish-black mica sparsely scattered in blotches made up of very fine flakes. In places thin, light green, epidote-colored seams occur. Somewhat irregular northwest joints traverse the rock, which is, however, for the most part structureless, and is quarried by firing the pieces that crack off, presenting a conchoidal fracture. On the north side of the west end of the mound occurs a vertical layer 3 feet wide, trending N. 55° E., of a soft, greenish, highly schistose, decomposing, chloritic rock. The least weathered specimens show a blackish color and some tendency to a crystalline texture. The vein is weathered down for 2 or 3 feet below the inclosing granite walls, both of which are seen. The schistose laminæ are parallel to the walls. Greenish epidote seams in the rock near by have the same trend as the vein. Though this granite may be somewhat difficult to obtain in dressable masses, it would probably make a very handsome and durable building and ornamental stone.

Necedah.—Dotting the great sand plain of the Wisconsin in Juneau and Adams counties are numerous bold, castellated outliers of the Potsdam sandstone rising abruptly from the plain and constituting very marked features of the scenery. From the same plain, and only about 3 miles west from one of the greatest of the sandstone bluffs—Petenwell peak—rises the quartzite hill at the foot of which the village of Necedah is built. The rounded contour of this hill serves to mark it at once as different in nature from the sandstone bluffs of the adjoining region.

The main Necedah bluff lies on the N. W. quarter of Sec. 25, T. 18, R. 3 E., the town line crossing over its eastern end; it is about half a mile in length, with its greatest extension east and west, and is highest and at the same time most bold and rocky on its eastern end, which rises 170 feet above the street below and about 510 feet above lake Michigan. A short distance southeast of the main bluff, on the N. W. quarter of the S.W. quarter of Sec. 19, T. 18, R. 4 E., is a small, craggy hill, 75 feet high, of the same rock as that composing the main hill, the intervening low ground being underlaid by horizontal sandstone.

The exposures on the main hill are mostly on the eastern and southeastern portions, where in places they rise nearly precipitously from the low ground at the foot. The rock seen here is for the most part a glassy, translucent, subgranular, grayish quartzite, much more nearly allied to the quartzite of the Rib and Mosinee hills, in Marathon county, than to that of the Baraboo ranges. Much of the rock is quite dark gray in color, the quartz then being still glassy, but smoky-tinted. Numerous small cavities and seams occur lined with half crystalline quartz and carrying a soft, pinkish, clayey substance; bluish-white quartz veins, ½ inch to 2 inches in width, and nests are also common, and these carry frequently fine-flaked, brilliant, specular iron, which occurs also occasionally in quite large masses, similar to those found in the Baraboo quartzite. No parallel grain is to be seen in this rock, nor any definite bedding planes. Numerous quite close joints occur, however, and these cause the rock to weather into smooth-faced, sharp-angled fragments. On the smaller bluff a very distinct parallel grain is to be seen trending N. 75° W., and showing a corresponding dip of 45° N. Here much of the quartzite is of a light pink color, looking, on a fresh fracture, almost like a fine-grained, pinkish granite, but the only prominent mineral is subgranular, translucent, pinkish quartz. Some specimens show mica plainly in very sparsely scattered small scales. In many places little centers of iron-staining seem to be decomposing mica scales. Other portions of this rock are opaque, white, and distinctly granular, and are seamed with fine black lines, arranged so as to show discordant stratification. These seams, when split open, appear to be composed of blackish mica. Bluish-white veins and nests occur here also.

Marion.—In the town of Marion, T. 18, R. 11 E., Waushara county, are three low granite knobs. Two of these, Stone and Pine bluffs, are on the N. E. quarter Sec. 27, about two miles in a N. N. W. direction from the quartz-porphyry hill of the town of Seneca, Green Lake county; and the third, a larger and bolder hill, lies on the eastern border of the marsh, on Secs. 12 and 13, and stretches to some extent over the line into the town of Warren. On all of these areas the rock observed is nearly the same, a pinkish, feldspathic granite, mottled with gray and green, closely resembling the Montello granite, from which it differs, however, in having a coarser grain, a less close texture, and a marked tendency to decompose. Reddish cleavable feldspar is the principal ingredient, occurring in facets up to one-eighth and one-quarter of an inch in diameter; quartz is abundant, fine, granular, and translucent; mica is sparse, and scattered in small greenish-black blotches. Large whitish porphyritic feldspar occurs. There is no sign of any arrangement of the ingredients or of any parallel grain to the rock. No definite bedding planes were observed on any of the outcrops, though numerous crossing joint planes occur, and quite regular flat slabs are sometimes obtainable. Veins of white quartz occur. The most marked characteristic of the rock is its tendency to weather and shell off in crumbling masses. Some of the large flat surfaces are so far crumbled as to be penetrated readily by a horse's hoof. The rock from these outcrops would polish easily, but its tendency to crumble renders it less valuable than the Montello granite.

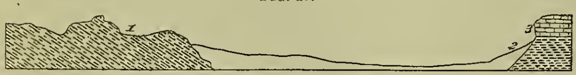
The following regarding this state is from the report on Eastern Wisconsin, by T. C. Chamberlin:

Mukwa.—The isolated outlier found in the S. E. quarter of the N. E. quarter of Sec. 26, and the N. W. quarter of the S. W. quarter of Sec. 25, town of Mukwa, Waupaca county, lies nearest the main Archæan area. This outcrop seems to have been unknown to the geologists heretofore, and came to my attention through information derived from Mr. Carr, of New London.

It consists of three large, and as many small, rounded, elongated, dome-like outliers, arranged nearly in a line trending W. 35° to 40° N., and rising near the center to a height of nearly 70 feet.

The rock consists chiefly of red feldspar, with which is associated a less quantity of quartz and a small and varying amount of a dark mineral, which was not seen in the distinct crystalline form, but which seemed to be an aggregation of minute blended blades of biotite. The crystals of feldspar are never large, seldom exceeding a quarter of an inch in length, and are usually quite minute, so that some portions, from which the dark mineral is absent, closely resemble red quartzite in appearance. The rock is intersected in various directions by veins of quartz. It is also cut into pyramidal masses by smooth, straight fissures, which are usually inclined at an angle of from 60° to 85° to the horizon. In trend these fissures constitute three groups: the first nearly north and south; the second nearly east and west; and the third northwest and southeast. There are also large irregular fissures, and occasionally points are to be observed from which an unusual number, both of the smooth and the irregular ones, seem to radiate.

FIG. 17.



PROFILE SECTION SHOWING THE RELATIONS OF THE MUKWA GRANITE.
1. Outlier of granite. 2. Potsdam sandstone. 3. Lower magnesian limestone.

The rock is very little affected by weathering, and affords an excellent building material, though the form of the blocks is unfavorable, and it is somewhat hard to dress.

No rock was found in contact with it, but about half a mile to the southeast, in the line of its trend, the lower magnesian limestone appears, into whose horizon the outcrop rises, though it lies chiefly in that of the Potsdam sandstone, as shown in the accompanying profile.

Berlin.—At Berlin, 30 miles south of the above, we next find an outstanding Archæan mass, (*a*) consisting of three large elongated domes arranged *en échelon*, bearing northeast. The rock is composed essentially of small crystals of orthoclase feldspar disseminated through a peculiar crypto-crystalline base of felsite and quartz, forming a quartz-porphyry. The crystals of feldspar are usually grayish before weathering, becoming reddish afterward. The base

a Comp. Dr. Percival's Report of 1856, p. 106.

in its unweathered state very much resembles quartzite, and is of dark grayish cast with a very slight reddish tinge, so modified by its translucency as to give to the whole what may be called a water hue. Very thin splinters may be fused before the blow-pipe with difficulty, forming a transparent glass-like bead. The effect of weathering is marked and peculiar. The color changes to a light reddish, pinkish, or grayish white, and occasionally to a bright red, while the mass becomes opaque and finely granular, and so soft as to be easily cut. There are occasionally spots, streaks, or leaves of dark material in the base, which are doubtless the portions referred to by Dr. Percival as "interlaminated hornblende and mica".

The rock is very uniform in character at all points exposed. It presents an obscure parallel structure giving rise to a somewhat definite system of cleavage, but traces of distinct bedding were not observed. The mass is traversed by extensive fissures, which are readily arranged in three groups, the predominant one of which bears northwest, and the smaller ones east of north and north of east, respectively, thus dividing the horizon into nearly equal arcs; but none seem to be dependent upon the cleavage structure of the rock.

Pine Bluff, R. 13 *E.*—Seventeen miles south of Berlin there rises out of the flood-plain of the Grand river a conspicuous mass of quartz-porphyry known as Pine Bluff. It ascends by steep and even precipitous acclivities to a height of 100 feet, and being entirely isolated from the surrounding elevations, and largely bare of soil and vegetation, becomes a striking object. The rock consists of white-gray and flesh-colored crystals of orthoclase and of glassy feldspar set in a very hard gray or black quartz-felsite base. The crystals of feldspar vary in size from three-tenths of an inch in length downward, but are rendered conspicuous by contrast of color. The rock is susceptible of a very high and beautiful polish, but is wrought with difficulty on account of its hardness. The dip is about 20° to the east of south. Obscure glacial striæ, still preserved, testify to its endurance. Their direction is south 45° west. The accompanying profile exhibits its relation to the Silurian formations, from which it will be seen that it rises to about the base of the Galena limestone.

FIG. 19.

NORTH AND SOUTH SECTION THROUGH PINE BLUFF.

1. Quartz-porphyry, Pine Bluff. 2. Lower magnesian limestone. 3. St. Peter sandstone. 4. Trenton limestone. 5. Galena limestone.

Marquette.—Near Marquette, a little more than 12 miles west of Pine Bluff, very similar quartz-porphyries display themselves in more considerable force, constituting a group of prominent hills. A portion of the rock is precisely identical in character with that of Pine Bluff, and the greater mass is but an unimportant variation from it, but certain portions depart from the porphyritic character, and become almost or entirely crypto-crystalline. One variety of this kind very closely resembles the more homogeneous of the red Huronian quartzites, and another is a compact, close-textured rock, usually of dark color, but sometimes greenish. Neither of these varieties occupies exclusively any one horizon, but the quartzite-like variety is found in the more southern outcrops, the last-mentioned kind immediately north of that, the darker porphyries next, and the coarser, lighter-colored ones in the most northerly exposures.

The bedding is very obscure, but the laminations of certain portions and belts of particular varieties of rock show the strike to be northeastward. The dip is made out with much less certainty, but appears to be to the northward, and to vary from 15° to 45°.

Though the Berlin porphyry differs from that of Pine Bluff and of Marquette in the absence of glassy feldspar, yet the close lithological alliance of the three is very evident, and they doubtless all belong to the same group of the Archæan series. The general strike of these formations, projected westward, encounters several similar outliers that are described in Professor Irving's report, and still farther southwest he has found similar quartz-porphyry overlying the Baraboo quartzite. There seems to be sufficient reason for regarding the latter as Huronian, so that the porphyries must be regarded as a newer portion of that formation.

All of these masses present the rounded contour of glaciated surfaces, and still bear the glacial groovings, and, in some cases, even remnant polished spots, and from all these trains of porphyry bowlders stretch away in the direction of the striæ.

Portland and Waterloo.—Thirty-five miles south of Pine Bluff, over an area entirely covered by Paleozoic rocks, some as recent as the Galena, we again encounter the Archæan rocks in the form of the quartzites of Portland and Waterloo.

The outcrops in the town of Portland are several in number. The most southwesterly is an oval island lying mostly in the S. E. quarter of Sec. 33, and is entirely surrounded by lowland or marsh. The outcrop attains but a slight elevation, and its rounded contour shows abundant evidence of the glacial agencies that have swept over it. Not only striæ, but deep, broad furrows, show the direction of movement to have been S. 15° to 20° W. Bowlders appear in great force upon the protected side of the island and doubtless thickly underlie the deep morass in that direction, as they appear again upon the hills beyond. Directly to the east, in Sec. 34, there is a slight exposure near the base of a somewhat elevated north and south ridge, of which it doubtless forms the nucleus, if not the chief portion.

Less than 1 mile north of these outcrops the quartzite again discovers itself on the brow and west flank of the ridge facing Waterloo creek. There is no evidence that any later formation overlies the quartzite between this and the two preceding outcrops, and so the three will be found mapped as constituting a single Archæan area. A short distance farther to the north (N. W. quarter Sec. 27) the quartzite rises in the midst of a marsh-like lake, constituting Rocky island. It may be characterized as a low dome covered with unsymmetrical *roches moutonées.*

About 2 miles southeast, at the foot of a hill, and on the edge of a marsh, occurs a low and limited outcrop (Sec. 35, S. E. quarter, and Sec. 36, S. W. quarter). One-half mile to the northeast, across a marsh, there occurs another exposure, similarly situated in a southern extremity of a north and south ridge, and about the same distance to the southwest still another one may be seen, the three lying nearly in a straight line and separated by marshes. They are regarded as being projecting knobs of a common area, and are so mapped. Between these and the three outcrops first mentioned, as also between both these and Rocky island, later formations intervene, so that they must be regarded as forming three distinct, though closely associated, surface areas.

MINNESOTA.

[Compiled mainly from notes by Professor N. H. Winchell.]

CRYSTALLINE SILICEOUS ROCKS.

More than half of the state is underlaid by that general class of rocks—the crystalline—to which granite belongs, and consequently the state has almost every variety of crystalline rock. These rocks also exhibit all degrees of durability and value for building purposes. The granular crystalline rocks are generally very durable; and, whenever they are exposed above the drift, can be wrought with profit and with the most satisfactory results. While in the northern part of the state there are large exposures of very fine light-colored granites, beyond the limits of settlements and roads, and particularly at lake Saganaga, those in the valleys of the Mississippi and Minnesota rivers are of more special and immediate interest. These have been somewhat quarried, and their products as building materials can be seen in some of the principal buildings in various parts of the state, as well as in cities outside the state. The gray granite that is quarried at Sauk Rapids, and which generally is seen in Stearns county, consists largely of quartz embraced in a matrix of orthoclase, with but a small proportion of mica or chlorite. Hence it is hard and very durable. The dark mica is biotite, and there is but occasionally a grain of hornblende. This last sometimes prevails largely over all the other minerals in small areas or veins, making a very dark-colored and also generally a coarser-grained rock. There is also occasionally a grain of triclinic feldspar and of magnetite, and some minute crystals of pyrite. These minerals have a relative hardness when expressed on a scale of 10 as follows, 7 being the hardness of an ordinary knife-blade:

Quartz	7
Triclinic feldspar	6 to 7
Orthoclase	6 to $6\frac{1}{2}$
Hornblende	5 to 6
Biotite	$2\frac{1}{2}$ to 3
Muscovite	2 to $2\frac{1}{2}$
Chlorite	1 to 2

About one-half of the whole rock is made up of quartz, and two-thirds of the remainder of orthoclase. About one-half of the rest is triclinic feldspar, and the residue is divided between the other minerals, biotite predominating. It is plain to see that such an assemblage of minerals constitutes a very firm rock, and one that is rather hard to dress, but when once cut to form and placed in a building it will endure indefinitely. The biotite, muscovite, and chlorite serve to make the granites easy to cut and to quarry; and particularly when they lie in sheets or in indistinct belts through the rock, giving it a faintly striped aspect, constituting a gneiss, the rock can be got out easily in large, long slabs or blocks. When these are evenly scattered through the whole rock, the rock is simply softened, and in quarrying the fracture will have to be more completely guided by the plug and feather. For taking a polish the absence of these soft minerals enhances the value of the rock. The durability of the Sauk Rapids granite was tested at Washington under direction of the chief of engineers, and was found capable of sustaining a crushing pressure of from 15,000 to 17,000 pounds per square inch. A quarry at Sauk Rapids has been longest known of all the granite quarries in the state, but it is not now (1880) as vigorously operated as those at Watab or at East Saint Cloud. Blocks 12 by 3 by $1\frac{1}{2}$ feet thick and 10 by $4\frac{1}{2}$ feet by 1 foot thick have been quarried, and blocks as large as 26 by 22 by 5 feet thick might be moved if desired. The material is now used mainly for monuments, formerly also for building and for bridge construction. Among the principal structures in which this stone has been used are the capitol buildings at Des Moines, Iowa (trimmings); the city hall, Minneapolis; Nichols & Dean block, Saint Paul.

The color of this granite, being a neutral gray, makes it suitable for a wide range of architecture. Light-colored and reddish granites are found at Watab, a few miles north of Sauk Rapids, and also in a few places near Saint Cloud and Rockville.

At Watab there are three principal varieties of different textures and colors, each being quarried from a different opening, so that the stone in each quarry is uniform as to texture and color. The red is located to the north of the gray granite, and is separated from it by a distinct line, a change being abrupt (within 6 inches). Although the quarry was opened some years ago, it was not operated during 1880. This stone is being used in the construction of the bridge over the Missouri river at Bismarck, and about 7,000 cubic yards will be used for this purpose. The following is a report on this stone, by Captain Edward Maguire, U. S. A., chief engineer, department of Dakota:

Two kinds of granite were used by the Northern Pacific Railroad Company in the masonry work on their bridge at Bismarck; first, a light-colored and reddish granite, found at Watab, a few miles north of Sauk Rapids, Minnesota. The quality of this stone was good, but its use was abandoned on account of the cost of quarrying it. The bed is very much cut up by seams, and in order to obtain the requisite sized blocks it was necessary to quarry about ten to one. The largest blocks that have been quarried are 6 by 4 by 2 feet thick; some blocks 30 by 12 by 5 feet thick have been moved, but were cut up for transportation. The texture is rather coarse and uniformly crystalline.

Captain Maguire reports an examination of gray granite from the Rock Island quarry, situated in a prairie about 4 miles from Saint Cloud, and there are at least 4 and probably 10 acres of this gray granite from which blocks of any size or shape may be quarried.

While the granites of Stearns county are massive or non-gneissic, those of the Minnesota valley are almost invariably of a laminated structure, and of a reddish color. One of the principal exceptions occurs in the large granite outcrop near the foot of Big Stone lake. The Minnesota Valley granites differ from the Saint Cloud granite, also, in being softer, on account of having less quartz and more of the cleavable minerals, orthoclase and mica. They are also easy to quarry, but they have not been much worked yet. Some of the recent cuts in the red granite near Montevideo, by the grading for the railroad, show a very superior variety of rather coarse grained red granite, which cannot fail ultimately to be in great demand. There are great stoneless tracts of prairie lying south and west of the upper Minnesota Valley region, and extend from near New Ulm to the foot of Big Stone lake.

The so-called granite of Duluth belongs to a very different class of rocks, and is more properly styled "gabbro", a new term derived from Italy, and applied to an igneous rock consisting of the triclinic feldspar, labradorite, augite, and a magnetic oxide of iron containing titanium. These minerals are all softer than quartz, which is wholly absent from the Duluth rock, but which makes up so large a part of the Saint Cloud granite. It is strange, therefore, that the Duluth rock should have been so generally regarded as harder than real granite, and particularly as harder than the Saint Cloud granite. The mineral augite, which makes up generally less than one-fourth of the whole, has a hardness of from 5 to 6 on the scale of 10, and labradorite is but little more. When this rock begins to decay, the augite changes first, making a greenish, soft mineral like chlorite, and this change sometimes is found to have gone on to a great depth in the rock without any change being seen in the other minerals. In such cases, while the rock is not much injured for building purposes, it is more easily quarried and dressed. While taken in a mass this Duluth rock may correctly be said to be softer than the Saint Cloud granite; it is tough and firm, being perfectly crystalline and compact. The magnetite in this rock sometimes becomes so abundant that it spoils it for building, and even becomes an iron ore, and has attracted attention as such. The iron ore reported some years ago at Duluth, at Herman, a few miles west of Duluth, and at Iron lake, north of Grand Marais, is all of this variety, and in some cases it is pure and valuable; but it is damaged by the presence of the titanium. The titanium is not so much a damage to the iron as an impediment in the reduction of the ore. At Duluth this rock has been used in some foundations, but the difficulty of dressing it, as well as of quarrying, has prevented its acceptance as a general building material. Its strength is about 17,000 pounds per square inch.

The gabbro quarry at Duluth, Saint Louis county, is from a mountain-like range extending northeast from Rice's point at Duluth. It is discussed in geological reports of Minnesota for 1879 and 1880, it being No. 1 of the *Minnesota Geological Survey* series. The rock is of the age called Cupriferous in Minnesota, the equivalent of the Potsdam in other portions of the country. Blocks of as large a size as could be handled might be quarried here. The mass of rock is but little jointed; its texture is a uniform crystalline, and it has been used thus far chiefly in trimmings for buildings and for rough walls at Duluth, and some for trimmings and steps at Saint Paul.

A trap from this formation has been quarried by the United States government to be used in the construction of breakwaters at Duluth. The stone is roughly and basaltically bedded, and it may be called imperfectly basaltic; its texture is uniformly crystalline; it is No. 53 of the *Minnesota Geological Survey*, report of 1880. It is a basaltified layer of igneous rock intercalated between sedimentary beds. There is an excavation made in trap-rock for the site of a new school-house in Duluth, and the stone is put in the foundation and basement of that building. It is seen in outcrop conspicuously in front of the engine-house in that city, and extends northeastwardly in the form of a low hill range or ridge; it seems to be that which forms the falls of Kinichiguaguag creek, near Duluth; it is No. 43 of the *Minnesota Geological Survey*, report of 1880. This stone is massive, close, and fine in texture, sometimes finely porphyritic; the mass of rock is distantly jointed.

No. 42 of the reports of the *Minnesota Geological Survey* of 1880 is not quarried; it is so situated in many places near Duluth that it might be quarried with profit where a stone easier wrought than No. 1 of the series is desired. In the weather it has naturally assumed numerous conchoidal-fracture planes. These make it difficult to get blocks of a given size and shape, since the pieces break in dressing along the old fractures, which are not parallel nor perpendicular, but cross at acute angles in all directions, like some massive shale in disintegrating. This rock is believed to be derived from the red shale of the Cupriferous or Potsdam series by the semi-fusion incident to the igneous ejections; other stages of crystallization, even to red granite and other less changed conditions as a perfect red shale, can be seen along the shore at points farther down the lake and at Duluth. Within the limits of Duluth it can be quarried as red granite; it is in the hill range on the slope facing the bay, and at the quarry at Rice's point is associated with No. 1.

In the hills back of Duluth it changes suddenly to a red granite, supposed to be derived from the fusion and metamorphism of the Fond du Lac red shales and sandstones when the igneous rock was poured out through and over them. These two kinds of rock (red syenite and gabbro) are closely intermixed in patches, sometimes of large area, and extend thus all the way to the northern boundary-line of the state, the red rock showing various stages of metamorphism and crystalline condition. The red granite in some places is very coarse grained and beautiful, something like Scotch granite, and in other places it is very fine grained and compact, as at Duluth. It contains quartz, generally in large quantity, red orthoclase, and green hornblende or chlorite.

At East Saint Cloud, Sherburne county, a massive Archæan granite is quarried for general building purposes and used chiefly at Saint Paul, Milwaukee, and Minneapolis. The trimmings of the United States custom-house at Saint Paul are of this material. There are three varieties, differing somewhat in texture and color. The one most used and highly prized is of a fine-grained uniform texture and gray color. It is often slightly gneissic or laminated in structure, and works more easily than the others; it is probably not so durable nor firm under pressure. The second variety is red, and contains a good deal of quartz, but takes a finer polish. It was not quarried during 1880 so much as in former years, chiefly because the plant of the establishment is situated some little distance from the favorable exposures, but there is abundant opportunity in the neighborhood for working this red granite. The other variety is not now quarried, but large quantities of it were formerly taken out and used chiefly as trimmings in the custom-house at Saint Paul, where, however, stone of both the other kinds is also to be seen. It has outwardly, and especially when chiseled for construction, as in the custom-house, very much the aspect of the gabbro quarried at Duluth, and might be mistaken for that stone on a casual examination. It has the reputation among the quarrymen of being very hard, and is said to require more frequent sharpening of the tools than either of the other varieties, which circumstance has prevented its extensive use.

The East Saint Cloud granite, when used for paving, is dressed roughly in blocks of about 10 by 3 by 5 inches deep. Blocks 50 by 12 by 6 feet thick have been moved; the size of blocks which may be quarried is only limited by the ability to handle; blocks 20 by 6 feet and as long as 60 feet may be quarried if desired.

There is a very firm syenitic granite near Motley, on the Northern Pacific railroad, which is similar in outward appearance to the Saint Cloud granite, and will furnish stone for a large tract of stoneless country west of that point, this being the most westerly outcrop of rock known on the line of that railroad within the state.

At Beaver Bay, Lake county, a red granitized shale of Cupriferous or Potsdam formation (metamorphic group, and is one of the conditions of the metamorphosed sedimentary rocks of the Cupriferous series) is somewhat quarried for dock construction. The ledge lies conveniently near the docks, in the construction of which this stone was used. The rock was taken out in the north side of the bluffs facing the bay. The material is rather fine in texture. The structure of the rock is somewhat basaltified, yet jointed transversely.

Four miles below Beaver Bay, on an island in lake Superior, a so-called red granite of the Cupriferous series is found, but has not as yet been quarried. It is No. 811 of the *Minnesota Geological Survey* reports. It is believed to be derived from some of the original sedimentary portions of the Cupriferous beds, and would make a very good building material if in the course of the settlement of the country it should become desired. The rock is uniformly crystalline in texture; at most points it is little jointed, but it is occasionally imperfectly basaltic.

There is a labradorite rock of the Cupriferous series exposed at the lake shore, 2½ or 3 miles east of Beaver Bay, which may be used for ornamental purposes as well as for general construction. The supply is abundant and easily accessible. The rock seems to graduate into the gabbro exposed at Rice's point. The texture of the stone is uniform and coarsely crystalline; it is bedded in some places and in others a solid mass.

At the lake shore, near the mouth of Baptism river, Lake county, there is a porphyritic felsite of the Cupriferous series; it is Nos. 138 and 139 of the Minnesota geological report for 1880. The stone is porphyritic, with quartz and perhaps adularia, and it is indistinctly laminated and basaltic in structure. The rock is also exposed 2 miles west of the great palisades, on the north shore of lake Superior, Lake county; it may possibly be used for ornamental purposes, and it illustrates the gradual change from the red shales of the sedimentary beds of the Cupriferous to crystalline rock. (See proceedings of the American Association for the Advancement of Science for 1880–'81.) In this locality there is also a metamorphosed shale (with adularia) of the Cupriferous series; it is No. 140 of the *Minnesota Geological Survey*. Specimens of the stone in the National Museum are a brick-red in color; it is usually banded and porphyritic, with quartz and translucent grains that seem to be adularia.

On Encampment island, Lake county, a hyperyte rock of the igneous group of the Cupriferous series is found; it has not been quarried for building purposes, but is interesting from a scientific point of view. In texture it is uniform and coarsely crystalline, and is irregularly jointed and bedded. On the shore of lake Superior, at Two Harbor bay, in Lake county, there is a dark, heavy, uniformly fine-grained rock, probably of the sedimentary group of the Cupriferous. It has not yet been quarried, but has a scientific interest in connection with the investigation of the crystalline rocks of this formation, as its outward characters have not been sufficiently distinct to indicate its affinities so as to warrant its being classed in either the igneous or metamorphic group of the Cupriferous. In the Report of the *Minnesota Geological Survey* for 1880 it is placed in the sedimentary rocks (metamorphosed), but this point is not well established. With it many comparisons have been made, and references in field-books, whenever it has been seen to occur, or where a rock like it has been met with, making it a sort of datum for the mapping geographically of rocks in other places.

A trap of the igneous group of the Cupriferous is quarried at Taylor's Falls, Chisago county, and used in the construction of foundations and rough walls at Taylor's Falls. The walls of several business blocks at this place are constructed of this stone. The color is dark, almost black, and as to the texture it seems to be made of pyroxene crystals embracing the other minerals, these causing a spotted exterior; otherwise the texture is uniform. This rock, from its proximity to Minneapolis and Saint Paul, is of economic importance because of its adaptability for paving blocks, for which purpose it would supply a most durable material. It may be described as tough rather than hard. It is the most southerly known exposure of the Cupriferous in the state, though in Wisconsin a similar rock outcrops a few miles farther south, near the Saint Croix river. Some interesting copper mining has been excited at this point by the discovery of the native copper in the rock and along some of the ravines. It is No. 820 of the *Minnesota Geological Survey;* the rock seems to have the characteristics ascribed to melaphyre by Pumpelly.

SANDSTONES.

The red quartzite at New Ulm, which also is seen in Cottonwood, Watonwan, Rock, and Pipe Stone counties, is sparingly used for a building stone at points contiguous, and one or two car-loads are known to have been shipped to Minneapolis. It is the hardest stone in the state, or in the United States, probably, that can be said to have been used for building. It consists almost wholly of quartz, the red color being due to iron oxide, which is disseminated among the grains, but does not enter them. As a layer embraced in this rock the material known as "pipestone" or catlinite is found in Pipe Stone county and other places in southwestern Minnesota. This rock it is very difficult and costly to dress into dimension blocks, but it is indestructible when once placed in a wall.

There is a quarry of the red quartzite in Courtland township, Nicollet county, near New Ulm, operated for ordinary building purposes and bridge construction, used at New Ulm and surrounding country. It was used in the construction of Sommer's block and the residence of Mr. Frank Erd, at New Ulm. The stone varies somewhat as to texture, some being loose-grained and sandy, and some firm, hard, and uniform. It is evenly-bedded in courses varying from half an inch to 4 feet in thickness; the joints and water-cracks are not distinct, but rather frequent. There is but little systematic quarrying done at this place; quarries are contiguous, and exhibit the same kind of rock. Some of the beds are shaly, and the dip about 15° toward the north-northwest. As compared with rocks at Sioux Falls, in Dakota, the opportunities for quarrying are greater here and the stone is much more easily wrought, owing to the fact that the beds are finer and softer, though it is probable that if it were to be deeply excavated it would be found to be firm and of a purplish color within; but at Sioux Falls a greater area of stoneless country surrounding the quarry will create a greater demand than ever will be felt at New Ulm.

Next in ascending order, as building materials come the sandstones proper, if we omit the black argillyte or roofing slates and their associates seen at Thompson, which will be treated under "Roofing slate". The red sandstones at Fond du Lac are probably the most valuable deposit, taken on all accounts, that the state possesses as a building stone of that kind. They are of the same formation as the New Ulm quartzite, but were less hardened at the time of their upheaval. They lie tilted toward the south or southeast, and are associated with and overlie a vast thickness of soft red shale, which passes sometimes to a shaly red conglomerate, the same that in other places about lake Superior is in contact with the igneous rocks, and becomes copper-bearing. This red sandstone is well known in Milwaukee, Chicago, and Detroit. The quarries in it farther east furnished the red sand-rock used in the Milwaukee court-house, and a great many brownstone fronts in that city and in Chicago were obtained from it. It was formerly quarried on Isle Royale, and sold in Detroit as "Isle Royale brownstone". While it consists almost entirely of quartz, the grains are not so firmly cemented or united as to render it objectionably hard. Its grain, color, and texture vary slightly. On Isle Royale, when quarried, it is fine-grained and rather brittle, being more highly metamorphosed than at Fond du Lac. At some points it has a mottling of red and gray, or even of green, as at Sault Ste. Marie, at the eastern end of lake Superior, where the ship-canal is cut in it and largely built of it. In some places it is so loosely cemented as to crumble and to be rendered useless for building, and in others it contains rounded quartz-pebbles of a nearly white color, or becomes wholly conglomeratic. At Fond du Lac some of all these features can be seen, but there is still at that place a great abundance of fine stone of the best quality. This great formation forms the southern rock barrier of lake Superior, almost without interruption, from Duluth to Sault Ste. Marie, but it is not always of so dark a color as it is at Fond du Lac. The famed "pictured rocks" of the south shore are formed of it, and the Apostle islands are caused by remnants of it that withstood the erosion of the glacial forces. Its strength, as tested at Washington, proved to be from 4,000 to 5,000 pounds per square inch. Several business blocks have been made from it in Duluth, and the new Westminster church at Minneapolis is being constructed of it. This formation is seen not only at Fond du Lac, but (probably) at Pokegama falls, on the Upper Mississippi, and in the base of the bluffs at Winona, but the most favorable and promising points for quarrying it are at Fond du Lac.

The principal quarry at Fond du Lac has been mainly engaged in getting out and shipping stone in the rough, but little being dressed at the quarry. The rock has in some of its heavy bedding stripes of light sand-rock and light spots in some of the brown. Sometimes scattered quartz-pebbles are seen in the light rock of the size of a pea, or even a hen's egg, but not much of it is conglomeratic. Lumps of red shale from 2 to 5 inches in diameter occur in belts coincident with the direction of the bedding. The bedding is even, in courses varying from 4 inches to 2 feet in thickness; the joints are distinct. The stone is used for general building purposes, chiefly at Minneapolis, Saint Paul, Brainerd, Duluth, and Fargo, Dakota, and Superior, Wisconsin. Among the buildings in the construction of which this stone was used are the Clark & Hunter block of Duluth, the Westminster Presbyterian church at Minneapolis, and some of the railroad buildings at Brainerd. There is a quarry on Missouri creek near Fond du Lac, the product of which is wholly shipped to Winnipeg for use by a contracting builder of that city. The Manitoba college is trimmed with stone from this latter quarry.

The freestone at Hinckley is probably not of the same formation, but pertains to a higher horizon—the Saint Croix. It is exposed on the banks of the stream passing through the village and at points farther down. As a building stone it is considerably lighter colored, or more nearly that of the Kasota stone, and more easily wrought than the Fond du Lac stone. It is in even, heavy beds, and can be easily got out. It is as firm and as desirable for all purposes of architecture to which it is adapted as the Cleveland freestone which is so largely used. It can be dressed more cheaply than the Fond du Lac stone and can be cut into ornamental forms for capping or for columns. Its compressive strength has not been tested yet.

The stone from this quarry is evenly bedded in courses varying from 6 to 18 inches thick; there are but few joints. The Saint Paul and Duluth Railroad Company operates the principal quarry at Hinckley, Pine county, for bridge construction, and the stone has lately been put into the foundations for the high bridges and trestle-work on that railroad along the dalles of the Saint Louis river. It is the only rock known between White Bear lake and the slate region of Thompson, which begins near Goose Lake station.

At Dresbach, on the Mississippi river and the Chicago, Milwaukee, and Saint Paul railroad, in Winona county, sand-rock of the Saint Croix, which is the lowest sand-rock in the geological scale of Minnesota, is occasionally quarried for ordinary building purposes and shipped to Minneapolis and Saint Paul. The stone promises considerable usefulness in the future, though as yet is but little quarried. The rock has been quarried to a limited extent also at Dakota, 2 miles north of Dresbach, and much attention has been attracted to the material at both these places, as it nearly resembles the Berea sandstone of Ohio, which is now largely used in first-class buildings in Saint Paul and Minneapolis, it being transported there by rail at considerable expense. The development of this industry in Minnesota, so far as Dresbach and Dakota are concerned, is due to the direct and immediate efforts and recommendations of the geological survey of the state in calling attention to it during 1880. There is an unlimited supply of this stone in the bluffs of the Mississippi river, but its best color is found only near the level of the water of the river. The stone is of a fine texture, and varies from a light gray to buff in color, some of it showing even and distinct stratification, and some being massive; it is evenly and horizontally bedded in courses from 3 inches to 8 feet thick. Blocks 8 by 4 by 4 feet have been quarried; and blocks as large as 20 by 8 by 6 feet, or as large as could be conveniently handled, might be quarried.

The other sandstones of nearly the same geological horizon are not very good for building, being too friable. They are exposed in the bluffs of the Upper Mississippi below Hastings, and of the Saint Croix below and above Taylor's Falls, where they have been put into one or two business blocks. They are of rather coarse grain and friable on first quarrying, but the weather operates to harden them somewhat in the course of a few months. When they are finer, and mingled with an aluminous sediment, they are also somewhat magnesian. They are then fit for rough walls, but for first-class architecture they cannot be used, owing to the thinness of the layer and the general incoherency of the grain. Still in some towns this kind of stone is employed exclusively for the general home demand, as at Hokah and at Lake City.

The Jordan sandstone of the geological horizon of that name in the Lower Minnesota valley is very much like that at Taylor's Falls, but is in a much higher geological horizon. It has been used considerably at Jordan, and serves a good purpose for general building, but it cannot be recommended for first-class structures. It is of a light color, but stained and clouded, or striped by a yellowish or rusty iron cement. It is likely that the darker-colored beds of this stone will be found most durable. This rock appears in the Minnesota valley, forming islands and rapids near Carver. If it were to be wrought along the Minnesota river, where it has been for a long time subject to the rusting and cementing action of the waters of the river at periods of flood, it would be found much harder and more valuable. The bedding is even, and in courses varying from 2 inches to 2 feet in thickness, jointing irregular, the texture fine, sometimes friable, and there are signs of irregular stratification. There are two principal varieties in the quarry; that from the bottom is of light gray or bluish color; that from the uppermost 16 feet of the ledge is the stone which has been hitherto used exclusively in building. The gray is very similar in appearance to the Berea, Ohio, sandstone. Among the buildings in the construction of which this stone has been used are the Foss & Wells flouring-mills, at Jordan, and the City mills and the American house (first story), at the same place.

Ordinarily the Saint Peter formation is very friable, and particularly where it is freshly exposed, or is being continually reduced by the action of winds or by running water. But when the river water occasionally or periodically overflows it, the repeated evaporation of the water leaves a deposit of iron-rust, which on entering among the loose grains of the rock soon so firmly cements them, especially on being thoroughly dried, as to make a useful building stone. Such a process goes on in all low grounds where water evaporates without free escape, and generally causes a rustiness on the mud or on the dead twigs or roots of the place, or even goes so far as to form a bog-iron ore. If a rock be exposed there it becomes more or less rusted, and if before incoherent it becomes firm. Although stone quarried from this formation has been put into the piers of the bridge at Fort Snelling in large blocks, it can hardly be said to constitute a reliable supply of good stone for the cities of Saint Paul and Minneapolis. When evenly and thoroughly cemented by the iron-rust it will form a durable rock, but its liability to inequalities in the hardness of the mass, to variations of color, and to the exhaustion of the supply will operate against its extensive use.

At Mendota, Dakota county, sandstone rock of the Saint Peter subdivision of the Lower Silurian is quarried for bridge construction on the Chicago, Milwaukee, and Saint Paul railroad. The piers of the bridge over the Mississippi river at Fort Snelling are built of this stone. This stone, which serves well for heavy masonry, and could be cut for ornamental work in structures, shows the effect of the waters of the Mississippi river in hardening the very friable white sand-rock, known as the Saint Peter sandstone. The outcrop in which the quarry is situated is in the bottom land of the river and rises but a few feet above low water. It is annually overflowed and has been for an unknown period evidently, at least since the glacial epoch, and it is to this fact that the cementation of the siliceous grains is due, the evaporation of the water as summer advances leaving a sort of iron cement. It is also probable that the cement is partly siliceous, since the waters of the river are slightly alkaline, and thus might dissolve some of the silica of the rock, depositing it again as a cement. No other such effect on the Saint Peter formation is known but in the valley of the Minnesota river. Above this place, the Shakopee formation is thus affected at Kasota, the Jordan at Van Osser's creek, near Louisville, and the Saint Lawrence at Jessen Land; in all cases the change of character being due to the interpenetration of iron oxide on the evaporation of the water of the river.

The stone used at and below Austin, taken from the low banks of the Cedar river, seems to belong to the Upper Devonian. It is believed to lie conformably over the Devonian limestones that are seen in outcrop farther down the river, a few miles south of the state line in Iowa. The stone itself in its natural color is of a light blue, and that color shows on most of the quarried blocks about the heart of the bedding, and on deep quarrying it would doubtless show only a blue color. Yet the stone as now used is very generally of a buff color to the depth of from half an inch to 3 inches, depending on the amount of weathering and oxidation. The thinner beds are altogether changed to that color. The texture of the stone is close, and the grain is homogeneous. Some large slabs and blocks are sawed for bases to tombstones, and worked down to a very smooth surface. It is more safely sawed to any desired dimension than cut or broken, yet it is not in the least crystalline. Its aspect at a distance is that of a fine-grained sandstone, yet it contains no apparent grit. It is so soft that it can be cut without difficulty, appearing much like an unusually indurated blue shale, but it hardens in use and serves a useful purpose in common buildings, but cannot be depended on for first-class structures. Its argillaceous composition will ultimately cause it to crumble, especially if it be subjected to frequent changes of moisture and dryness.

At several points in the banks of the Minnesota river between New Ulm and Mankato a hard, siliceous sandstone of Cretaceous age is exposed, which has supplied some very good building material. The layers are about 4 inches in thickness, and are tough and firm. They are associated with alternating layers of a friable sandstone, which aids in their extraction. These beds are sometimes so coarse as to justify their being designated as conglomeratic. The stone is very durable as a building material, but the toughness and hardness of the texture and the thinness of the beds, make it more suitable for flagging than for building. It is typically exposed on the land of William Fritz, Sec. 16, T. 109, R. 29, in Nicollet county and other places near.

LIMESTONES.

The lowest limestones in the geological scale are those seen in the bluffs of the Mississippi river and in the Saint Croix valley. They generally form the tops of the bluffs, and cause the precipitous portions, the sloping talus being taken up with one or more of the sandstones above mentioned. These limestone beds present a varied lithology, and cause some very interesting topographical features. As a building stone they are wrought at all points where there is a demand (except Lake city), between Stillwater and Winona, along the Mississippi valley on the Minnesota side, and also at several places farther west, as at Caledonia, in Houston county, Lanesborough and Rushford, in Fillmore county, and at points in Winona county. The material they supply is in general a magnesian limestone of a light buff color, a firm but sometimes vesicular or porous texture, and often having a considerable proportion of quartz. An analysis of a sample from Sugar Loaf, Winona, gave the following result:

	Per cent.
Insoluble (mainly quartz)	24.21
Ferric and aluminic oxides	3.32
Calcium sulphate	4.32
Calcium carbonate	47.11
Magnesium carbonate	20.67
Total	99.72

Showing that nearly one-fourth of the whole consists of quartz. In other places would be found less quartz; and this is particularly the case at Frontenac, where the rock is so even-grained and so free from quartz that it is sawed by machinery into such slabs or blocks as are wanted. The quarries at Winona and Red Wing are in beds of this stone that are quite similar as to texture, being open and loose, or having small scattered cavities. In these cavities are sometimes linings of drusy quartz crystals. In other beds this quartz is gathered instead into nodules of chert or flint, which, although having a white exterior, are hard, and often gray within. This is the condition of the quartz in the stone at Frontenac, but these flint lumps are not common there. In other places whole beds are cherty and worthless for a building stone. This formation, which probably at the present time furnishes more stone than any other in the state, is destined to be still further used for the same purpose, as it is most favorably situated at its exposures both for excavation and for shipment and transportation, and supplies one of the best materials for all purposes of architecture. It varies from a light buff to a light drab color. When placed in a structure it has a lively and cheerful expression. At Frontenac it is cut into ornamental forms with comparative ease, and the same kind of beds as those at that place are found throughout the southeastern part of Goodhue county and the northern portion, at least, of Wabasha. It is but slightly changed after many years exposure to atmospheric influences; indeed, it has not been in use long enough yet in the state to show any change whatever by lapse of time, although it is in some of the oldest buildings of the state. The homogeneity of its composition and texture, as at Frontenac, and the regularity and thickness of its bedding, are qualities that enable it to supply slabs and blocks of any desired dimensions. Its resistance to pressure, amounting to 5,000 to 7,000 pounds per square inch, is sufficient to warrant its use in all ordinary structures, while for door moldings and caps, for sills and water-tables, and for all trimmings to brick structures, it is unsurpassed.

The limestone of the Saint Lawrence horizon, the lower portion of the great magnesian limestone of the west, in the vicinity of Stillwater lake, is often somewhat siliceous, and the determinations made at the National Museum for this report show it to be properly sometimes a dolomite and sometimes a siliceous dolomite. A chemical analysis of the samples of the stone usually show a high percentage of magnesia, considerable iron, and siliceous matter. At a quarry of this limestone at Stillwater, on lake Saint Croix, and on the Saint Paul and Duluth railroad, the ledge is about 45 feet thick, and extends still farther below. It alternates in bands of compact and of vesicular rock from 3 to 6 feet each, and there is about an equal amount of each kind, all lying in horizontal courses. The coarse and vesicular dolomite is used for the heaviest masonry, such as bridge construction; it is in beds of from 18 to 30 inches thick, and is more firm and durable than either of the other varieties. One variety is called "sand-rock" by the quarrymen, though plainly containing very little, if any, quartz sand, and has a uniform and granular texture. The other principal variety is most useful for general purposes; it is especially sought for and adapted to use for sills, water-tables, and caps, making a stone which is fine and uniform in texture, and of uniformly light buff color. It yields a good surface under the hammer and chisel, and is employed for bases and tombstones; it is also used for ashlar, pilasters, and copings. The use of this stone thus far has been only local, and the following are some of the buildings in the construction of which it has been employed: The state prison, public school-houses, one Catholic church, store building of Mr. Isaac Staples, Universalist church, and the Fayette-Marsh block, all in Stillwater.

The Saint Lawrence limestone is quarried at Stockton, Winona county, for bridge construction and foundations, and employed in the railroad work along the Winona and Saint Peter railroad and in the towns on that road. The stone was used in the construction of the railroad round-house at Winona. In texture it is generally uniform, but sometimes vesicular, cherty, and geodic; in color it is buff; it is a dolomite containing a small percentage of iron. The stone is evenly and horizontally bedded in courses usually from 9 to 25 inches. There is a coarse concretionary (apparently brecciated) condition sometimes seen in this formation from 25 to 100 feet in thickness, which has to be entirely thrown away or used as filling by the railroad. A concretionary condition occurs in isolated masses and nodules, and does not extend far horizontally; at least it is not always present at any given horizon. The quarry is operated by the Chicago and Northwestern railroad, and most of the best stone is used in bridge and other construction. The Saint Lawrence is quarried also at Winona for general building purposes and flagging for local use; some of it is burned for lime and shipped to Minneapolis and Saint Paul. The location of the principal quarry is on an eminence known as Sugar Loaf hill. The stone has been used in the construction of a Congregational church, an Episcopal church, and the jail at Winona. It is usually fine and uniform in texture, but some of it is porous and contains quartz lumps. The color is usually buff; it is evenly and horizontally bedded in courses from 4 inches to 3 feet in thickness; there are signs of irregular stratification. Blocks 8 by 6 by $2\frac{1}{2}$ feet thick have been quarried, and blocks of any size that can be handled may be quarried. The perpendicular joints are usually from 10 to 20 feet apart. The magnesian limestones of Minnesota are generally buff in color—at least the dolomites are—the only variation from buff being in some of the aluminous parts of the Trenton, when the term "dirty drab" might be used, perhaps.

The Saint Lawrence limestone quarried at Red Wing, Goodhue county, is used locally for general building purposes and for quicklime. It was employed in the construction of Christ church, the Red Wing and Diamond flouring-mills, the first stories of the Saint James hotel, and the residence of Dr. A. B. Hawley, all at Red Wing. It is a dolomite, fine in texture; some is vesicular and some compact, and the color varies from buff to light buff. It is evenly and horizontally bedded in courses varying from 4 inches to 3 feet. Blocks 8 by 6 by 2½ feet in thickness have been quarried, and blocks of any size that can conveniently be handled may be quarried. The quarries at Red Wing do not differ much in the manner and kind of stratification, or in the quality of stone produced, from those at Stillwater.

At Frontenac, in Goodhue county, this formation is quarried for general building purposes, and used to some extent also for bases and tombstones. It was used in the construction of Barney's block, in Saint Paul. It is here also a dolomite of medium fine and very vesicular texture, buff in color, and evenly and horizontally bedded in layers often as thick as 5½ feet; it is jointed at irregular intervals. The dimensions of the largest block that has been quarried are 11 by 7 by 5½ feet, weighing 18 tons; this is about as large as can be obtained from the quarry. Saws and rubbing-beds are used in dressing this stone at the quarry. This stone is considered one of the best in the state; it is seen in some large first-class buildings in both Minneapolis and Saint Paul, and the front of a large block in Minneapolis is being constructed of it by Mr. H. D. Wood.

That limestone formation (Shakopee) which is wrought at Mankato, Ottawa, Kasota, Shakopee, and Saint Peter lies about 100 feet higher in the geological scale than the last mentioned, but it is in nearly all places where wrought of nearly the same character and as useful for all purposes, though it does not present the evenness of texture and freedom from quartz seen in the Frontenac stone. At Kasota the river has at some early time stained it in the same way that it has the Saint Peter sandstone, near Mendota, giving it a rusty pink color, or a fawn color, as described by Featherstonhaugh, and at the same time greater tenacity and endurance under pressure—10,000 pounds per square inch. For its beauty, its regularity of bedding—which is sometimes nearly 2 feet in thickness—and its homogeneous texture, which renders it easy to shape into all forms, it is adapted to ornamental work as well as heavy masonry. It is cut, as at Mankato, into posts, sills, caps, and water-tables. For its adaptability to all uses it is worthy of being ranked with the Waverly sandstone, which is beginning to be imported into Minneapolis and Saint Paul from Ohio, and it is more enduring even than that under the action of atmospheric changes, owing to the more general and abundant dissemination of the calcareous cement, while its variegated coloring and its more lively expression make it preferable in many kinds of work. It is used in the State Lunatic Asylum building at Saint Peter. The Episcopal church and the old asylum building are also constructed from it. The Baptist church in Saint Paul is built of the Kasota stone. In old structures where it has been exposed for a number of years to the disintegrating action of the elements it shows as hard and sound as ever. It even becomes harder at first on exposure as the quarry water dries out.

The Shakopee, the upper member of the Lower Magnesian, is quarried at Kasota, Le Sueur county, for general purposes of construction, and especially for bridges, flagging, and tombstones. It is used throughout Minnesota, and in Eau Claire, Madison, and Hudson, Wisconsin; Le Mars, Sioux City, and Muscatine, Iowa; Sioux Falls, Dakota, and Winnipeg, in Manitoba. The following are some of the principal buildings in the construction of which it has been used: In the Insane Asylum at Saint Peter; trimmings in Saint Mary's church, Minneapolis; Plymouth church, Minneapolis, and Gilfillan's and Odd Fellows' blocks, in Saint Paul. The stone is a dolomite, ferruginous, and contains considerable siliceous matter. Specimens of the stone at the National Museum are dendritic. The stone at Kasota is all, or nearly all, stained with iron having a faintly-pinkish color, although originally buff. This stain comes from the flooding of the Minnesota river at early (glacial) times. The stone is subcrystalline and vesicular, with signs of irregular stratification, and is evenly and horizontally bedded in courses from 3 to 4 feet in thickness. Blocks 10 by 11 feet by 1 foot thick have been quarried, and blocks of as large size as could be conveniently handled may be quarried. Around the joints there is a recent penetration of iron and carbonaceous stain, sometimes 6 or 8 inches in the joints, having a wavy outline, according to the rate and ease of penetration by infiltrating water. This is usually cut away as waste in dressing blocks of the stone. Much of the stone at Kasota and some of the equivalent beds at Mankato have a color (designated by Featherstonhaugh as "fawn-color") not common to building stone. It is an accidental quality due to the more free penetration or chemical retention of the iron of atmospheric ferrated waters. Wherever the stone of the Shakopee formation is found so situated as to have been covered by the Minnesota river in its flood stages, or in the floods of the glacial epoch, it is uniformly so colored. In none of its layers, when found in higher land in the interior of the state, is this color found, but it has usually the buff color of the weathered siliceous limestones (non-argillaceous). The highest-priced stone of the Kasota quarries is that which is most colored by the presence of iron, being faintly reddish or pink.

Near Mankato, Blue Earth county, the Shakopee limestone is quarried for railroad-bridge construction and for general building purposes, and extensively used along the line of the Chicago, Saint Paul, Minneapolis, and Omaha railroad, the Winona and Saint Peter railroad, and the Chicago, Milwaukee, and Saint Paul railroad; in western and southern Minnesota; Eau Claire, Wisconsin; Sioux Falls, Dakota; Le Mars and Sioux City, Iowa; and the following are some of the buildings in the construction of which it has been used: The trimmings of the public-school buildings at Sioux Falls and Albert Lea, Minnesota; the jail at Blue Earth; the state normal school and other schools at Mankato. The stone is here also a dolomite, containing some siliceous matter, usually ferruginous; buff in color, subcrystalline, sometimes fine, close-grained, and sometimes open and vesicular, with cavities of half an inch or less in diameter; signs of irregular stratification, evenly and horizontally bedded in layers often 6 feet in thickness; it is irregularly jointed, and blocks 8 by 4 feet by 18 inches have been quarried, and blocks 20 by 10 by 6 feet might be quarried. All the quarries in the vicinity of Mankato are in the same beds, and very nearly the same details of stratification are present. There is a bed of shale connected with the rock at Mankato which in some particular localities becomes more calcareous, and is possibly suitable for a cement. The light blue color which appears in the deep portions of some of the quarries indicates the original color of all the rock; on further quarrying this blue color will probably increase in amount. The Galena limestone (at first a light buff stone) at Mantorville, in Dodge county, shows the same change in the deeper layers. In the quarry of the Winona and Saint Peter railroad, near Mankato, for quarrying convenience the layers are designated as follows, from the top downward:

1st. White ledge, very fine-grained stone.
2d. Red ledge, harder and pinkish.
3d. Gray ledge, coarse-looking stone.
4th. Soft ledge, will not stand frost.
5th. Bridge stone, coarse in texture.

The Trenton limestone, which is largely used at Minneapolis, Saint Paul, Northfield, Faribault, and Chatfield, and was formerly quarried at Fountain for shipment to points farther west on the Southern Minnesota railroad, is a bluish, rather dark colored stone, that varies in value very much at different places between Minneapolis and the southern part of the state. At points toward the north, nearer the old shore-line of the Paleozoic ocean, much aluminous shale was deposited, even in those comparatively quiet times when marine animals flourished and on their death supplied a considerable calcareous sediment. Farther south the quiet, lime-producing epochs were less mixed with aluminous sediment, and were separated more distinctly by periods of agitation when large amounts of shale were deposited. Hence in this formation at Minneapolis and Saint Paul the aluminous shaly ingredient is distributed through the calcareous, and also constitutes heavy beds of itself, while at Northfield the calcareous layers are pure; at Fountain they are almost free from alumina and sand, and at the same time in passing toward the south the purely aluminous beds become less frequent as the calcareous become more numerous. The cities of Minneapolis and Saint Paul have to depend very largely on the Trenton limestone for building material or to import from other places. The stone itself has an attractive and substantial aspect when dressed under the hammer, the variegations due to the alternating shaly and limy parts giving the face a clouded appearance as of gray marble, without being susceptible of a uniform polish. Where protected from the weather the shale will endure and act as a strong filling for the frame-work of calcareous matter for a long time; but under the vicissitudes of moisture and dryness, and of freezing and thawing, it begins to crumble out in a few years. This result is visible in some of the older buildings, in both Saint Paul and Minneapolis, and has provoked a very general inquiry for some suitable substitute in those cities. The natural color of the stone on deep quarrying is blue, but it is often faded to an ashen drab to the depth of several feet, depending on the ease with which water and air find access within. The porous layers are apt to be most faded. The long-weathered surface is of a light buff color, or if iron be present in dripping water or contained in the stone as pyrites, so situated as to be oxidized, the color is sensibly deepened to a rusty yellow, and at the same time the stone is rendered more enduring on account of the irony cement. This is noticeable at Minneapolis and at Saint Paul, where the old river bluffs, formed before the last glacial epoch, have endured the exposure of a much longer period than the river bluffs between Fort Snelling and Minneapolis that have been formed by the recession of the falls since the last glaciation. The shaly portions in particular, where closely mingled with the calcareous, are so stained and hardened that the rock seems almost another formation. It becomes separated into layers 2 or 3 inches thick. Some of the first large buildings erected in Saint Paul were made largely or wholly from such iron-stained and weathered parts of this formation, and, although they do not present that uniformity of color and appearance of solidity and strength that the dark blue stone lately quarried gives to a building, the stone itself has withstood the climate and storms of this latitude more successfully than later buildings constructed wholly of the blue-stone. Toward the southern portion of the state this changed condition is not so noticeable, indeed it is not so possible. The beds are more compact and calcareous, and the effect of the elements is more superficial.

In the vicinity of Saint Paul the rock is a slightly-magnesian limestone, containing protoxide of iron. The texture is fine and semi-crystalline, usually showing signs of regular stratification, evenly and horizontally bedded in courses from 3 to 24 inches in thickness, joints 10 to 30 feet apart; blocks 6 by 2 feet by 1 foot have been quarried, and blocks 10 by 5 by 2 feet may be quarried. Saint Paul and vicinity is the only market, and the following are some of the principal buildings in the construction of which the stone has been used: The Fire and Marine Insurance building, the cathedral, the McQuillan block, the German Catholic church, the custom-house, and most of the stone buildings in Saint Paul.

In the immediate vicinity of Minneapolis the stone contains varying amounts of magnesia, ordinarily hardly sufficient to be called a magnesian limestone. The upper layers in nearly all of the quarries are made up of a siliceous dolomite.

The blue, slightly-magnesian limestone, however, preponderates at all the quarries, and silica and protoxide of iron are nearly always present in greater or less quantity. The following is a full section of the Trenton, as exposed at the Minneapolis quarries, given in descending order:

1. Dolomite, somewhat argillaceous, making a durable building stone, but generally not regarded as highly as the rock of No. 5; it contains numerous casts of fossils; thickness, 8 feet.
2. Similar to No. 1, or gradually becoming more impure with shale; thickness, 2 feet.
3. Calcareous green shale, mainly in one bed or layer; thickness, 4 feet 8 inches.
4. The last passing gradually into a calcareous shale resembling the well-known building rock of this vicinity, sometimes used for rough walls, distinctly set off from the next below; thickness, 2 feet 4 inches.
5. The regular building stone of Minneapolis. The shale which impairs this stone is intimately disseminated through the calcareous layers without showing regular lamination, yet causing a mottled or blotched exterior on being dressed; the fossil remains are usually comminuted; thickness, from 10 to 14 feet.
6. A vesicular, less argillaceous, but magnesian and rather softer rock lying near the bottom of the blue limestone and generally not distinguished from it; thickness, 18 to 24 inches.
7. Blue shale, worthless for building; thickness, 2 feet.

As to the texture of the Minneapolis stone it is generally fine and compact, seldom vesicular, and often interlaminated with shaly belts. At some places it separates into laminæ of from 1 inch to 2 inches on weathering; some of it is mottled with argillaceous spots, but is otherwise compact, though showing fragmentary fossils. The color of the stone most used at Minneapolis for construction is a light blue, and until recently it was used exclusively, but at present building stones from Ohio, Iowa, and Illinois are being introduced. Some of the building stones from other parts of the state are also being used in the city, particularly that from Frontenac and from Kasota. The Trenton at Minneapolis and Saint Paul splits under the weather along the dark argillaceous belts that pervade it, and for that reason is not now regarded as a first-class building stone. The better rubble from the upper layers of the Minneapolis quarries really embraces the best rock for dimension work, and as to quality it is as durable a rock as the highest priced; it is sold cheaper because of irregular shape in fracture, rendering it unfit for range work. However, the quarries in the central and northern part of the city do not have this rubble, nor the "soap rock", which is sold for poor rubble, that layer having been denuded by the glacial and drainage forces so as to leave only the regular "quarry rock", which is No. 5 of the section before given of the Trenton at Minneapolis. The lowest layers in all the Minneapolis quarries show some variation in the composition and texture.

The following is an analysis of the dolomitic white limestone at the Baxter quarry:

	Per cent.
Carbonate of lime	55.533
Carbonate of magnesia	26.002
Iron and alumina	3.075
Insolubles	16.220

The blue limestone which prevails throughout this section is present in the same quarry. While this formation as a building material at its northern outcrops at Saint Paul and Minneapolis is rather inferior, at its southern exposures it furnishes a dark blue stone of excellent quality. Nothing can be more suitable for heavy walls, and especially for foundations below the water-table, and for all gothic structures, than the blue limestone taken from the formation at Fountain, or at some of the quarries at Faribault.

At Cannon City, near Faribault, Rice county, the Trenton limestone is a calcareous dolomite, containing protoxide of iron and silica; color, bluish-drab; massive, uniform, fine, and fossiliferous in texture; evenly and horizontally bedded in courses varying from 4 inches to 3 feet in thickness. Blocks 12 by 4 feet by 10 inches thick have been quarried, and blocks 20 by 3 feet by 15 inches thick may be quarried if desired. It is perpendicularly jointed at intervals. The material is used for general building purposes sometimes, and formerly for table-tops and work of that character. The market is at Faribault and within a radius of 20 miles of that place, where it was used in the construction of the Deaf Mute Asylum building, Shattuck School building, Episcopal church, and the public-school buildings.

The stone from the Faribault quarries is in the same stratigraphical horizon as that in the quarries at Minneapolis and Saint Paul. A comparison shows that the siliceous and the argillaceous impurities seen at the first-named place have greatly diminished in passing from north to south. There is a shale bed underlying the building-stone layers and separating them from the underlying Saint Peter sand-rock. The beds themselves are sometimes a foot thick, but are more generally from 6 to 8 inches in thickness. On deep quarrying they combine into heavier layers.

At Minneapolis, and to some extent also at Saint Paul, there is a very different sort of stone in the Trenton limestone formation overlying the beds that are wrought, which is more enduring than the regular building stone. This does not appear in the quarries near the falls, but is seen in those near the university, where the formation has not been so much eroded. This rock is generally rejected by builders, as already stated, and is confounded with the worthless shale that separates it from the regular building-stone layers. It is an impure limestone, containing a large per cent. of silica and alumina, and also of carbonate of magnesia. It is more correctly a dolomite, resembling in that respect the rock at Red Wing and at Winona, though not having the bright, cheerful color of the stone at those quarries. It is subcrystalline, rough to the touch, hard, but splitting to thin lenticular chips under the weather. It is of a blue color within, but on exposed surfaces becomes a dirty buff. The grain is close, except for the cavities resulting from absorbed fossils. The fragments into which the stone weathers out are brittle and somewhat sonorous under the hammer. The older portion of the State university contains a large amount of this stone, and its superior durability can there be seen. This part of the Trenton limestone is about 8 or 9 feet thick, and is separated from the blue-stone usually wrought by a thickness of 5 or 6 feet of worthless shaly rock, which builders sometimes smuggle into a wall.

Still higher in the geological scale are limestones that appear in the southern counties, known as Upper Trenton and Galena. The banks of the streams that pass into Root river in the western part of Fillmore county and in southwestern Olmsted exhibit many large exposures of the Upper Trenton, and there are many quarries in it, but they are mainly for quicklime. They might be utilized for building stone, since the rock is heavy, firm, free from shale and sand, and easily accessible. The Galena beds are extensively wrought at Mantorville and at Spring Valley, and somewhat at other points in Fillmore and Olmsted counties, and in northwestern Goodhue county. The color of this rock is buff, sometimes dark buff, although on deep quarrying the heart of the beds shows that its normal color, like most other limestones, is blue. Its composition, like that of the rock at Red Wing and at Winona, is dolomitic, comprising a large percentage of carbonate of magnesia, but it is without the quartz that is found in the limestones along the Mississippi, and is on that account less hard to quarry and cut, as well as less durable. Its texture is open, even porous, with minute cavities, and sometimes with larger openings, due to the absorption of fossils. In this latter case it presents a rough and forbidding aspect. This, however, is not common, the sedimentation having been generally so undisturbed by chemical or mechanical agencies that the layers are yet well preserved. The grain is crystalline and somewhat granular. Minute crystals of brown spar often line the cavities. It sometimes also embraces iron pyrites, which, weathering out, stains the face of the rock with iron rust. The granular texture seen in some parts of this formation, which is a character seen in most magnesian limestones, has sometimes made it pass for a sandstone. As a material for building it is a little surprising that this formation has not been more employed. It occurs in fine exposures in the southeastern part of Goodhue county, abundantly in Dodge county, as well as in Olmsted and Fillmore, along the streams, and can be extensively wrought. It furnishes a building material not only suitable for all ordinary uses in foundations and abutments for bridges, but one that cuts easily to a regular and smooth surface. Its bedding is sometimes heavy, reaching 2 or 3 feet in thickness, and the stone is strong enough to endure both pressure and long weathering. It is of a light and lively color, and in that respect has the advantage of darker-colored stone.

The Galena limestone is quarried at Mantorville for general building purposes and to some extent for monument bases. The principal markets are Rochester, Mantorville, and Spring Valley. The following are some of the buildings in the construction of which the stone has been used: Wright's hotel, two school-houses, the court-house, and Ginsburg's brewery, in Mantorville. Blocks 22 by 25 by 2½ feet may be quarried. The stone is evenly and horizontally bedded in courses varying from 6 inches to 3 feet in thickness; joints are irregular, crossing each other at varying angles. The various quarries here are near each other and furnish the same kind of rock. Mantorville is one of the old and important quarry towns in the state, but of late years, owing to poor wheat crops, there has been but little demand, and the quarries have been comparatively unproductive. The material is a siliceous dolomite containing iron in the form of sesquioxide.

The limestone of Hudson River age is quarried at Clinton Falls, Steele county, near Owatonna, for walls and buildings, but more especially for foundations at Owatonna and in the surrounding country. It is a siliceous dolomite containing protoxide of iron; in color it is a drab; its texture is sometimes slightly vesicular, but usually fine and compact; shows signs of irregular stratification, and is evenly and horizontally bedded in layers from 2 to 6 inches thick. Blocks 4 by 4 feet by 4 inches are the largest that can be quarried, on account of the frequent joints.

The Devonian limestones are of two very different sorts. One kind is found in Fillmore county, southwest of Spring Valley, and particularly along the tributaries of the Upper Iowa river. This stone in all respects except its more even and close texture, being without the porous features, is like the Galena limestone at Mantorville. Its color is the same, but its even and non-vesicular texture is enough to distinguish it from the Galena. The bedding is also less thick, being, when in exposure, usually less than 8 inches, though when quarried it is also in heavy beds. It is a yellowish, magnesian limestone, sometimes with a finely arenaceous composition, and is suitable for most purposes in common masonry. It is tolerably free from calcite lumps, but has some chert nodules. It is, however, generally useful for a cut stone in its outcrops in Fillmore county. It has been but little opened in Minnesota, principally because the region in which it occurs has not yet developed so as to create a demand for first-class stone for building. In Michigan and Ohio this formation supplies some of the most valuable limestone for building. The other sort of Devonian limestone overlies the last, and is much finer grained. It is light-colored, or sometimes nearly white, hard, and fine. It is uniform in grain and texture, and not in the least porous. Some parts of it would make a beautiful white, or nearly white, marble, if it were deeply quarried. In ordinary working it breaks with a conchoidal surface, but by some care a uniform cutting can be made in any direction. Some of the beds of this rock are about 10 inches or a foot thick, but they are more frequently about 4 or 6 inches, and can then be got out in slabs of considerable size. It is a fortunate circumstance that sometimes layers of clay are interposed between the beds, which facilitates their being obtained in sizable blocks. The most favorable point for quarrying this stone is at Le Roy, in the southeastern part of Mower county.

Limestone suitable for all purposes of building is found well exposed for quarrying along Deer creek, at Frankford, in Mower county. The age of this rock is not fully established, but is supposed to be of the Upper Silurian age. This stone is suitable for heavy masonry, being often 3 feet thick or more. The stone has about the same color as that at Le Roy, but is somewhat darker. Its texture is vesicular, with abundant calcite and some chert, and it is apparently a magnesian limestone.

SLATE.

At Thompson, where the Saint Paul and Duluth railroad crosses the Saint Louis river, the Huronian slates have been opened for the production of roofing slate, and with very good success. This enterprise is not now carried on, but there is no known reason why it should not be revived and made profitable. The slate is black, hard, and compact, fine and uniform, contains no spots developing crystals, pebbles, or other defects, and is apparently of the best quality. Considerable quantities which were taken out over ten years ago have been exposed on the ground to the weather at that place, and show no effect from such severe tests. The amount of the supply here is exhaustless, but of course some care must be exercised in selecting the beds for quarrying. Slates of different grades of hardness can be obtained, which will supply material not only for roofing, but for writing slates, tables, mantels, and all other uses to which such slate has been applied. The locality is perfectly accessible from the south by the Saint Paul and Duluth railroad, and from the west by the Northern Pacific railroad.

A good quarry in this slate was opened at Knife Falls, Carlton county, by the Saint Paul and Duluth Railroad Company, in 1880. The quarry is at a point 5 miles north of the Northern Pacific junction, near the northern boundary-line of Carlton county. Considerable stone was taken out, but none has been shipped or dressed in the condition of roofing slate. All that has been quarried was designed for flags, and the pieces are from a quarter of an inch upward in thickness and generally contain about 6 square feet, though some are larger. They are dark blue or nearly black, smooth and uniform, and well adapted for flagging, flooring, or marbleizing. The form of the natural slabs, as determined by transverse joints, is subrhomboidal and rectangular. No prices or markets were established before the whole enterprise, which must have involved an expense of $15,000 or $20,000, was abandoned by the railroad company, which abandonment is said to have been brought about in pursuance of the policy of the company to relinquish all extraneous enterprises and conduct only railroading. This termination of such a movement has had a bad effect on the reputation of the slate. Slates were quarried in 1870 on this formation at another point about 3 miles distant, and the weather has not yet injuriously affected it where used as roofing. This attempt was also very expensive to the owners, and, when the financial stringency came on, it was also abandoned. This formation appears very abundant in Minnesota farther north and east, especially about Vermillion lake, where the slates are less brittle and of a light green color.

PAVING STONE.

For pavement in ordinary roads or in the streets of cities a variety of material has been used, but in general the harder and tougher kinds of rock are the best. Sandstone is altogether too soft, unless it has been hardened into a quartzite by some method of metamorphism. Such changed sandstone is the quartzite at New Ulm and southwestward to Rock county, and also the quartzite or cemented sand-rock of the Cretaceous below New Ulm, in which the cement, being principally silica, has compacted the entire mass so as to form one very tough substance. This latter, however, is probably not obtainable in very large quantities, and its cemented condition is variable and perhaps not extensive. Still, whatever there might prove to be would, especially in connection with the Potsdam quartzites of New Ulm and of Rock and Pipe Stone counties, furnish a supply ample for that part of the state and for a large export to adjoining parts of Iowa and Dakota. The limestones of the Lower Magnesian, viz, those at Winona, Red Wing, Mankato, Kasota, and Shakopee, are better for paving material than other limestones that contain less silica, being firmer and harder and less soluble by water. Of good road material Minnesota has a superabundance. The granites, greenstones, traps, and quartzites form the most conspicuous feature in the geology of the northern and eastern portions of the state. The so-called trap-rock at Taylor's Falls is the most accessible of the firmer kinds of stone, excepting the pebbles and bowlders found in the drift scattered nearly all over the state. The granite at Saint Cloud and Sauk Rapids is also accessible, and is nearly as durable. The gneisses of the Minnesota valley are very suitable for the same use, and the rocks of the north shore, being very largely tough dolerites, are superior for this purpose. Some of the best exposures are at Duluth of stone known as "Duluth granite". These dolerites of the north shore are wrought into rounded forms on the beach by the action of the waves, and sometimes these rounded stones alone constitute the beach. They have been carried by ship-loads from Minnesota to Chicago and other cities for use in paving streets. They are found in considerable numbers in grading the streets of Minneapolis and Saint Paul, associated with similar forms of other hard rock, and are thrown with the dump and buried again. A little thoughtfulness would save thousands of dollars to each city.

FLAGGING.

So far as known, the state is not abundantly supplied with stone that is naturally and easily separable into sheets for flagging. Yet it is to be borne in mind that there has not yet been created a large demand for flag-stones, and that perhaps when the demand arises some of the quarries now in operation, or others, will be found to possess a good supply of flag-stones. Some of the beds most likely to furnish such stone of a durable character are the lighter colored, or at least the thinner bedded, portions of the red quartzite at New Ulm, or at some other points southwest of there. In the exposure of this quartzite at Redstone, near New Ulm, some of the lower layers are argillaceous and thin, and can be got in large slabs, which, with proper handling, could be broken to shape and size for flagging; but in general such beds are covered by a large thickness of firm, heavy layers of quartzite.

The Cretaceous beds at Fritz's quarry, a few miles below New Ulm, and at other places near, also will furnish a pretty good flagging, which it would be much easier to obtain than the stone at Redstone, the beds being separated by other layers of incoherent sand-rock. There are places in the Minnesota valley, above New Ulm, where the quarries would also furnish a good flagging stone, but of course, while more enduring in use, this stone would be more difficult to quarry. Of the limestones, or siliceous limestones, the beds of the Saint Lawrence or Shakopee formations are most promising. The former is in outcrop, as already stated, all along the Mississippi river from Winona to Hastings, and thence up the Saint Croix valley to and beyond Stillwater, and the latter is characteristically exposed at Shakopee, Ottawa, Kasota, and Mankato. Some of the thinner beds furnish a very superior stone for flagging, which is now somewhat used for that purpose. At the present time it is generally broken up for lime-burning or is sold as inferior building stone. The exposures of the Saint Lawrence formation at Hebron and other places in Nicollet county, and at Saint Lawrence, nearly opposite Jordan, in the Minnesota valley, are also very favorably situated for obtaining flagging; at Saint Lawrence particularly the beds are of about the right thickness. Some firm slabs of flag-stone are obtained at Kasota.

In the northern part of the state nothing is known that will answer for flagging, unless it be certain layers in the red sand-rock at Fond du Lac, or the argillite at Thompson. The former can be easily tested and readily obtained, but it would be rather soft for such use. It can be got in large slabs, but it would be refractory to work into shape and slippery in use, though very firm and durable when once laid.

IOWA.

By W. J. McGee.

The principal sources of knowledge of Iowa geology are the three reports of Owen, (*a*) Hall, (*b*) and White. (*c*) Unfortunately, the official surveys on which these reports were based were not carried to such detail as to afford more than a general outline of the geological phenomena of the state, and accordingly the published information on the subject is much less full and accurate than could be desired. Moreover, since the last of these surveys was brought to a close, additional natural exposures of strata have been discovered, the number of artificial exposures has been tripled, and, in consequence, beds probably distinct from those officially recognized have been brought to light, and material defects in the official maps have been detected.

In the dozen years that have elapsed since the publication of White's report many data have been collected by different observers. These are in part scattered through various publications, but are yet mainly unpublished. Among the latter are the observations I have made during the past four years, extending over the Cambrian, Silurian, and Devonian systems, which observations, though made in a desultory and unsystematic manner, and imperfectly connected, have been drawn upon almost exclusively in the preparation of the following descriptions, so far as the above-named systems are concerned. The descriptions of the newer systems are based mainly on the works of Hall and of White, especially of the latter, though in nearly every stage the observations of these gentlemen have been supplemented by my own. Since, however, careful and systematic geological work is yet required in every portion of the state, it is manifest that no high degree of accuracy can be claimed. Particularly reliable or particularly unreliable representations will be specifically indicated in the following pages. A few modifications in the classification of the rocks have been introduced for reasons mentioned in the detailed descriptions of stages. Synonymy, etc., may be learned from White's report, already cited.

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a *Report of a Geological Survey of Wisconsin, Iowa, and Minnesota* * * * . Made under instructions from the United States Treasury Department. Published by authority of Congress. Philadelphia, 1852.

b *Report on the Geological Survey of the State of Iowa.* * * * Published by authority of the legislature of Iowa. 1858.

c *Report on the Geological Survey of the State of Iowa to the Thirteenth General Assembly.* Des Moines, 1870.

GENERAL GEOLOGICAL SECTION OF IOWA.

GROUP. (*Era.*)	SYSTEM. (*Period.*)	SERIES. (*Epoch.*)	STAGE. (*Age.*)	*Thickness.*
				Feet.
Psychozoic	Quaternary	Glacial	Drift	200
Mesozoic	Cretaceous	Lower Cretaceous	Inoceramus	50
			Woodbury	150
			Nishnabotna	100
			Fort Dodge	35
Paleozoic	Carboniferous	Coal Measures	Upper Coal	325
			Middle Coal	150
			Lower Coal	200
		Sub-Carboniferous	Saint Louis	80
			Keokuk	90
			Burlington	125
			Kinderhook	200
	Devonian	Hamilton	Hamilton	250
	Upper Silurian	Niagara	Niagara	50 to 350
	Lower Silurian	Trenton	Maquoketa	20 to 125
			Galena	20 to 250
			Trenton	75 to 200
		Canadian	Saint Peter	80
			Lower Magnesian	350
			Potsdam	300
	Cambrian	Primordial	Sioux	100

QUATERNARY PERIOD.

DRIFT.—Under this general term are included the several beds of aqueo-chemical, vegetal, glacial, lacustral, and alluvial origin, which represent no fewer than eight distinct deposits, and which cover the sedimentary strata over more than 99 per cent. of the state. While the thickness of the drift is variable, it is generally sufficient to preclude the economical extraction of the underlying rock for industrial purposes, and at the same time to embarrass geological investigation, except in the deeper valleys of erosion; and over fully one-third of the state its depth and continuity are such as entirely to conceal the older strata.

Over much of the northern half of the state erratic bowlders of granite, syenite, and other crystalline rocks abound in the drift, and are more or less extensively employed for building and ornamental purposes. They are found in greatest abundance and perfection and of largest size in Butler, Bremer, Black Hawk, and Buchanan counties, where, as in all the northern third of the state, they either lie upon the surface or are but partially buried. Farther southward they diminish in size, become wholly buried, and finally diminish in number. The large bowlders have been most largely worked in Buchanan county, chiefly at and near Independence; but they are pretty largely employed for heavy foundations, bases, monuments, etc., at Osage, Mason City, Charles City, Waverly, Marshall, Eldora, and elsewhere. Smaller bowlders are also used for foundations, etc., either in their natural form or simply broken into irregular fragments (by blasting or by plugs and feathers), or, more rarely, dressed, in nearly every county in the northern part of the state, where they serve as a substitute for the inaccessible bedded rocks; but the demand is so variable and the supply so limited that the industry is neither important nor permanent.

CRETACEOUS PERIOD.

INOCERAMUS.—This newest stage of the sedimentary strata of Iowa consists of three conformable chalky beds, of which only the uppermost is sufficiently indurated to form a weak and friable limestone. It is not known except in the bluffs of the Sioux river in Plymouth and Woodbury counties, and it is practically worthless for purposes of construction, though the upper division is sometimes employed for cheap foundations, etc., in the vicinity of Sioux City.

WOODBURY.—The materials forming this stage are either sandstones, generally shaly and impure, or argillaceous, arenaceous, calcareous, or (rarely) bituminous shales. It is exposed along the Missouri and Sioux rivers in Woodbury county. At and in the vicinity of Sioux City the purer sandstone layers are quarried to the value of perhaps $1,000 or $2,000 per year, the product being used for common rubble, riprap, macadam, paving and curb stones, etc. The material is tolerably suitable for such purposes if care is exercised to exclude the obscurely, shaly, or otherwise defective portions. There is so much waste as to enhance its cost, but it can nevertheless be furnished at a less price than stone transported thither from better quarries.

Nishnabotna stage.—The Nishnabotna stage is mainly a coarse-grained, friable sandstone, generally quite ferruginous, sometimes gravelly and passing into pudding-stone, and rarely clayey. When cemented it is usually by iron, and it hence assumes the reddish-brown color of the hydrated sesquioxide. It is frequently obliquely stratified, and is generally massive or with very irregular and obscure bedding and jointage planes. It is exposed along the Nishnabotna river in Cass county, in Guthrie county, and in a few other localities; the only important quarry being at Lewis. A few smaller quarries are operated near Lewis, and others are said to be worked in southeastern Guthrie county.

Fort Dodge.—The stage to which it seems appropriate that this name should be applied is a deposit of nearly pure light gray, regularly-bedded gypsum, resting unconformably upon Saint Louis and Lower Coal strata, and unconformably overlain by drift, supposed to extend over an area of about 25 square miles in the vicinity of Fort Dodge. The bedding is horizontal, and it is generally distantly and vertically jointed. It is also finely laminated horizontally in alternate white and gray lines, the latter containing all the slight impurity with which it is charged. It is quite soft when first quarried, but hardens considerably on exposure. Some years ago it was quite extensively used as a building material, but it has now fallen into disrepute. Among the structures built from it are an arched culvert over Two-Mile creek, on the Illinois Central railway, and the depot building on the same railway at Fort Dodge, both of which were erected from 15 to 20 years ago. Four years ago the culvert was seen to be in good condition, and during the past season but little sign of dissolution could be detected in the depot building. Foundations built at about the same time are, however, reported to have given way. It is now almost exclusively employed in the manufacture of plaster of paris.

I have made but few and casual observations in connection with the Cretaceous rocks of the state, and hence their description is mainly taken directly from White's report. It is probable that much of the northwestern third of the state is underlain by Cretaceous strata; but the depth of the drift is so great as to prevent the actual determination of the geographical extent of the system. The classification adopted is that of White, except as regards the gypsum deposit, which is provisionally given a specific stratigraphical designation and included within the Cretaceous system. As shown by White, the deposit is apparently a precipitate of sedimentary character (*Geology of Iowa*, 1870, II, p. 300), and it hence must have been laid down in a basin isolated from the sea and subjected to gradual evaporation; and since the Cretaceous seas extended farther northeast than those of any other age between sub-Carboniferous and Quaternary times, it is regarded as most probable that this little inland basin was filled by sea-water during that period, and desiccated during the elevation that closed that period in Iowa.

The limited information as to the employment of the Woodbury sandstone for building purposes was mainly derived from incidental observations made some years ago; but from reports of a resident during the past season it appears that the material is used to about the same extent as at that time.

CARBONIFEROUS PERIOD.

Upper Coal.—The materials forming this stage of the general Iowa section are, as far as known, pure, magnesian, argillaceous, arenaceous, and earthy limestones, generally intercalated with shaly bands and partings, together with shales, clays, sandstones, and a thin coal seam. The pure and magnesian limestones are regularly, smoothly, and approximately horizontally bedded, and generally distantly jointed by the "clay seams" of the quarrymen; though the ledges, especially in the pure limestones, are independently cut up into angular blocks of various sizes by irregularly-ramifying vertical "dry seams", which often simulate fresh fractures. The area occupied by this stage is very considerable, though most of it is so deeply covered with drift that the rocks are accessible only along waterways.

In addition to the quarries specifically reported on there are small quarries supplying local demands for common rubble (used chiefly for cheap foundations, etc.) at Glenwood, Malvern, Red Oak, Macedonia, Corning, Bedford, Clarinda, Numa, and Winterset, in southeastern Cass county, in southern Decatur county, and elsewhere, which collectively produce building material to the amount of many thousands of dollars annually; indeed the demand for building stone for all except the more costly structures in the southwestern part of the state is chiefly met by the product of such local quarries. They are, however, so irregularly worked as to render it quite impossible to collect reliable statistics of their operation and product. All of these quarries are in limestone, the sandstones being worthless for building purposes so far as known.

The dolomite, which occurs only at Winterset, and in a few ledges at Earlham, is light buff or grayish-buff, finely saccharoidal, homogeneous, tough, quite free from grit, and seldom penetrated by dry seams. It well resists exposure and the action of frost, and is in all respects an excellent stone. The pure limestone is whitish or light gray, sometimes with a bluish tinge, finely subcrystalline, the fracture being generally conchoidal. It usually occurs in only a few ledges at any point, intercalated with impure limestone, but is not confined to any part of the area of the Upper Coal rocks. It is somewhat injured by dry seams, and does not perfectly resist the action of frost. The impure or argillaceous portions are light buff, yellowish, bluish, and sometimes blue-black, especially when freshly quarried; is approximately homogeneous, fine, compact, and brittle, and much cut up by dry seams. This stone is soon destroyed by frost, especially when kept moist, as at the ground level in foundations. Both the pure and argillaceous phases are remarkably uniform in lithological character over the whole area of the stage.

MIDDLE COAL.—This division of the Coal Measure series consists of shales, clays, sandstones, and limestones, with half a dozen thin coal seams, the limestones and sandstones occurring in thin, discontinuous beds. Its strata occupy a variable, tortuous belt, bounding the area of the newer stage, but not yet satisfactorily separable, geographically, from the Lower Coal stage. St. John mentions (*Geology of Iowa*, 1870, I, p. 284) that the limestones of this stage are quarried in the western part of Dallas county, and that the sandy ledges afford a fair freestone near Adel and south of Indianola; but it appears, from inquiries made, without visiting these localities, that neither here nor elsewhere are these rocks systematically quarried to any considerable extent.

LOWER COAL.—The lowest member of the coal-bearing rocks in Iowa is mainly composed of shales, clays, and friable sandstones, with occasional thin layers of impure limestone and a number of valuable beds of coal, the whole occupying a very considerable but extremely irregular area. Over this area (which was largely determined by Hall and White) the strata are tolerably uniform in character and approximately horizontal, though sandstones predominate toward its eastern and northern margin, and in the isolated outliers, and the beds are apparently disturbed by a number of gentle parallel undulations which coincide in direction with the principal waterways. In some cases certainly, and apparently in nearly all, the lines of erosion follow the anticlinals. Moreover, its attenuated margin is deeply lobed by the erosion of the tributaries of these streams and by all minor waterways which originate within its area. Accordingly it is quite possible that the terminal portions of many of the eastwardly-extending lobes are nearly insulated; while conversely, the Story county, Pella, and other sub-Carboniferous exposures may be completely surrounded by coal-bearing strata. The rock occurs in the southeastern part of Jones county, near Oxford, but its extent is not known. A brown sandstone also occurs in the eastern part of Delaware county, 5 miles south of Dyersville, and a ferruginous conglomerate is found in small quantities in the northeastern part of Howard county; but these exposures equally resemble the Nishnabotna sandstone, and may possibly not belong to either the Cretaceous or the Carboniferous systems.

The limestones of the stage are, so far as known, worthless for building purposes; but the sandstones, which are usually coarse, more or less ferruginous, heavily bedded or massive, rather distantly jointed, and often obliquely laminated, are quarried in many localities, chiefly near the margin of the area occupied by the stage, or in its isolated outliers. At Red Rock (9 miles north of Knoxville) it yields an excellent freestone of brick-red color, which attracted much attention a few years ago, but which is now mostly abandoned in consequence of the opening of quarries in superior limestone and sandstone strata of the Saint Louis stage in the vicinity. A less valuable freestone is reported to be quarried in a small way near Ripley, and in Boone county, 10 miles west of Sheldahl. At Steamboat Rock (4 miles north of Eldora), Eldora, near Marshall, at Kellogg, and south of Sigourney, a coarse, brown, friable, ferruginous sandstone, sometimes conglomeratic, which supplies local demands for common masonry, is quarried in a primitive manner whenever the material is called for; the aggregate annual product (excluding Eldora) is, on an average, about 80,000 cubic feet, worth about $2,500, but the output appears to have been less than usual for the past year or two.

The sandstones of the outliers are, as a rule, superior to those of the Lower Coal area proper. At the Dutch colonies, in Iowa county (East Amana, Amana, Middle Amana, Höhe Amana, West Amana, and Homestead), lying from 5 to 10 miles east of Marengo, it is finer and firmer than in the localities previously mentioned, and generally obliquely laminated. It is employed in the construction of the principal buildings, including mills and factories, in the several towns. The laborers of the colonies work the quarries whenever building material is required, or they are not otherwise engaged, moving about 75,000 to 125,000 cubic feet of rubble per year; but since this labor has no financial equivalent, and the product is common property, the value of the material is indeterminate. In the outliers of Muscatine and Scott counties the rock is still more extensively utilized as a building material. In the western part of this area it is lithologically similar to that found at Amana, or somewhat coarser and more friable, as in the Hare and Starke quarries; but eastward it is finer and less ferruginous, as in a quarry near Buffalo and the Goetsch quarry, in Davenport, where it is fine, uniform, clean, imperfectly cemented, and light buff or white in color. In the last-named quarry it reposes unconformably upon Devonian limestone, both being quarried, but neither extensively.

SAINT LOUIS.—This stage is made up of three distinct divisions. The uppermost of these consists mainly of pure limestone, sometimes brecciated or concretionary, sometimes regularly bedded, compact, finely subcrystalline, homogeneous and brittle, with a conchoidal fracture, and is overlain by a bed of clay, the whole being some 40 feet in thickness. The middle member is a sandstone or freestone, usually regularly bedded, distantly jointed, firm, homogenous, and hard; its thickness never exceeding 20 feet, so far as known. The lowest bed is an equally homogeneous, compact, regularly-bedded, distantly-jointed dolomite of unusual strength, fineness, and toughness. The area over which the strata of this age form the floor of the drift is not known with sufficient accuracy to permit of separating this from the older stages of the sub-Carboniferous series; but its outcrops are known in Lee, Des Moines, Henry, Washington, Van Buren, Jefferson, Keokuk, Wapello, Mahaska, Marion, Story, Hamilton, and Webster counties; its identity in the second as well as in the last three of these counties being stated on White's authority.

The uppermost division is the least valuable as a building material, though it is largely quarried for that purpose at Franklin, Mount Pleasant, Ottumwa, Chillicothe, Givin, Sigourney, Ames, Fort Dodge, Webster City, and elsewhere. In all of these localities it forms a fair, sometimes excellent, building stone. It has also been quarried for use in lithography, chiefly near Farmington, where the rock is similar, lithologically, to that found at Franklin. It is no longer used for this purpose, since it has been found to contain too many dry seams, often cemented by crystalline carbonate of lime. Its ordinary color is light buff, light gray, or nearly white, sometimes with a bluish tinge; and its normal texture, where of value as a building material, is fine, homogeneous, brittle, and sometimes very hard, as at Ottumwa. This phase resembles the pure limestone of the Upper Coal stage. It is, however, impure in its northwesterly extension. At Ames and at Webster City it is generally buff or yellowish in color, somewhat earthy or argillaceous, and quite similar to the impure portions of the Upper Coal limestone; while at Fort Dodge it is almost silty in part, dark blue or black when freshly quarried, though weathering to gray, and very erratic and refractory under the hammer when first extracted. It need hardly be said that the stone from these quarries does not well resist the action of frost. Little is known of the Webster City quarry further than that it supplies local demands for cheaper masonry, and that it is not largely operated. The city is in part supplied with better stone from the Farley quarries.

The middle division is largely quarried at Keokuk, Fairfield, Mount Pleasant, and Dudley. At Fairfield it is composed of siliceous sand in a calcareous matrix, and is irregularly bedded and closely jointed, rendering it difficult to find blocks of large dimensions; but it is so hard, and resists disintegration so perfectly, that a door-sill in constant use for twenty years exhibits scarcely perceptible wear. Ten miles northeast of Fairfield a small quarry, used locally, is said to yield much larger blocks of similar quality. Near Oskaloosa the rock is reported to be much the same as at Fairfield. It is here used for millstones with partial success. At Keokuk and at Mount Pleasant, but especially at Dudley, the ledges are smooth, uniform, distantly jointed, and free from dry seams, permitting the extraction of blocks 10 by 20 feet, or larger, though it is here less hard and indestructible than at Fairfield. The rock is generally gray or bluish-gray in color.

The lowest and magnesian member is extracted at Keokuk, Mount Pleasant, Chequest creek (5 miles southwest of Kilbourne), Brighton, Washington, Givin, Ottumwa, Dudley, Tracy, Pella, Durham, and Knoxville. At Washington, Brighton, and Knoxville it sometimes exhibits a styolitic structure, and is in addition rather irregularly stratified and closely jointed. At Durham, Pella, Tracy, Dudley, Givin, Chequest, and Mount Pleasant, however, it is regularly and rather heavily bedded, quite homogeneous, and distantly jointed. Its color varies from bluish-gray at Washington and Knoxville to bluish-buff at Chequest, yellowish-buff at Pella and Tracy, light buff at Givin and Durham, and whitish at Mount Pleasant; and in texture it is finely saccharoidal or compact, homogeneous, and tough, resembling in some cases the Upper Coal dolomite. At Chequest it is susceptible of a fair polish, and is widely known as "Chequest marble", and at Tracy, Pella, and elsewhere it may be carved with great facility. The bluish tinge is remarkably permanent, as at Washington, where fractures exposed for a number of years exhibited no perceptible alteration in color, and appeared almost as fresh as if just taken from the quarry.

KEOKUK.—This stage comprises two members, the upper being an irregular mass of shaly or calcareo-siliceous strata, abounding in geodes, while the lower consists of compact grayish or bluish limestone, generally regularly bedded, with shaly partings. The area covered by the rocks of this age is known to be limited, though it cannot yet be delineated cartographically. The only localities where these rocks are known to occur are portions of Lee and Des Moines counties, and a narrow belt along the Des Moines river, in Van Buren county, where they have been brought to the surface by one of the gentle anticlinals already referred to, coupled with the erosion of the valley. The stage appears, from White's observations, to attenuate and perhaps disappear toward the interior of the state.

The pure limestones of Keokuk age, like those of the Saint Louis and Upper Coal stages, are finely sub-crystalline, compact, brittle, homogeneous, and hard; light gray, whitish, and slightly bluish in color; but the larger portion is earthy or argillaceous, as is much of that of the Upper Coal. These impure limestones are buff, yellowish, or bluish, uniformly bedded, separated by shaly partings, which sometimes graduate into the ledges and again develop into considerable layers of clay; they are distantly jointed, but much cut up by independent systems of dry seams ramifying through each ledge, and liable to suffer disruption and disintegration when exposed to the atmosphere and frost. The Keokuk strata are not extensively quarried, the important quarries being confined to Keokuk and Bentonsport.

The smaller quarries in the vicinity of Keokuk and near Bonaparte, 5 miles southeast of Bentonsport, are also in this stage. The material is employed to some extent for dressed caps, sills, etc., as well as for rubble, macadam, and other common grades of building stone.

BURLINGTON.—This stage, like the Saint Louis, is made up of three well-marked beds. The uppermost division consists mainly of light gray, whitish, or buff, regularly-bedded, compact, subcrystalline limestone of approximate purity, with occasional clayey or shaly partings, becoming siliceous, cherty, and irregular toward the top. The middle member is predominately siliceous, but it is generally shaly, seldom sandy, and without compact and regular strata. The lowest division is a yellowish or grayish, compact, pure limestone, regularly and rather heavily bedded centrally, but cherty both above and below. The highest member constitutes about one-half and each of the two lower divisions about one-fourth of the total thickness of the stage. Its geographical extent is probably still less than that of the Keokuk division of the sub-Carboniferous rocks, since it is known only at its typical locality, Burlington, along lines of erosion in Des Moines and Louisa counties, and in the northern part of Washington county.

The Burlington rocks are practically identical with those of Keokuk, and are similarly used for common masonry and occasionally for dressed work. They are, however, extensively quarried only at Burlington. Portions of the uppermost division are nearly white in color, fine, compact, homogeneous, and hard, with a conchoidal or splintery fracture, like the so-called lithographic limestone of the Saint Louis stage. This phase has been used to some extent for ornamental purposes, but it contains too many incipient fractures and is too liable to unexpected disruption to be of special value.

KINDERHOOK.—The rocks of this age, which occupy a singularly long and narrow belt, are of rather variable character. At Burlington nearly the whole thickness of the stage is made up of shales and clays, with a few unimportant beds of limestone at the top, which include oolitic and magnesian layers. This phase is tolerably constant throughout Des Moines county, the dolomite forming the upper, the oolite the middle, and the shale the basal and principal portion. Along English river in Washington county the dolomite is considerably thicker (the oolite remaining inconspicuous), and, though rather earthy and irregularly bedded, is quarried in a small way near Riverside and Kalona, yielding common and heavy rubble, locally used for foundations, well-rock, bridge-piers, etc.; the average annual product of the several quarries probably falling below $1,500 in the aggregate. The stage is next known in Tama and Marshall counties, on both sides of the Iowa river. Here the basal shaly division is mainly absent or concealed beneath the river level, not to appear again in Iowa, and the two calcareous divisions are of predominant importance. At Montour the oolite is heavily bedded or massive, regularly and tolerably distantly jointed, and gray or bluish-gray, weathering to buff or yellowish. On the opposite side of the river the same oolite is less heavily and more regularly bedded, and is quarried by a number of individuals for lime and common rubble, the rubble supplying the vicinity and the towns of Toledo and Tama. These quarries are generally operated by farmers during leisure time, and yield collectively perhaps 75,000 cubic feet per year, worth about $750 at the quarries, or $3,000 delivered. A similar phase is presented at Conrad, Grundy county, where the material is more extensively utilized. Near Le Grand the uppermost or magnesian bed shows a thickness of over 40 feet, while the oolite is mainly beneath the river. Here the dolomite is regularly and rather heavily bedded, distantly jointed, compact, fine, and homogeneous, and generally buff, whitish, or yellowish in color. The coarser ledges are here so extensively used for rubble, bridge work, dimension stone, and other purposes as to require a railway station for the sole use of the quarry; while the finer ledges, which are often beautifully veined by iron peroxide, are sawed into slabs and shipped to distant markets for ornamental purposes, under the name of "Iowa marble". Near Dillon the same dolomite is unusually hard and firm, and is the sole member exposed. At and near Iowa Falls the two uppermost divisions of the same stage (as identified by White) again appear; but here the limestone is pure, finely subcrystalline, compact, hard, and without a trace of oolitic structure, and the dolomite is remarkably magnesian, generally heavily but regularly bedded, though in part massive and tolerably distantly jointed. Both members are quarried quite largely. The purely calcareous bed here resembles lithographically the brittle white limestone of the Burlington, Keokuk, Saint Louis, and Upper Coal stages. Several small quarries have been opened in the Kinderhook strata toward and above Alden, along the Iowa river; but their product is insignificant. At Humboldt and Dakota both the oolitic and subcrystalline phases of the middle bed, as well as the magnesian division, are exposed and largely quarried. Near the headwaters of Lizard creek the purely calcareous division again approaches the surface over a considerable area, and is exposed in a number of localities in both the oolitic and subcrystalline aspects. It is here quarried in a small way by half a dozen individuals in both Humboldt and Pocahontas counties, the total value of the annual product falling short of $1,000. The material here appears to be of unusual strength, hardness, and homogeneity, is regularly bedded and not very closely jointed, and promises to be of great value when the quarries are properly opened and adequate means of transportation provided. In addition to the foregoing there are small quarries near Ackley and Hampton which yield thinly-bedded, "shelly", (*a*) irregular limestones representing this stage, and another of like character is said to exist near Eldora, where a ravine cuts through the Lower Coal sandstone. The product of these quarries is trifling, and the real value of the material is very small since the use of it is almost an injury to the consumer.

DEVONIAN PERIOD.

HAMILTON.—The Devonian rocks of Iowa are extremely variable, both lithographically and paleontologically, but our knowledge concerning them is meager. The predominant lithological phases may be enumerated and described in the order of their excellence:

1. The "Old State House" dolomite.
2. The Mason City dolomite.
3. The Mason City limestone.
4. The La Porte limestone.
5. The Osage dolomite.
6. The Buffalo limestone.

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a The convenient term "shelly" (probably a corruption of *shaly*) is frequently applied by quarrymen in this state to rock which separates into irregular plates, generally an inch or less in thickness, and a foot or more in diameter. Such rock may not be shaly, as shown by the comparative purity of the Kinderhook limestone where it exhibits this phase. The phrase "excessively thin-bedded" might be equivalent, if the limited lateral extent of the plates were also borne in mind.

7. The Iowa City limestone.
8. The Waverly limestone.
9. The Independence limestone.
10. The Cedar Rapids limestone.
11. The Fayette breccia.
12. The Rockford shale.
13. The Independence shale.

1. The first of these is a peculiar, heavily-bedded or massive, slightly-magnesian gray limestone of remarkable homogeneity, toughness, and durability, largely made up of comminuted fragments of fossils, chiefly *Atrypa reticularis*. It is found at the North Bend or Old State House quarry, 9 miles northwest of Iowa City, not visibly associated with other strata; and only since the collection of statistics for the Census Office was completed has it been found to pass beneath apparently conformable strata of limestone of the Iowa City phase at Roberts' ferry. It is not known except in the immediate vicinity of the great bend in the Iowa river.

2. The Mason City dolomite is a rather heavily and regularly bedded brown and brownish-buff, distantly jointed, saccharoidal, homogeneous, tough, and compact magnesian limestone, lying conformably beneath pure limestone strata, and only known in the deeply-eroded valleys of Lime and Willow creeks at Mason City.

3. The third phase is a light gray or white, compact, homogeneous and brittle, finely subcrystalline, pure limestone, usually rather heavily bedded and distantly jointed, though considerably cut up by independent systems of fractures in each ledge. It closely resembles the pure limestone of the Upper Coal at Earlham, Stennett, Corning, and other localities; of the upper division of the Saint Louis at Franklin, Farmington, Mount Pleasant, Ottumwa, and elsewhere; of the Keokuk and Burlington at their typical localities; and of the middle division of the Kinderhook at Iowa Falls. Similar rock occurs elsewhere in occasional ledges, as at Garrison, Waterloo, Orchard, Floyd, Marble Rock (where the name of the town was derived from it), Osage, and Mitchell. The phase indeed appears to graduate into that of Iowa City on the one hand and into that of Waverly on the other, though it is approximately uniform throughout at Mason City.

4. The La Porte limestone is rather heavily and regularly bedded, compact, homogeneous, rather finely subcrystalline, but at the same time slightly tough. It is not quite pure, is somewhat unctuous to the touch, resists the action of frost fairly, and resembles the Mason City limestone as regards jointing. It appears to be normally bluish-gray, changing to gray or whitish on oxidation; but, as in the Saint Louis dolomite of Washington and Knoxville, the alteration is accomplished so slowly that partially-oxidized blocks remain distinctly mottled for years. A precisely similar phase has not been detected elsewhere, though certain ledges of the La Porte quarry are essentially identical with certain ledges occurring at both Iowa City and Waverly.

5. The Osage dolomite is a somewhat earthy and slightly magnesian limestone of light buff or yellowish color, and of tolerably fine, homogeneous, and compact texture. It is regularly bedded, sometimes with earthy, shaly, or cherty partings, rather distantly jointed, but sometimes independently seamed. It exhibits in a slight degree the tendency to become separated into angular fragments on exposure to the atmosphere, and especially to frost, which characterizes all of the inferior rocks of this stage. It is of rather variable character, and can only be arbitrarily separated from portions of the Waverly limestone. It occurs associated with limestones of the Mason City and Iowa City phases at Osage, Mitchell, Saint Ansgar, and Orchard; with the Waverly limestone at Waverly and Waterloo; with the Mason City limestone at Marble Rock (where it exhibits but very slight tendency to fracture on exposure), and with the Iowa City, Buffalo, Independence, and Iowa City phases at Davenport.

6. The Buffalo limestone is irregularly bedded, obliquely and rather closely jointed, blue, but weathering to gray within a year or two after quarrying, generally abundantly fossiliferous, and extremely hard, brittle, and refractory. It is quarried at and near Buffalo, where the fossiliferous portions are slightly used for ornamental purposes, chiefly for paper-weights, table-ornaments, and the like, large pieces of uniform character being difficult to procure. It is liable to become fragmentary on exposure. A somewhat similar but less hard and pure fossiliferous limestone is found at Charles City and Nashua, and unfossiliferous rock, resembling that of certain ledges of the Buffalo quarry, occur at Davenport, West Union, and in a few other localities.

7. The phase assumed at Iowa City is that of a non-magnesian but sometimes argillaceous, fine-grained, subcrystalline limestone, blue or even black on fresh exposure, but rapidly weathering to gray, buff, or whitish. It is tolerably regularly bedded, with occasional shaly or clayey partings, generally distantly jointed, but much cut up by independent systems of dry seams and fractures of fresh aspect, and it is quite disposed to become fragmentary on exposure. It occurs at Iowa City, Roberts' ferry, Muscatine, Atalissa, Garrison, La Porte (in the five last-named localities associated with other phases), Solon, Fairfax, Marion, and elsewhere. At Bristow the rock is quite similar, and at Rock Falls and West Union (in part) it partakes somewhat of the character of the Buffalo limestone. At Iowa City and Roberts' ferry it abounds in crystalline masses of the Hamilton corals, *A. cervularia davidsoni* and Farvosites (of two or three species), forming respectively the Bird's-eye and the Fish-egg varieties of the so-called Iowa City marble.

8. The Waverly limestone differs from the last in being more earthy, slightly magnesian, more yellowish in color, and still more disposed to become fragmentary on exposure. It occurs at Waverly, Shell Rock, Waterloo, Independence, Raymond, Vinton, Davenport, and Chatham, generally associated with other phases. Some blocks obtained a number of years ago from the latter locality, however, resemble the La Porte stone.

9. The Independence limestone is hard and brittle, blue, but weathering to gray, irregularly stratified or shelly, and regularly and closely, though often obliquely, jointed. It prevails near the eastern margin of the stage, as near Cresco and Lime Springs, north of Waucoma, at Fayette, Quasqueton, Independence, and in several smaller quarries It is usually fossiliferous, fragmentary, and somewhat similar to the Buffalo limestone.

10. The Cedar Rapids limestone somewhat resembles that of Iowa City, save that it is without regular jointing or bedding, and is so extremely fragmentary as to be worthless, except for macadam, railway ballasting, etc. It occurs at Cedar Rapids, west of Mount Vernon, at Atalissa, and in part of the Davenport quarries, where it is associated with other phases.

11. At Fayette, Quasqueton, and elsewhere, a bed consisting of angular fragments of compact, brittle limestone, embedded in a matrix of similar material, occurs. It is of no value for purposes of construction.

12 and 13. Neither the Rockford nor the Independence shales yield materials that can be used for building purposes in their natural condition. Both are made up of shales and clays.

It will be observed that a number of the quarries mentioned in the foregoing paragraphs are not represented in the tables. All of these are small, except a few which have been practically abandoned within a few years. More than thirty different openings have been visited during previous years. In the aggregate the average annual product of these small Devonian quarries is about 1,000,000 cubic feet, and the value of this at the quarries is about $22,000; though the value of the stone used for building purposes is considerably less than this. The material has been used mostly for foundations and underpinnings; some for bridge work, flagging, sills, etc., and some for railway ballast and for macadam. Most of it has been used in the vicinities of the quarries; a little has been shipped from Rock Falls and from Nashua.

The Devonian rocks of the state have been casually examined by a number of geologists in different localities, and have been referred to several stages, including the Chemung, Hamilton, Marcellus, Corniferous, and Upper Helderberg; but in view of the meager knowledge of the several beds yet acquired, it has been deemed the least objectionable course to provisionally group all together under the name of the single stage to which they were assigned by White.

UPPER SILURIAN PERIOD.

NIAGARA.—This sole stage of the Upper Silurian, as found in Iowa, is nearly everywhere a buff, brownish, yellowish, or whitish dolomite; though hard, brittle, and vesicular, non-magnesian masses of gray color, burning into excellent lime, occasionally appear. Considerable portions abound in chert, which usually exists in the form of nodules; but it permeates the material sometimes to such an extent as to form continuous but generally vesicular and irregular ledges, the cavities being filled with dolomite. Other portions are friable, cavernous, vesicular, destitute of homogeneity, shelly, or cut up by dry seams. All such portions, which collectively constitute by far the greater part of the stage visible from the surface, are of course quite worthless for other constructive purposes than road-making. The portions extensively utilized for building material are either regularly and rather heavily bedded and distantly jointed, finely saccharoidal, homogeneous, and tough, and of buff, light buff, or whitish color, as at Farley, Le Claire, Littleport, Volga, Cascade, Clay Mills, Maquoketa (in part), Buena Vista (in part), Princeton, and in most of the smaller quarries of Clayton, Dubuque, Jackson, and Scott counties; finely laminated horizontally, distantly jointed, and without dry seams, finely saccharoidal and tough, and of buff, yellowish, or whitish color, as at Anamosa, Stone City, Mount Vernon, Olin, Hale, Fairview, and Buena Vista (in part); heavily bedded or massive, distantly jointed, saccharoidal, moderately tough and firm, and brown, brownish-buff, or brownish-yellow in color, as at the Williams quarry (between Postville and Clermont), Waucoma, Cresco, Brainard, and Foreston; irregularly bedded and jointed, somewhat friable, finely vesicular, imperfectly homogeneous, and varying from brown to white in color, as at Clinton, Lyons, Comanche, and Sabula (in part); tolerably regularly but variably bedded and distantly jointed, though with occasional dry seams, firm, hard, and somewhat brittle, buff or light buff, with veinings of oxide of manganese, as at Delhi, Monticello, Central City, Maquoketa (in part), Sabula (in part), De Witt, and Tipton; or, finally, tolerably regularly bedded and not distantly jointed, fine, compact, homogeneous, brittle, and blue or light blue in color, as at Manchester, where alone this aspect has been seen. In nearly all of these phases the rock discloses occasional dry seams, which are generally straight, diagonal to the jointing, vertical, and discontinuous, often terminating in both directions in a single block; which seams may be partially or wholly cemented by crystalline calcite or dolomite, generally stained with iron oxide, and never simulate fresh fractures. They are seldom abundant in the larger quarries, but are nearly everywhere a source of some annoyance to the quarrymen, since they are most likely to occur in the larger blocks. The great importance of this stage as a source of building material has already been pointed out.

The number of small quarries not represented in the tables is about 40, the average annual product of which is about 800,000 cubic feet of stone, valued at the quarries at about $18,000. The stone is used almost exclusively for foundations, principally in the vicinity of the quarries.

LOWER SILURIAN PERIOD.

MAQUOKETA.—The materials forming this stage are mainly shales and clays, with occasional irregular and discontinuous beds of impure limestone; none being of value for building purposes. Its strata only appear in a narrow belt along the eastern margin of the Niagara stage. The stage becomes so attenuated in thickness in its northwesterly extension as to be quite unimportant both stratigraphically and geographically, though it can be traced to the north line of the state.

GALENA.—The greater part of the Galena stage consists of heavily bedded or massive and rather distantly jointed buff dolomite, of firm and tolerably compact texture, though sometimes vesicular or cavernous; but its upper portion is more argillaceous, regularly bedded, with shaly partings, and with its ledges independently but distantly fissured. The area occupied by the stage is inconsiderable, though, like the Maquoketa, its attenuated northwesterly extension can be traced quite to the state line. The rocks of the Galena stage are extensively quarried only at Dubuque, but they are extracted for local consumption near Elgin, at Elkader, near Massillon (4 miles west of West Union), and in a few other localities; the total product of these small quarries reaching about 50,000 cubic feet, worth not over $1,000. Twice this amount should also be added for the small quarries at Dubuque not specifically reported.

TRENTON.—In its more southerly exposures this stage is mainly composed of compact, hard, and brittle, blue or bluish-gray limestone, frequently rich in fossils, irregularly bedded, often shelly, rather closely jointed, and disposed to disintegrate rapidly. Northwardly it increases greatly in thickness, mainly by the addition of beds of clay and shale. It is occasionally buff or grayish in color in shallow quarries (*i. e.*, those of less depth than that to which oxidation has extended), destitute of fossils, and slightly argillaceous, when it considerably resembles the Iowa City phase of the Hamilton. The hard, brittle, fossiliferous portions, which are not greatly different from the Hamilton limestone as found at Buffalo and Charles City, are also generally slightly argillaceous, the clay appearing in irregular dirty lines or blotches after exposure.

The rocks of the stage are largely quarried at Decorah and Waukon. At Florenceville they are extracted for rubble and dimension stone to the extent of some 30,000 cubic feet, worth about $750 annually, the material supplying local demands, and being moved occasionally to Cresco and neighboring towns. The rock is here fine, compact, and brittle, breaking with a conchoidal fracture, and ringing under the hammer. It is normally blue, but is bluish-gray near the surface. At a depth it is massive, but near the surface it is divided into somewhat irregular ledges by smooth, clean, horizontal fissures. At Bluffton (between Florenceville and Decorah) it is quarried for local use to about as great an extent, though the value of the product is probably below $500. At Elgin, Frankville (6 miles northwest of Postville), Postville, and Clayton there are local quarries whose average product will equal that of Bluffton.

At Bluffton, Frankville, and Clayton the dark blue, fossiliferous phase is represented; but at Elgin and at Postville the rock more resembles that of Florenceville, though containing occasional, and sometimes abundant, trilobites. At Guttenberg both phases are tolerably largely quarried, perhaps half of the buildings in the town being constucted from Trenton limestone extracted in the immediate vicinity. The annual product of the two or three quarries here has been less than usual for a few years, but probably reaches 100,000 cubic feet, worth about $2,000. The stone is used for rubble, dimension work, and road material. A small quarry at Buena Vista (5 miles below the mouth of Turkey river) has yielded material employed in the construction of a large warehouse, and a large amount of railroad ballasting, but the average product is below $500 per year. In addition to these there are many small and unimportant quarries, some of which supply but one or two consumers, scattered over the whole area occupied by the Trenton stage.

SAINT PETER.—This stage is literally a bed of siliceous sand of remarkable purity and uniformity. It is nowhere sufficiently indurated to form a valuable building material in its natural condition.

LOWER MAGNESIAN.—Rocks of this age only appear in and along the valleys of erosion in the northeastern part of the state, where they form the summits of the picturesque bluffs of the Mississippi and the Oneota rivers and their tributaries. The material is essentially a coarse, saccharoidal, vesicular, cavernous, and non-homogeneous light buff dolomite, usually heavily but rather irregularly bedded, and without well-defined jointage planes. It is only rarely that the material is at the same time so firmly indurated, so free from irregular cavities and crystalline nodules, so homogeneous in texture, and so uniformly bedded as to be available as a building stone, and even where these several conditions are as favorable as they are ever found to be, the rock is rather coarse, irregular, and otherwise inferior. Its resistance to atmospheric action is, however, eloquently attested by the mural precipices, castellated battlements, slender pinnacles, and rugged declivities which combine to form the magnificent scenery for which its area is justly famed. It is extensively quarried only at McGregor and Lansing, though, like the Trenton, it abounds in unimportant quarries which sometimes supply but a single consumer.

In Minnesota this stage has been separated into three members (Shakopee, Jordan, and Saint Lawrence) by N. H. Winchell, while in Wisconsin a like number of probably not equivalent divisions ("Main Body", Madison, and Mendota) have been recognized by Irving; but none of these divisions can be either stratigraphically or geographically traced, nor have they indeed been clearly identified in Iowa.

POTSDAM.—This stage is predominantly sandy, and consists mainly of imperfectly-cemented sandstones, with occasionally shaly intercalations which sometimes develop into considerable beds of fossiliferous shale. It is exposed only in the walls of the deep valleys occupied by the Mississippi and Oneota rivers and their principal tributaries. It is not known to be quarried except at Lansing, where it forms an inferior material for common masonry. (The Potsdam of Hull and White is the equivalent of the Saint Croix of N. H. Winchell.)

SIOUX.—As developed in Iowa, the Potsdam sandstone is made up of hard, brittle, homogeneous, and rather fine pink or reddish quartzite, irregularly bedded or massive, and closely jointed, the jointage planes being frequently oblique to the vertical and not rectangular in the horizontal plane. It is found only in the extreme northwest corner of the state, and extends thence into Minnesota, where it is denominated Potsdam by N. H. Winchell.

There is a possibility that quarries of some importance have not been reported from some of the counties in this state. There are 19 counties known to be so deeply drift-covered as to be destitute of exposures of bedded rocks. These are Audubon, Carroll, Clay, Crawford, Decatur, Dickinson, Emmet, Fremont, Greene, Harrison, Lyon, Osceola, Monona, O'Brien, Palo Alto, Sioux, Wayne, Winnebago, and Wright. There are 32 counties in which there may be some small quarries which have not been indicated, though all possible inquiries as to their existence were made in passing through. These are Adair, Appanoose, Boone, Clarke, Dallas, Davis, Des Moines, Guthrie, Hamilton, Henry, Humboldt, Jasper, Jefferson, Keokuk, Lee, Louisa, Lucas, Madison, Mahaska, Marion, Mills, Page, Plymouth, Polk, Ringgold, Shelby, Union, Van Buren, Warren, Washington, Woodbury, and Worth.

The remaining 48 counties were so thoroughly examined that it is quite certain that no important omisssions have been made.

MISSOURI.

BY G. C. BROADHEAD.

GENERAL GEOLOGICAL SECTION.

					Feet.
1	Quaternary	Alluvium.			
		Loess.			
		Drift.			
2	Tertiary?				
3	Cretaceous.				
4	Carboniferous	Coal Measures	Upper Coal Measures.		
			Middle Coal Measures.		
			Lower Coal Measures.		
		Sub-Carboniferous	Chester group		
			Saint Louis group.		
			Keokuk group.		
			Burlington group.		
			Chouteau group	Chouteau limestone.	
				Vermicular sandstone and shales.	
				Lithographic limestone.	
5	Devonian.				
6	Upper Silurian.				
7	Lower Silurian	Hudson river			60
		Receptaculite, or Galena group			40 to 130
		Trenton			100 to 200
		Black River and Bird's-eye			50
		Calciferous / Potsdam	Magnesian limestone series	First Magnesian limestone	150
				First or saccharoidal sandstone	130
				Second Magnesian limestone	200
				Second sandstone	150
				Third Magnesian limestone	300
				Third sandstone	80
				Fourth Magnesian limestone	300
			Potsdam sandstone		5 to 90
8	Archæan	Porphyry	Huronian.		
		Granite.			

ARCHÆAN.

This includes the granites and porphyries and their associated and intrusive beds in southeast Missouri. The granites are generally coarse in texture, feldspathic and quartzose, deficient in mica, red in color, or else of various shades of gray, sometimes blending into a reddish-gray. They crop out in massive beds in the northern portions of Iron and Madison counties and in the southern part of Saint François county, with isolated exposures in Sainte Genevieve and Crawford counties. They afford our best quality of building stones. In some localities there is evidence of disintegration and decomposition on a grand scale; as, for example, 8 miles west of Fredericktown. At this place a well sunk 75 feet in depth passed entirely through granitic sand. In the western part of Madison county, at Lloyd's, south of Blue mountain, we also find evidence of considerable disintegration. These are probably due to chemical causes.

The phenomenon of rocking-stones is exhibited near the Ozark quarries, 4 miles southwest from Iron Mountain.

In the northern part of Madison county, east of the Saint François river, gray porphyritic granite appears over an undulating district near the Iron Mountain railroad. West of the Saint François river, the red granite rises into mountain peaks.

A syenitic granite forms a "shut-in" (*a*) on Saint François river near the Einstein mine, forming the "rapids" in Saint François river. It is traversed at this place by a dike of black dolerite 44 inches wide bearing S. 60° W. A few miles north of this, also on the river bank, we find it containing numerous specks and scales of micaceous iron and also much pyrites. Half a mile west the granite is traversed by a narrow dike of black dolerite 11 inches wide at the north end and 4 inches at the south end. From the north end it bears S. 32° W. for 30 feet, thence it gradually curves to S. 82° W. a distance of 5 feet. The adjacent granite wall has been slightly darkened and indurated by contact.

At the "Lloyd" place, in Sec. 15, T. 33, R. 5 E., a shaft in decomposed syenite has revealed a vertical dike 18 inches wide bearing northeast and southwest. Two hundred feet northwest another shaft reveals a north and south dike of similar rock 2 feet wide. The dike is of a gray dioritic character. A quarter of a mile east there is a greenstone dike 8 feet wide bearing a little west of north. Washings of sandy débris thrown out show a good deal of deep black magnetic-iron sand. Washings in the roads at several places within a few miles also reveal a good deal of this sand. In the southern part of Saint François county, west of Saint François river, a pit has been sunk on a rich deposit of micaceous iron which, being very soft, was at first supposed to be graphite.

The granite is also sometimes traversed by quartz veins, as in Sec. 2, T. 33, R. 5 E., and Sec. 6, T. 33, R. 6 E.; also on Cedar creek, where very large quartz crystals have been obtained. At the Einstein "silver" mines, in Madison county, the rocks indicate an association of diorite and serpentine. The exact position and relation of the beds could not be ascertained, as all work had been suspended, but the specimens left include serpentine, green and violet-colored fluor, clear and white quartz, argentiferous galena, wolfram, iron pyrites, and zinc-blende. The massive rocks near the river are red and gray granite, with red porphyry just west of them.

Only recently has much attention been directed to the quarrying of granite. There are but two quarries worked to any extent, the stone from which is used for paving streets and for general building purposes, principally in the city of Saint Louis. The stone from a quarry 4 miles west of Iron Mountain, Iron county, has been used in a pavement on Washington avenue, Saint Louis, for about 6 years, and the pavement is still in good order. The flagging around the Southern hotel, at Saint Louis, is also of this granite; also the front of the residence of Mr. Charles G. Stiefel. The amount of granite which may be obtained in this locality is practically inexhaustible. The eastern portion is a stratum of gray granite probably a mile in width. It has not been found farther north, but extends southwardly into Madison county for a distance of about 5 miles. The red or reddish-gray granite lies west of this, and is probably several miles in width, extending southwardly into Madison county, where it is wider in its east and west extension and more red in color. It extends south more than 10 miles, nearly to the mouth of the Little Saint Francis river.

The granite from the quarry at Knob Lick, Saint François county, is a coarse, feldspathic rock, made up of red feldspar and limpid quartz, with rarely a dark-colored bronze or black mica. It occasionally contains *lenticular* or ellipsoidal pockets of fine-grained, micaceous, gray granite, and these spots are often pyritiferous. Otherwise the quality of the rock on the whole seems good.

On the surface there are in several places large, rounded bowlders, some 20 feet high, resting on a small foundation, and some rocking-stones also occur. These large masses are roughly outlined and sent to market for building purposes. The smaller blocks are rough-dressed into 6-inch paving blocks and shipped to Saint Louis. Vertical joints sometimes occur, and a discoloration of 3 inches sometimes appears. One inch of the weathered crust occasionally crumbles off.

Feldspar has for several years been taken from the Sainte Genevieve quarries and used in glazing certain ironware.

Porphyries are often exposed in Madison, Iron, Wayne, Saint François, and Reynolds counties, and form the highest peaks in this region, being elevated from 200 to 660 feet above the valley. The foot of these mountains is

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a A local term signifying that steep, rocky cliffs approach close to each bank of the stream.

generally flanked by porphyritic conglomerate, or limestone and sandstone of Potsdam age. The testimony of the rocks goes to show that previous to the formation of sandstone and limestone the country presented the appearance of rough porphyry knobs rising from 1,000 to 1,500 feet above the sea. In these depressions was the Potsdam sea, in its early ages quite tempestuous, as is evidenced by the conglomerates and coarse sandstone, chiefly formed of eroded fragments from the Archæan rocks. These sandstones occupied the shore-line of the Potsdam sea. In the course of time these waters became more quiet, and calcareous sediments with occasional sandy matter were formed; but observation shows that this deposit in no place extends along the Archæan slopes over 350 feet above the present valleys.

The porphyries, in their typical and most common form, seem to be a fine-grained, impalpable mixture of orthoclase and quartz, generally of a red, brownish, or purple color, sometimes dark gray or black, and porphyritic chiefly from the presence of feldspar crystals and often grains of crystallized quartz. Most of the porphyries on their edges show a shade of red; many of them are banded and show cleavage planes; in some we find well-marked lines of stratification, and some even show ripple marks, indicating a sedimentary origin. At Pilot Knob the porphyry incloses rounded pebbles, and epidote, hornblende, and serpentine occur; also beds and veins of specular iron represented on a large scale at Pilot Knob, Iron Mountain, and Sheppard mountain, some of the ore at the latter place being magnetic. Slate, resembling roofing slate in character, occurs on Buck mountain, in Iron county, and dikes of diorite and dolerite are sometimes seen.

At the so-called Tin mountain, in Madison county, the porphyry is traversed by coarse dioritic dikes and black dolerite, and on the waters of Captain's creek a dike of coarse syenitic greenstone, 75 feet in width, cuts the porphyry. In Sec. 16, T. 32, R. 6 E., there is an interesting exhibit of a series of dikes traversing dark porphyry (see Fig. 8 in *Missouri Geological Report*, 1874). Against the porphyry wall on the east are 10½ feet of greenstone, next west a few inches of dolerite, then 4 feet of porphyry, then 2 feet of greenstone, then porphyry. The course of the dike is S. 45° W.

In Iron county, in Sec. 9, T. 32, R. 4 E., a dike of hornblende rock, standing several feet above the general surface like a wall, can be traced north and south for one-eighth of a mile. On Gray's mountain, in Wayne county, and in the southeast part of Iron county we find exposed beds of steatite. In the northeast part of Reynolds county and the northern part of Madison county eruptive porphyry has been found of a gray color, and containing large crystals of white feldspar.

In Iron county are found amygdaloidal rocks flanked with porphyry. The amygdules are of a white mineral. A few miles southward the porphyry contains blue crystals.

A good exhibition of a dolerite dike in porphyry is on Mine La Motte property, at Jack diggings, and there is another dike at a cave on Rock creek. The porphyry is generally very hard and difficult to quarry.

SEDIMENTARY ROCKS.

A section of the unaltered Sedimentary in connection with the Archæan of southeast Missouri is about as follows:

1. Twenty feet of coarse, sometimes vitreous, sandstone, the second sandstone of Missouri geologists.
2. One hundred and twenty-five feet chert beds, with some clay and quartzite; contains *Murchisonia straparollus*, orthoceras, and a few species of trilobites, typical of the calciferous sand-rock.
3. One hundred to 300 feet of magnesian limestone, chert, and quartz, crystalized in drusy cavities; corresponds to the Third Magnesian limestone.
4. Magnesian limestone, 100 to 150 feet.
5. Fifty feet gritstone and lingula beds, to be referred to the Potsdam age.
6. Ozark marble, 5 to 50 feet.
7. Five to 90 feet sandstone and conglomerate.
8. Porphyry, } Archæan.
9. Granite, }

The Lower Magnesian limestone, with the lingula beds just below, incloses the lead mines at Saint Joseph, in Saint François county, and also the mines at Mine La Motte. The galena is found with these rocks in horizontal beds between the layers of limestone, or occurs as a replacement of limestone beds, or is disseminated in the limestone; and these I regard as by far the richest lead deposits of the west.

The Third Magnesian limestone may be found over the greater part of 20 counties of Missouri, often forming mural escarpments along the streams, and sometimes extending to the highest hills. It is generally lead-bearing. It is both coarse and finely crystalline, and is often a pure dolomite of a bluish-gray or flesh color. It very rarely contains shale beds; but, especially in the upper part, there are some thick chert beds. At the lead mines of Washington county it is often cavernous, and includes numerous drusy cavities lined with minutely-crystallized quartz. At some of the mines, especially those of central Missouri, it has undergone a decomposition, and quantities of dolomitic sand are thrown out. It is well exposed along the Osage river from 10 miles above its mouth to the line of Benton county; on the Gasconade from 20 miles above its mouth to its head, and on the two Pineys. It is seen on Osage river, first near Castle rock; passing up stream it gradually rises, and at the south line of Osage county it attains a thickness of 180 feet. It is often cavernous in the middle and lower beds, and sometimes forms natural bridges across streams. Many of the caves occur in this limestone, and saltpeter has been made from the clay deposits on the floor of the caves. Of note we might name Friede's cave, 10 miles northwest of Rolla. Other caves are found in Maries, Pulaski, Miller, Ozark, and in other counties of south Missouri. This formation also seems to be the source of many large springs in south Missouri, from which flow those bold, swift, clear streams, affording unsurpassed water-power. On the Osage, in Miller, Morgan, and Camden counties, the Third Magnesian limestone forms steep, mural escarpments and wild, picturesque scenery.

The second sandstone lies next above; it is generally coarse, whitish, or slightly brown, tinged by iron, occurring more often in thick beds, and affords a good building stone. It is often the top rock on the cherty hills of south Missouri; and the pineries, when found, generally grow here. It is also the formation containing most of the iron deposits of central Missouri.

The Second Magnesian limestone chiefly forms the Missouri bluffs from Saint Charles county to the west line of Cole county, often extending from the foot of the bluffs to their top. It contains very few beds suitable for building purposes, but the lower 25 feet are thickly bedded, some dolomitic, and with some intercalated beds of sandstone, affording a very good coarse building stone; for example, near Rolla, at Hermann, the Osage and Moreau, near Pacific railroad, at Jefferson City, and near Stoutland, in Camden county. But above these beds there is scarcely 1 foot in 50 feet of this formation suitable for building purposes. This is also occasionally lead-bearing. Most of the limestones in the upper half are readily acted on by frost. The middle and upper portions contain numerous green and drab shale beds, with many intercalations of concretionary chert, sometimes assuming curious grotesque forms.

The saccharoidal or first sandstone is found along the Mississippi hills from near Sainte Genevieve via Plattin creek, through Jefferson county, the western part of Saint Louis county, thence up the Missouri river, chiefly capping bluffs nearly as far west as Jefferson City. It is also pushed up to view on Sandy creek, in Lincoln county, near Auburn, and on the north line of Lincoln, west of Prairieville, and on Spencer creek, Ralls county, near the Saint Louis, Hannibal, and Keokuk railroad. It is generally a pure white sandstone, containing 99 per cent. of silica. It is well exposed at Crystal City glass-works, where it is used in the manufacture of fine plate-glass. At this place it is pure white and soft, and about 40 feet are exposed. At Pacific, Franklin county, it is well exposed for 100 feet, the upper 70 feet being a pure white soft sand; the lower part is tinged with oxide of iron. Due north of this, on the Missouri bluffs, Saint Charles county, it is 133 feet thick. Thirty miles east of this, or a few miles west of Saint Louis, borings reached it at 1,300 feet below the surface.

This sandstone is regarded as superior for glass-making, but it is often not sufficiently coherent for building purposes, though there are a few exceptions, namely, the stone used on the Missouri Pacific railway at Berger and between Hermann and Gasconade. Some quarries on the hills near by afford a beautiful pink-banded sandstone. Obscure fragments of a large species of orthoceras have been met with in Gasconade county, some of which measure 8 inches in diameter, others nearly 2 feet.

The First Magnesian limestone is found in Pike, Ralls, Lincoln, Saint Charles, Warren, Callaway, Boone, Franklin, Saint Louis, Pettis, Jefferson, Sainte Genevieve, and probably in a few other counties. Its greatest thickness is about 150 feet. It is generally easy to work, and forms a durable building stone of some beauty. Its prevailing colors are drab and buff. It caps the hills at Pacific, Franklin county. Missouri college, Warren county, is built of it, and very good quarries can be opened near by.

The Black River and Bird's-eye formation is probably found in Lincoln, Pike, Ralls, Saint Charles, Saint Louis, Warren, Franklin, Jefferson, Perry, Sainte Genevieve, and Cape Girardeau counties, but is wanting in central and southwestern Missouri. The upper beds are often full of winding vermiform cavities. The lower often have minute specks of calcite, and are likewise varied in color and would sometimes polish into a handsome marble. Such are found in Warren county on the hills near affluents to the Missouri, and are well exposed near heads of Tuque creek and Charette. The colors are drab, pink, purple, flesh-color, and buff. Another handsome variety found in Warren county has a brown appearance, with dark, almost black, winding lines, as of fucoids. Some of these would undoubtedly look handsome if polished, and are also durable. *Ormoceras tenuifolium* and other characteristic fossils have been found.

The Trenton beds, lying above the Black River beds, occur generally in thin layers of a bluish-drab color and may generally be found resting upon the Black River beds. At Danville, Missouri, and on Loutre river, near west line of Montgomery county, also at some places in the northern part of Lincoln county, it occurs whitish or else variegated, with many specks of calc spar disseminated, and appears very well when polished. The upper beds are almost entirely made up of numerous fossils, including *Orthis, Pleurotomaria Murchisonia*, with occasionally *Ceraurus pleurex anthemus*.

The Upper Trenton or Receptaculite limestone is found from Cape Girardeau, along the river counties, to Jefferson county, thence northwest to the town of Pacific and along the Missouri bluffs from Saint Charles county to the eastern part of Warren county, thinning out westwardly. It is also found in Lincoln, Pike, and Ralls counties, resting on Trenton. It is quite cavernous in these counties, but in the counties on the Missouri and lower Mississippi it is a good building stone, and it also burns into an excellent quality of lime. The upper beds are brownish-gray, the lower a white, crystalline limestone. In Warren county the upper 20 feet is a light gray, the lower 8 feet a dark brown limestone. *Receptaculites Oweni* is everywhere found. We also find *Chætetes lycoperdon* and sometimes a trilobite. It corresponds in age with the Galena group of northern Illinois, but is not galeniferous in Missouri.

The Hudson River formation is found only in some of the counties on the Mississippi river. The beds are chiefly shaly, and are sometimes very pyritiferous. I regard this group as the source of most of the mineral springs of northeast Missouri. It affords some good flag-stone beds in Lincoln and Pike counties.

The Upper Silurian is best developed in Perry and Sainte Genevieve counties, where occur several hundred feet of drab and variegated limestone, which looks handsome when polished. In Pike county we find a drab and brownish limestone, sometimes in very thick beds, closely resembling the Grafton beds, and as useful for building purposes. We find this at Bowling Green, Paynesville, and between Frankfort and Louisiana. In Warren and Montgomery counties and the eastern part of Callaway county there are about 20 feet of a coarse, gray, crinoidal limestone, which is said to be a good "fire rock".

The Devonian is not of sufficient importance to take rank among building stones. It is best developed in Callaway county, where it affords many fine organic remains.

SUB-CARBONIFEROUS.—In the lowest, the Chouteau or Kinderhook group, we find at its base, at Louisiana, 55 feet of dove-colored, compact limestone, having a conchoidal fracture. This rock has every appearance of a lithographic limestone, and was so named by Professor Swallow. In other portions of the state the same limestone is represented by a thickly-bedded dolomite, and as such it is found on Sac river, in Cedar county, and at Taborville, in Saint Clair county.

Above this limestone are the vermicular sandstone and shales, characterized by winding, vermiform cavities from northeast to southwest Missouri. It is a friable, easily-worked sandstone, sometimes affording good beds for building purposes. The thickness, including the shale beds, is about 75 feet. Above this is the true Chouteau limestone, the upper beds of a coarse, gray, and sometimes ferruginous, crinoidal limestone, containing *Leptæna depressa* and *Spirifer marionensis;* below this is a thickly-bedded magnesian and sometimes argillaceous limestone, containing geodes of quartz and calcite and occasional chert beds. Where not too subject to frost action it affords a useful building material; as such it is found in Pike, Lincoln, Ralls, Boone, Callaway, Pettis, Cooper, and Greene counties. The lower part is formed chiefly of thin layers of dove-colored limestone, which was seen 100 feet thick a few miles west of Sedalia.

The next above is the Burlington group, called by Professor Swallow the Encrinital. In Saint Charles county we find at the top about 17 feet of chert, with alternations of red clay. The middle beds are gray and coarse; the lower gray and brown, generally coarse and encrinital. Crinoid stems are commonly diffused throughout, the lower strata sometimes abounding in well-preserved *Crinoideæ*. This group is found at Burlington, Iowa, Quincy, Illinois, Louisiana, Missouri, and is well exposed on the Mississippi bluffs in counties north of Saint Louis, and from the western part of Saint Charles county, in remote hills, as far as Howard. It is occasionally met with in southwest Missouri, in Cedar, Dade, Greene, and Christian counties, where it is often cavernous, containing large and beautiful caves. The streams in Greene and Christian counties owe their origin chiefly to springs in this formation.

The upper beds of the Keokuk group are sometimes shaly, with geodes of quartz, and some of them are quite beautiful. The lower beds are gray and bluish-gray, with lenticular and concretionary chert beds. *Archimedes*, *Hemipronites crenistria*, and crinoid stems are numerous, and some fish teeth are found. This is the limestone of Keokuk, Iowa. It is found in the central part of Saint Charles county, in Saint Louis, Boone, Howard, Monroe, and Cooper counties, and is especially well developed in southwest Missouri, from Henry county southwest. It is the lead-bearing rock of Dade, Jasper, Cedar, Newton, and Lawrence, and is also found in McDonald and Barry counties. It is, in part, equivalent to the siliceous group of Tennessee, and is well developed in Benton county, Arkansas. It is probably 300 feet thick in its greatest thickness, and affords good quarries for building purposes. The Saint Louis group is best developed in Saint Louis and Saint Charles, and is also found in Lincoln, Lewis, Clark, and Knox counties. It is generally a compact, dove-colored, or finely-crystalline ash-gray limestone, with generally a splintery fracture. It is much finer grained than any other group of the sub-Carboniferous. It is also cavernous in Saint Louis, Saint Charles, and Lincoln counties, as shown by occasional funnel-shaped sink-holes which communicate with subterranean passages. The outlets of these sink-holes about Saint Louis have generally become filled, and ponds are the result. The characteristic fossils are *Melonites*, *Lithostrotion*, *Productus*, and *Hemipronites crenistria*, with numerous *Bryozoa*, with sometimes beautiful *Crinoideæ*. The lower or Warsaw division abounds in *Archimedes* and *Pentremites*.

The Chester group of 200 to 300 feet of limestone, with a sandstone, is found in Perry and Sainte Genevieve. The sandstone, often ferruginous, is found in northeast and southwest Missouri. Good quarries of this sandstone may be opened near Newtonia, Newton county; near Lamonte, Pettis county; in eastern and northern portions of Cedar and near Lamine, in Cooper county, and a very good quarry is worked near Sainte Genevieve.

The Coal Measures include the Upper Coal Measures (barren), 1,300 feet; Middle Coal Measures (productive), 320 feet; Lower Coal Measures (productive), 300 feet.

In Atchison there are exposed 180 feet of rock, including, at top, 40 feet of sandstone and red shale beds, with limestone and beds of calcareous shales below, containing well-preserved remains of mollusca, some of them presenting a strong Permian type. Below these are chiefly shale beds, with some limestone and occasionally sandstone, but with very little coal or even bituminous shale. There are thicker limestone beds in the Upper Measures than below, and they are also better for building purposes than those of the Middle and Lower Measures. Nevertheless some (especially the blue limestones) contain a good deal of pyrites, and are necessarily inferior. Those most suitable may be quarried at Kansas City, Jackson county, and in Cass, Clay, Platte, Andrew, Holt, Nodaway, Atchison, Daviess, Livingston, Mercer, and Harrison counties.

The middle series are chiefly sandstone, with some limestone beds and some coal beds of workable thickness, but rarely contain good beds of building stone. The Lower Coal Measures are the productive measures; they also contain beds of valuable sandstone for building, with numerous outcrops in southwest Missouri. Much of it is also suitable for making grindstones. The quarries near Miami station, in Carroll county, and near Meadville, Linn county, are the best in north Missouri, the others being inferior. In southwest Missouri most of the sandstones are bituminous.

Recapitulating, we would briefly say that the granite of southeast Missouri is the best material for building purposes. The pure limestones are generally of good quality. But few of those of the Upper Carboniferous are durable, nor are many of the beds of the Second Magnesian limestone. The sandstones are most eagerly sought after, chiefly because they are easy to quarry and to work into shape. They also answer better for city work. The best include the Potsdam of southeast Missouri, found in Madison, Saint François, and Iron counties. Others may include the sub-Carboniferous of Sainte Genevieve, Newton, Cedar, Pettis, Howard, and Cooper counties; also, the sandstones of the Carboniferous, found among the Lower Coal Measures of southwest Missouri, chiefly in Barton, Vernon, Cedar, Saint Clair, Henry, Johnson, and Carroll counties. The second sandstone along the Osage and on hills of southwest Missouri is also a good building stone.

Saint Louis quarries.—The most extensive limestone quarries in this state are located in and near the city of Saint Louis. The formation is the Saint Louis division of the sub-Carboniferous period. The extent of the quarry industry in this locality is not so much due to the superiority of the stone as to its accessibility to the Saint Louis market. A representative section of the quarries is shown at Mr. Moran's quarry, which shows 20 feet of loose material; 20 feet of thin, shelly limestone, in layers from 3 to 8 inches in thickness; 3 feet of brownish-colored limestone, containing some chert. From this quarry a specimen of *Productus marginicinctus*, a very rare fossil peculiar to this group, has been obtained.

The stone from this quarry is used for the construction of foundations and other ordinary building purposes, and for street pavements, especially for macadam. The stone from the best Saint Louis quarries is strong and durable, and is also well adapted to the manufacture of lime. Its principal use has been in the construction of foundations. The excavation has been carried at one quarry to a depth of 60 feet, but at present the quarry is not worked to a greater depth than 40 feet, 20 feet of the lower portion of the excavation being filled with water. A section at this quarry shows 8 feet of cap-rock; 8 feet of limestone in thin layers; 9 feet of limestone in layers 12, 4, and 2 inches thick, and below this a massive, heavy bed of limestone; still lower the beds are from 1 foot to 2 feet thick, this being the most applicable for building purposes. The quarry of Mr. Philip Steifel has become somewhat noted for its fine mineral specimens, including calcite, pearl-spar, dog-tooth spar, millerite, and fluor-spar. The fluor-spar is of a yellow color; the calcite is white, or colored on the outside with millerite. In some places the limestone has a greenish tint from the presence of nickel-sulphide. The millerite has bunches of stray hair-like crystals of a bronze color, and each crystal is a delicate hair-like mineral. It has been found penetrating the calcite and extending from side to side in the limestone. It is also frequently found associated with the pearl-spar.

Among the most valuable of these quarries as regards the quality of the material are three at Cote Brilliant, about 2½ miles from the city of Saint Louis. Its development is only retarded by its being at a greater distance from the market than many of the other quarries.

A section at one of these quarries shows 25 feet of loose material; 15 feet of gray limestone, in layers about 3 inches in thickness; 4 feet of limestone, in layers of variable thickness; 2 feet of close-grained gray limestone; five 3-inch layers of gray limestone; one 22-inch layer of gray limestone; and 15 feet of limestone below the water level.

The best layers are pure limestone, susceptible of being quite highly polished, very strong and durable, and quite well adapted for architectural purposes.

The formation in the quarry of Mr. Gottlieb Eyerman probably belongs to the upper portion of the Saint Louis group, though it may belong to the next higher, the Chester group.

Jefferson City quarry.—The greater part of the quarry product is used at present by the Missouri Pacific Railroad Company for the construction of bridges; the small fragments are used for ballast, and small slabs are sold to citizens of Jefferson City for ordinary building purposes.

The following is a section at this quarry:

1. Soil and clay	6 feet.
2. Unevenly-bedded limestone and chert, in thin beds, suitable for ballast only	12 feet.
3. Fine-grained homogeneous rock, in even thin layers, locally called "cotton rock"	4 feet.
4. Gray limestone with numerous small cells filled with white powder	2 feet.
5. Chert beds	2 feet 6 inches.
6. Drab, evenly-bedded limestone, also called cotton rock	9 feet.
7. Gray, hard, cellular limestone, generally preferred for bridge construction	10 feet.

No. 6 is similar to the rock which was used in the construction of the state-house, which was erected about forty years ago. It is occasionally slightly discolored with stains of iron, of which minute globules and specks are seen, apparently changed from pyrites. The layers from this rock are of quite uniform thickness, many of the 4- and 6-inch layers making a very handsome paving stone. It has been quite extensively used in Jefferson City, where it has been termed cotton rock, by which name it is also known in other localities in this state. The prevailing color of this rock is drab, but in some localities it has a bluish tint, and is liable to disintegrate rapidly on exposure to the action of frost. Some of the drab layers also readily disintegrate on exposure to the weather. The best of the material needs to be quarried early enough in the season to allow the quarry water to become dried out before the stone is exposed to the action of frost.

No. 7 is a harder rock, and is not well adapted for cut work, though a very desirable material for heavy bridge construction, for which little dressing is necessary, and for which the qualities most desirable are those of strength and durability. The rocks at Jefferson City may all be referred to the Calciferous sand-rock group, known in Missouri as the Second Magnesian limestone series. Fossils are very rarely found. A section of 200 feet may be seen at Jefferson, and only a *lingula* is found in the upper beds; the other beds abound in fucoids. Lime manufactured from some of the layers possesses hydraulic properties.

Boonville quarry is located on the bluff side of the Missouri river, just above the railroad bridge, and about 12 feet above the ordinary water-level in the river. When the river rises to the level of the quarry operations are necessarily suspended. The bluff rises steeply above the quarry for over 100 feet, so that the quarry cannot advance far inward on account of the rapidly-increasing amount of cap-rock. The layers of stone are generally tolerably even, and from 10 to 16 inches in thickness, with occasional partings of calcareous shale. A vertical section of quarry rock 16 feet in thickness is exposed. The strata dip slightly to the west. A little to the east, at the bridge, about 30 feet of gray, cherty limestone are exposed, containing, as far as could be seen, only specimens of an *Archinedipora* and a turbinated coral. The quarry rock lying above this also contains specimens of *Archimedes*.

Sedalia quarry.—The product of this quarry is used locally for foundations. The strata quarried lie at the junction of the Chouteau or Kinderhook group with the Burlington beds. The following is a section of the quarry:

Loose material	5 feet.
Gray ferruginous limestone, in two layers	5 feet.
Buff limestone, shading to blue below	3 feet.
Shales	1 to 3 feet.
Blue limestone, with chert concretions and some masses of calcite	5 feet.

The floor of the quarry rests on a rock similar to the lowest which has been quarried. The lowest beds are the least durable, the upper 5 feet of limestone being quite durable. These two layers belong to the Burlington group, and the beds below them to the Chouteau.

A number of small quarries have been worked in this vicinity. From some of these blocks 4 feet thick may be obtained, all, however, containing more or less chert concretions and masses of calcite. One of the older quarries shows much of the rock shattered by frost.

Clinton quarry is located about 4 miles south of Clinton, Henry county. It furnishes material to the town of Clinton, principally for sidewalk pavements. The stone is an argillaceous limestone, and occurs in a stratum about 15 feet in thickness, and in layers from 2 to 10 inches in thickness. The thinner layers are drab-colored throughout; the heavier layers have a lead-blue color in the interior, and those layers which have not been exposed to atmospheric action also have the lead-blue color. Below this quarry rock occurs a seam of bituminous coal 4 feet in thickness, which is one of the best coals of southwest Missouri. Below this again there are 9 feet of blue shales, with ironstone concretions to the level of the water in Grand river. Similar beds occur near Brownsville, Sabine county, and may be referred to the same geological age.

Kansas City quarries.—The stratum of limestone designated in the *Missouri Geological Reports* as "No. 87, general section, Upper Coal Measures", has been quarried extensively at quarries in bluffs of Kansas City and for 2 miles further east; also in a quarry opposite the Union depot, Kansas City, now abandoned on account of expense of stripping. The rock is also occasionally quarried in bluffs at and above Rosedale. Its color is generally a light gray, becoming locally a bluish-gray, and, when exposed, a lighter and often ferruginous gray. The middle portion of about 9 feet is beautifully oolitic, and is most valuable for building; it works freely and is easily dressed.

Below Kansas City the stripping at first is only a few feet, but of course increases as the operations extend into the bluffs.

Limestone No. 90, Upper Coal Measures, lying a little above, is often quarried and used for ordinary foundation work, while the limestone under consideration is used for general building purposes. It may be seen in the basement walls of the Merchants' exchange, the *Journal* office, and the building at Twelfth and Washington streets, Kansas City. It contains the characteristic coral *Campophyllum torquium* (O. and S.). It is generally evenly bedded in layers from 6 to 16 inches in thickness, and is much used in foundations. It is apparently durable and of more than usual strength. Its texture is homogeneous, and often has numerously-disseminated bright calc-spar specks. The color in the quarry is a grayish-drab, weathering to a brownish-drab, and shows a brownish discoloration along the joints.

Limestone No. 96, of Upper Coal Measures, also found here, is a bright gray rock with numerous specks and short lines of calcite. It contains also many fossils whose shells are of pure calcite, or else the interior is nicely crystallized. The strata are generally from 6 to 9 inches thick and of very irregular bedding. The entire stratum is 30 feet thick. An examination of the various quarries in Kansas City indicates that about 50,000 cubic yards of rock have been removed and used in the city during the past twelve or fourteen years. This includes from 9,000 to 10,000 cubic yards from the bluff opposite the Union depot, 30,000 cubic yards from southwes Kansas, and the remainder from south Kansas. The various railroads have probably taken out and used 10,000 cubic yards not included in the above.

There is quite a number of localities in Missouri where limestone has been quarried or may be quarried, beside those in which there are actually working quarries as represented in the tables. Three miles north of Canton, Saint Louis county, the Central Marble and Stone Company has recently opened a quarry in the sub-Carboniferous formation. The beds vary in thickness from a few inches to 8 feet. Considerable quantities of this stone have been quarried for bridge abutments, foundations, and for flagging. The stone has a uniform texture and gray color, but becomes darker on exposure to the atmosphere; and this may prove a defect if the discoloration does not go on uniformly. The quarries are located less than half a mile from the Saint Louis and Keokuk railroad and one mile from the Mississippi river.

Near Bowling Green, Pike county, the Niagara limestone has been quarried in a small way for the past forty years, and has been quite largely used for bridge abutments on the Chicago and Alton railroad, and occasionally for the construction of buildings. A dwelling in Bowling Green, built about forty years ago, is of this material, and the stone still looks well and shows no signs of disintegration. There are two quarries. A section at one quarry shows 4 feet of soil and gravel, 4 feet of shelly limestone, and 12 feet of building stone in three layers, the upper of which is 2 feet in thickness, and the two lower each 5 feet thick. This stratum of building stone is separated from a stratum of equal thickness below by 1 foot of shales. This last stratum of building stone consists also of three layers, 4, 6, and 2 feet in thickness. At the other quarry about 40 feet of rock are exposed in layers from 1 foot to to 2 feet in thickness. The stone when first quarried has a bluish-gray color and weathers to a brownish-buff color.

Near Glencoe, Saint Louis county, the Trenton limestone has in former years been quarried for building purposes. There are at present quite extensive quarries still in operation, but their product is all manufactured into lime. At Cape Girardeau, Cape Girardeau county, is quarried the Lower Silurian limestone, most of the material being burned, and that which is most suitable being reserved for purposes of construction. At present some of this stone is being shipped for repairing the state capitol of Louisiana, which was built of this stone, and was partly destroyed during the late war. The quarry is situated about three-quarters of a mile from the wharf, on the Mississippi river, and the stone was at one time quite largely shipped to the south. An analysis of this rock by Dr. A. Litton, for the *Missouri Geological Report*, gave carbonate of lime, 99.57; silica, a trace; alumina, a trace.

The total thickness of rock exposed at the quarry is about 30 feet, the upper portion being in thinner layers and a little darker in color than the lower. The lower portion is a beautiful white limestone, and blocks 6 feet in thickness could be obtained.

Near Rolla, Phelps county, quarrying has been done in a small way in the lower portion of the Second Magnesian limestone. This stone has been used for the construction of culverts and bridge abutments, and near the same place a thinly-bedded, hard, and durable limestone occurs which has been used for sidewalks.

Some of the limestones in southeast Missouri have been called marbles. The Cape Girardeau limestone has been termed a marble by some. In the *Kansas City Review of Science and Industry* the marbles of southeast Missouri are described; and it is given as the reason why these marbles have not been extensively developed, that they usually occur in beds not of sufficient thickness to furnish blocks of adequate size for the purposes for which marbles are usually employed. It states that near the head of Cedar creek there are several outcrops of variegated red and drab marbles. A section of rocks on a southeastern branch of Cedar creek shows 10 feet of coarse magnesian limestone resting on 10 feet of light drab marble of fine grain traversed with brown veins. Near the mouth of Cedar creek, Madison county, some of the finest exposures of the most handsome varieties of marble occur. It is handsome when polished, and the outcrops show that it is very durable. At the head of Tom Suck creek, in Reynolds county, are thick beds of flesh-colored marble. Two miles north of Cape Girardeau, on the land of Dr. Thomas Holcombe, are outcrops of variegated purplish-red limestones, with occasional calcite specks in heavy layers. Marbles of fine texture passing through various shades of flesh-color, yellow and green, pink, purple, and chocolate, all handsomely blended, are said to occur in Sainte Genevieve county. These marbles occur in the Potsdam and Niagara formations. The Potsdam marbles are found on Stout's creek and Marble creek, in Iron county; Cedar creek, Marble creek, and Leatherwood creek, in Madison county; and Tom Suck creek in Reynolds county. The Niagara marbles are found in Cape Girardeau and Saint Genevieve counties.

Near Mooresville, Livingston county, limestone in the lower portion of the Upper Coal Measures has been quarried since 1866, but the quarries have not been regularly worked. A section there shows 1 foot of soil, 4 feet of shelly limetone, 2 feet of clay shale, 1 foot of bituminous shales, 6 inches of clay shales, from 2 to 3 feet of blue fire-clay, and 9 feet of oolitic limestone valuable for building purposes. The rock is rather hard, quite strong and durable, and is especially applicable for heavy masonry. This same formation has also been quarried in hills 5 miles south of Princeton, Mercer county, near the line of the Chicago, Rock Island, and Pacific railway; also on the Wabash, Saint Louis, and Pacific railway, Clay county, about 8 miles from Kansas City. It may also be found near the base of the bluffs at Kansas City, and at several places near Pleasant Hill, Cass county, where it is locally termed cotton rock, and is said to withstand a higher degree of heat than many other limestones.

At Forest City, Holt county, there are several limestone beds exposed, and also a soft sandstone, but the stripping is generally so heavy that the best layers of the rock cannot be extracted with profit. Limestone also crops out 2 miles above Forest City, and beyond this for 20 miles no building stone occurs.

Near Amazonia, Andrew county, 14½ feet of evenly-bedded, ferruginous gray, and somewhat oolitic limestone occurs. A quarry of this rock was formerly worked 2½ miles northeast of Savannah, and the stone was transported by wagons to Saint Joseph and used in the construction of buildings. Similar quarries might be opened near the line between Andrew and Buchanan counties, and the same formation also crops out near Atchison, Kansas.

Near Greenwood, Jackson county, the Missouri Pacific Railroad Company has opened a quarry, but the material is used principally for ballast, and only a small amount has been used for the construction of culverts. Oolitic limestone of the Upper Coal Measures has also been found near Greenwood, and is used for purposes of construction on the Missouri Pacific railroad. The stone is well adapted for rough masonry.

Near Pleasant Hill, Cass county, there are several quarries situated in different localities which have occasionally been worked. The stone has been used principally for the construction of railroad bridges and culverts, and for local purposes. The formation belongs to the Upper Coal Measures, and consists of a number of limestone beds, some of which are oolitic and some shelly. Blocks 2 feet in thickness and of any length and breadth desired may be obtained.

At Neosho, Newton county, a whitish-gray oolitic limestone is quarried for lime. This stone works freely, and would be well adapted for purposes of construction. A coarse, dark gray limestone is also quarried near Neosho, some of which contains many chert concretions.

The sub-Carboniferous limestone has been quarried for local use at Springfield, Greene county. The quarry rock shows a face of 10 feet in depth of coarse, gray limestone. The upper beds resemble the Keokuk limestone, and the lower beds are more of the Burlington type. The geological divisions recognized in Iowa, Illinois, and eastern Missouri cannot strictly be sustained in southwest Missouri.

The Second Magnesian limestone has been quarried near Marshfield, Webster county. The exposure shows one bed 33 inches in thickness of buff limestone. This appears to be a durable stone, easy to quarry and to dress. It is covered with but little cap-rock, but the stripping would be slightly increased as the excavations would be extended into the hill. There are two good exposures a few hundred feet apart.

Quarries of sandstone.—At a quarry located 1½ miles west of Miami station, Carroll county, there are two grades of material produced. The poorest quality contains many plant remains, and shows dark lines of fragments of plants, along which it is often fractured by frost. The best quality is free from these defects, and is a rather beautiful gray sandstone. There is a vertical face of about 70 feet exposed, the lower 45 feet being without any seam of bedding, but containing occasional concretionary masses of harder sandstone. At the top there is a depth of about 6 feet of soil and clay, and below this are 20 feet of rough and sometimes shelly sandstone layers. The quarry rock is a rather coarse, gritty, sandstone, making an excellent building stone, and being also valuable for the manufacture of grindstones. The concretionary masses are of no value whatever. They have some argillaceous layers interstratified, and also contain many nice fragments of plant remains. Although there seem to be no bedding planes in the lower 45 feet, still there are a few faint, banded, dark carbonaceous streaks occurring from 6 to 12 feet apart. The absolute percentage of waste material embraced in the concretionary masses amounts to about one-fiftieth of the entire mass. The concretionary portions disintegrate quite rapidly on exposure to the weather, but the other material is very durable. This quarry has been actively worked for about fifteen years, and the rock has been shipped to various markets in Missouri, Kansas, Iowa, and Nebraska. Eastwardly along the bluffs the rock has a more brown color, and is not so highly esteemed.

The Warrensburg quarries are of the same geological age as the above. At the quarry of Messrs. Bruce & Veitch the rock when quarried often shows planes of cross lamination, and this, although otherwise of good quality, is not of sufficient value for shipping purposes, but is used locally for ordinary purposes of construction. Considerable loss results from this defect. The planes of these laminæ are separated by carbonaceous matter. The stone in this quarry is quite soft when first taken out, and hardens on exposure. Various openings have been made in this vicinity which are not now worked. From one of these 6,000 cubic yards were excavated, and from another 500 cubic yards. Three-quarters of a mile northwest, on the land of Mr. Bunn, a coarser sandstone of the same geological age appears, about 20 feet in thickness, forming a solid bluff on the Blackwater for several hundred yards, and seems to underlie an area of about 10 acres.

Quarries 2 miles north of Warrensburg occupy a tract of probably over 200 acres in sandstone of the Lower Coal Measures. The total thickness of this sandstone is over 100 feet. The quarries have not developed the entire thickness suitable for building purposes, only 45 feet in depth having been quarried.

The sandstone hills are bounded on the north by Blackwater river, on the west by Post Oak creek, and on the east by Potts branch. Approaching Warrensburg from the north we still find sandstone, but of an inferior quality. In the railroad cuts and southward, and throughout the town, and for a short distance north, the rock is generally brown and soft, and crumbles to powder on exposure. It also sometimes alternates with shaly beds, and sometimes incloses beds of ferruginous conglomerate, and but rarely is it suitable for building purposes.

Northwardly, as we approach the quarries, the rock is more homogeneous, the color becomes a light gray, and bluish-gray in deeper quarries. Concretionary masses of a harder sandstone not easy to work, in fact worthless for shipping, sometimes occur. These contain many carbonaceous stains and fragments of calamites and other plants. A trunk measuring over 1 foot in diameter, with its bark half an inch in thickness changed to bituminous coal, was taken out. It is supposed to belong to a coniferous tree, probably *Dadoxylon acadicum* of Dawson.

North of the Blackwater good quarries have also been opened, and over thirty years ago columns for the court-house at Lexington, Missouri, were cut out. Those columns are still entire, and are discolored only by time.

The Normal School building at Warrensburg was the first structure of note in which this stone was used, but since then it has been largely shipped to many places, including Saint Joseph, Kansas City, and Saint Louis, Missouri; also Chicago, Illinois, and Lincoln, Nebraska.

In 1871 the quarries were opened, and in 1874 one firm shipped 900 car-loads over the Missouri Pacific railway. A block 20 by 6 by 2½ feet was taken out and used in the Chamber of Commerce building at Saint Louis. The rock weighs 140 pounds to a cubic foot when dry, but only from 145 to 150 pounds when first quarried. It forms a large proportion of the face-stone of some Saint Louis dwellings, and it was also used in the Union Depot building at Chicago. It stands the test of time very well. It is not known to have scaled off, but after long exposure it becomes darker on the surface and somewhat stained.

The Miami and Warrensburg quarries are systematically worked by means of channeling and wedging. No powder is used except for removing the cap-rock.

A quarry in Clinton, Henry county, furnishes stone for ordinary construction for local use. A section of the quarry shows 3 feet of loose material, 4 feet of sandstone in layers from 1 inch to 4 inches in thickness, and below this 7 to 8 feet of sandstone in layers from 2 to 3 feet in thickness.

The Sainte Genevieve quarry is located about 1½ miles from the Mississippi river, which furnishes the means of transportation. Blocks of the largest size desired can be obtained at this quarry. Pieces 150 feet long, 20 feet wide, and 10 feet thick are often channeled off and loosened with the wedges.

The Insurance building at Sixth and Locust streets, Saint Louis, was chiefly built of this stone, including the figures on the top. The stone has been much tarnished by the smoke of the city. Among the other structures of this material are the Singer Sewing Machine building in Saint Louis, the approaches to the Saint Louis bridge, the arsenal at Rock Island, Illinois, and the state capitol of Iowa. Everywhere the stone has proven very durable. The quarry shows 25 feet in thickness of good uniform rock; the layers, 1½ to 5 feet thick, can be split readily into thin slabs if required. It is occasionally false-bedded, and then contains fragments of plant remains, chiefly carbonized. The thin layers are very much ripple-marked and the texture of the rock is generally homogeneous. It is soft when first quarried and hardens on exposure. It is a good fine grit, and a number of grindstones have been made of it.

The geological age of the formation is the Chester group of the sub-Carboniferous. The bluffs near by show about 25 feet of gray limestone of the Saint Louis group lying below it.

KANSAS.

GEOLOGICAL SECTION.

			Feet.
1	Tertiary	Pliocene sandstone	150
2	Cretaceous	Niobrara	200
		Fort Benton	260
		Dakota	500
3	Permian	Limestone and shales	1,000
4	Carboniferous	Upper Coal Measures: Limestone, shale, and sandstone	1,300
		Middle Coal Measures: Shales, coal, sandstone, and limestone	370
		Lower Coal Measures: Sandstone, limestone, shale, and coal	350
		Sub-Carboniferous limestone	150

GENERAL DESCRIPTION.

Sub-Carboniferous.—The sub-Carboniferous occupies a very limited area in the southeast corner of the state, but is highly galeniferous, as the lead mines in southeast Kansas occur in this formation.

Carboniferous.—The Carboniferous, as developed in the Lower Coal Measures of southeast Kansas, incloses some thick and valuable coal beds. It also includes many beds of sandstone of an excellent quality for building purposes and good flag-stones. These may be found of good quality and well exposed in Cherokee, Crawford, Bourbon, Neosho, Labette, Montgomery, Wilson, Woodson, Greene, and Elk counties.

The Middle Coal Measures include several good beds of workable coal, and coal has been mined at Oswego, Fort Scott, Thayer, and near Toronto, and in Osage county. In Bourbon and Linn counties we find several thick limestone beds, but the western outcrops in Greenwood county are chiefly of sandstone.

The Upper Coal Measures in northeast Kansas include a number of limestone beds, with a good deal of shale and some sandstone, but in southern Kansas we find but few beds of limestone, nor do the Upper Coal Measures include many strata desirable for building purposes.

The Permian is made up of beds of drab-blue shales, with occasional limestone strata. In the lower series we find many excellent beds of rock for building purposes; some of the strata are slightly magnesian. The middle beds are now very much worked; in fact quarries are now opened and successfully worked upon all the lines of railroad where this rock is found. The character of the rock does not materially differ in the various quarries, whether in northern, central, or southern Kansas. The building stone of the lower strata is not so soft as that higher in the series. The color is always the same shade of drab or buff. The beds are all softer than those of Carboniferous age; and, being at the same time durable, they are much sought after by builders. While I call these rocks Permian, I must say that the contained fossils have also been obtained from the Upper Carboniferous of Missouri and Kansas; in fact, I believe nearly every well-known Permian fossil of Kansas has also been obtained from the known Upper Carboniferous strata of Kansas City, Missouri. Lithologically the rocks seem different, and we have mostly to be guided by their general appearance, which is very easily recognized even in small specimens.

Cretaceous.—The Dakota group is easily recognized, it being composed entirely of sandstone or shales. The sandstones are sometimes of a dirty white color, but are more often a ferruginous brown. Good specimens of fossil leaves of dicotyledonous plants are sometimes found; also occasional layers of clay, ironstone, and some thin deposits of a poor quality of coal.

The Fort Benton group in the lower part consists of dark shales, with beds of brown limestone in the upper part, which are very much used for building purposes. Although this rock is very soft, it is otherwise very durable and strong enough for buildings of several stories in height. One bed, banded red or brown and buff-brown, I have traced from Mitchell county through Russell and Ellsworth counties to Rush county. It is easily wrought with a common saw, and forms handsome walls, but is too soft for sidewalks.

The Niobrara group of western Kansas affords the white-chalk beds, which furnish a very handsome white stone, but it is too soft for many purposes. It is extensively developed in western Kansas. This formation contains many rare and interesting remains of extinct vertebrata. The Tertiary is confined to northwest Kansas.

The building stones of Kansas, although extensively used, are much softer than those of the states east, but, being easily worked, are being used now in many cities. Most of the Permian strata are too cellular or porous.

Quarries.—The stone quarried near Irving is used at Atchison, Kansas City, and on the line of the Union Pacific railroad, which passes at a distance of about half a mile from the quarry. The rock is quarried for a distance of three-quarters of a mile in the bluffs south of the railroad. The upper or western quarry is from 15 to 20 feet above the valley; the lower quarry is from 30 to 40 feet above it. The outer rock is blasted off and used for ballast on the railroad. After the stripping is taken off a level floor is sometimes exposed from 20 to 30 feet wide, and extending several hundred feet along the hill. The limestone formation quarried here is of no great thickness. At the upper quarry there are 3 feet of shales and soil, and below this three layers of limestone, the first 8 inches in thickness and the other two each 13 inches in thickness. At the lower quarry there is 1 foot of soil, and below this are four layers of limestone 9, 12, 16, and 19 inches in thickness, respectively, the last sometimes divided into two layers. The stone is quite soft and easily quarried, and is also easily dressed when first taken out, but hardens on exposure. The strata are very nearly horizontal and the beds are of quite uniform thickness. For the construction of railroad bridges and other like structures the stone requires but little dressing.

From a quarry on the hill-top 1 mile southwest of Frankfort the stone is used principally for foundations, though a church and a school-house and some storehouses have been constructed of it. There are other small openings both to the east and to the west of it. The hill is about 150 feet high, and the quarry rock occurs near the summit, with shales below, while a good bed of building stone appears near the base of the hill. The beds here worked are apparently the same as those quarried near Irving, and dip to the west from 80 to 100 feet in 7 miles.

The Atchison quarry furnishes stone for ordinary building purposes for local consumption. The limestone is here only from 4 to 8 feet in thickness. Sometimes it is cross-laminated, when it can only be used for common purposes. The bedding is generally even and horizontal.

Stone near Manhattan is quarried chiefly on the hill-top, about 200 feet above the valley of the Kansas river. A large portion of that used for the superstructure of buildings is taken out about 30 feet below the summit of the hill. A section of the rocks here is about as follows: Soil, 1 foot; limestone for bridge construction, 16 inches; limestone, 11 inches; flag-stone, 4 inches; two layers of limestone, 12 and 14 inches; depth not exposed, 30 feet; shaly, bluish limestone, 2 feet; building stone, 1 foot; and dark shale to the base of the hill, 170 feet, with a few limestone beds and red shale about half-way down.

The stone used for bridge masonry is cellular and coarser than the other, but is equally strong and durable. Of the stone from these quarries there have been constructed in Manhattan an addition to the college building, six churches, the Adams hotel, and several fine residences.

There are about 35 common buildings in Topeka built from the stone from a neighboring quarry. They are all roughly built and laid in mortar. Some buildings have brick fronts, with stone in the remainder of the superstructure. This stone is also used in foundations. From another quarry the stone is shipped to various points along the Missouri Pacific railroad in Kansas and Missouri. This stone was used in the construction of the Congregational church and the public-school building at Emporia, Kansas, and an opera house is now being constructed of it in the same town. The Missouri Pacific Railroad Company has selected this material for the construction of shops, one about to be built at Parsons, Kansas, and another at Sedalia, Missouri.

The stone from a quarry near Lane, Franklin county, is used principally at Ottawa and at Garnett, and some has been shipped to Chicago. One of the buildings of the asylum for the insane at Osawatomie was built of this stone. There are two varieties of stone obtained at this quarry, one a little darker in color than the other, and more uniform and compact in texture. The darker-colored variety has been dressed and sent into the markets for several years under the name of "coralline" limestone. It is sometimes called oolitic limestone, being largely composed of small fossil fragments very much like the Indiana oolitic limestone and having also a similar appearance. This variety has a very firm, compact structure, and is susceptible of being quite highly polished. In the lighter-colored variety the fossil fragments are many of them larger and not so uniform in size, showing some evidence of stratification in alternate layers of coarser and finer material; and the interspaces between the fossil fragments are not well filled, giving the stone a rather open and vesicular structure. This stone being easily quarried and dressed, is quite extensively used for buildings and trimmings. The quarry which is here most largely worked is on the point of a bluff about 100 feet in height. A branch of the Missouri Pacific railroad passes along the base of the hill, and provision might easily be made by which the stone could be placed on a car at the quarry, but at the present time it is drawn a distance of 1 mile to the station. A section of the quarry shows the following: Loose material, 4 feet; vesicular buff limestone, one layer 4 feet in thickness and another 1 foot in thickness; gray, irregularly-stratified limestone with some chert connections in layers from 2 to 6 inches in thickness, 6 feet; blue shale in thin laminæ, 1 foot; irregular layers of buff limestone, 2 feet; gray limestone, 4 feet; and bluish-gray or drab oolitic limestone, 6 feet. This last has lately been most extensively used for building purposes. The layers are from 18 to 24 inches in thickness. These beds are all referred to the upper portion of the Carboniferous period. They are also well exposed along the bluffs of Pottawatomie creek from near Lane to Garnett. The upper quarry rock has been quarried at Greeley on the hill-top and used in railroad masonry. It has also been quarried near the Lawrence and Southern railroad, north of Garnett, and appears in the Marais des Cygnes bluffs near Ottawa for a distance of 15 miles to the east. Good specimens of fossils can sometimes be obtained from this formation.

The geological age of the formation in which the Cottonwood quarries are located is probably the middle or upper part of the lower beds of the Permian period. The rocks here lie below those quarried at Marion Center and Florence, and are probably above the Dunlap stone. Blocks of any length and breadth desired, and 2½ feet thick, can be obtained from these beds. The quarries are easily worked by channeling and wedging. The stratum of quarry rock is, however, only about 6 feet in thickness, overlaid by a few feet of thin limestone layers and shales. The stone is used for general building purposes at Kansas City, Saint Joseph, Omaha, Des Moines, Pueblo, Denver, Lincoln, Atchison, Leavenworth, and Topeka. The material may be seen in the west wing of the state-house and in the basement of the post-office at Topek; in the basement of the depot at Pueblo; in the court-house at Leavenworth; in Creighton college at Omaha; in the depot at Atchison; in the Missouri Valley Life Insurance building at Leavenworth; and in numerous other buildings along the line of the Atchison, Topeka, and Santa Fé railway.

The beds quarried at Marion Center belong to the Middle Permian, and are at a horizon above those quarried at Cottonwood station, as has already been stated. A general section here shows: Flag-stone layers from 2 to 6 inches in thickness, 5 feet; magnesian limestone, 16 inches; yellowish-drab soft limestone, uniform in texture, easily dressed, and used for the construction of buildings, 23 inches; and drab-colored limestone, considerably fractured and containing numerous chert concretions, 20 feet. The material from this quarry has been used in the construction of the asylum for the blind at Wyandotte, and the asylum for the insane at Topeka.

The Florence quarry is now worked only to a small extent for flagging, and occasionally some building stone is taken out. Most of the stone quarried is manufactured into lime and cement, the lower beds being used for lime. The excavations extend along the side of a hill for a distance of about 1,000 feet. A section here shows: Local drift, 4 feet; drab limestone in thin layers used chiefly for lime, including also flag-stone layers and some stone which has been used for purposes of construction, 14 feet; below this are 6 feet of rough layers of limestone; 2 feet of yellow shales; and 6 feet of rough limestone, sometimes apparently in two layers, with occasional cavities sometimes 2 inches in diameter. These strata are evidently equivalent to those at Cottonwood station, all of well-known Permian type, with typical Upper Carboniferous fossils. This stone was used in the construction of a sugar factory at Sterling, Rice county, and of a church at Topeka.

The formation quarried at Augusta probably belongs to the Upper Permian beds. The quarry rock lies at the base of a hill and includes 6 feet of soft, buff-colored limestone in layers 1 foot and 2 feet in thickness. A few feet higher in the hill flag-stone layers occur 2, 6, and 8 inches in thickness. This stone is a little harder than the building-stone rock, and is used principally for sidewalks. Another building-stone quarry has been opened 1½ miles south of Augusta, where the rock presents a favorable appearance. Although quite soft, the stone is sufficiently strong for all ordinary structures and is quite durable. It has been used in the construction of some stone buildings at Augusta and at Wichita. Its largest use is perhaps for foundations and trimmings.

There are probably a half dozen irregularly-worked quarries of the same kind of stone around and in Fort Scott. It is locally used for buildings, walls, foundations, and also for pavements. There are several houses built of it, and it stands the wear of from ten to fifteen years exposure very well. It turns to a brownish color on long exposure, and it possesses all the strength required for common structures. The layers are generally separated by thin, brown, calcareous, shaly bands, often containing fragments of *Crinoideæ* and other known Carboniferous fossils.

The following is a general section of Fort Scott strata: Limestone, 4 feet; calcareous shales, 1 foot; bituminous shale, 4 feet; coal, 8 inches; shales and fire-clay, 3 feet; hydraulic limestone, manufactured for that purpose here, 5 feet; blue and bituminous shales, 3 feet; coal, 18 inches; fire clay, 4 feet; and shales and sandstone, about 75 feet.

The stone quarried at Winfield has a uniform light drab or gray color, and is soft and very easily worked. It is quarried by means of plugs and feathers, the holes being bored with a common 1½-inch auger having no point. These holes can be bored by one man at the rate of 6 inches in depth per minute. The stone has a handsome appearance and a good reputation for durability. It is shipped for general architectural purposes to Wellington, Ottawa, Leavenworth, Topeka, Atchison, and Wichita, Kansas; and to Kansas City, Missouri. A hotel, two school-houses, several churches, and other buildings have been constructed of it in Winfield, where over 10 miles of sidewalk have also been paved with flags from the quarry of Messrs. Hodges, Moore & Co. Some of the flags laid down are 10 feet long and 8 feet wide, and much larger sizes can be obtained. The rock occurs in layers from 4 inches to 2 feet in thickness, and the fine even stratification allows the heavier beds to be split into thin flags. There are usually from 4 to 6 feet of good building stone capped by from 3 to 5 feet of rough limestone.

COLORADO, CALIFORNIA, MONTANA, UTAH, ETC.

By William Foster.

In collecting data for the following report, notes were obtained from ledges in regions where the quarry industry is but slight; in some cases observations were made on ledges not yet quarried for building purposes.

The whole line of the foot-hills in the eastern slope of the Rocky mountains, in Colorado, is of outcrops of sandstones which vary considerably in color and texture. They are quarried in many places both for local use and to ship to Denver, which is the chief market for them all.

At Fort Collins a very compact sandstone is taken out for "footings" and foundations of all kinds. It is especially applicable to this purpose on account of its being capable of withstanding great pressure. It is also split into flags for sidewalk paving, but its color makes it objectionable for superstructures, being striped with different shades of reddish-brown. There is another sandstone near the same locality which can be quarried in blocks of any size required and in any quantity; it has a uniform light color and fine grain, and cuts almost as easily as chalk, but grows much harder on exposure.

At Morrison, in Jefferson county, are quite extensive quarries of both red and almost white sandstone of the Jurassic period. The white is only fit for foundations, but the red is a favorite stone for trimmings and also for whole buildings. It absorbs a large amount of water if left lying on wet ground, and then falls to pieces if exposed to frost, but it lasts well in masonry.

At Manitou, El Paso county, an almost white sandstone of the Cretaceous period is quarried, which is now being used in Denver in the construction of Tabor's new opera house; also in the new Union depot, and in many other buildings for trimmings.

At Cañon City, where the Arkansas river cuts through the Cretaceous beds, are two quarries just opened: the Branford on one side and the Berlin on the other. The stone is light greenish in color and cuts very easily, and is being taken out at the Branford quarry for the walls of the new court-house for Arapahoe county at Denver.

At Coal Creek, near Cañon City, is another good sound stone. Still farther south, at Trinidad, Las Animas county, stone is quarried and shipped to Denver. Some "Trinidad stone" was put into the James office building in Denver. A little red granite split from bowlders has been used from a locality owned by the government, the

Platte cañon, between Jefferson and Douglas counties. It will not polish, on account of an excess of mica and hornblende. There are plenty of fine granites all through the mountains, but on account of the expense of working and transportation to market they are not used.

In the immediate vicinity of the town of Castle Rock there is a large amount of lava (rhyolite) quarried, and, as with other stones, Denver is the chief market. The Denver and Rio Grande Railroad Company has used a good deal of it for stations, etc., along the line of its road.

The rock splits in all directions easily with a hammer, has great strength in proportion to its weight, and makes a very handsome building with a stone face or rubble work. It will not take a polish or even answer for nice cut work, as it is porous and full of soft places called "mud-holes" by the workmen.

The only building stone which is quarried in Wyoming is at Sherman, the highest point on the Union Pacific railroad. At this point, the summit of the Black Hills, the road cuts through a very heavy body of red granite similar to the Scotch, but with much larger crystals. The monument to Mr. Ames is being quarried and cut at Sherman. Mark Hopkins, of San Francisco, had some taken out for his residence in that city, for steps, vases, etc.; his tomb at Sacramento is also built of it. The stone is very hard to work, and the sharpest tools are required, or the crystals of feldspar will fly out instead of cutting.

There is plenty of good granite in both Montana and Idaho, but there is no demand for an article which would cost so much there. A little stone has been used in the roughest kind of buildings, such as storehouses, breweries, and for foundations of some buildings, all taken from bowlders. Utah has a great variety of fine stones fit for buildings—marbles, limestones, sandstones, and granites—but as yet no regularly-worked quarries. Most of the stone work is done by the Mormon church for its own purposes, and the bodies of rock are mostly public property and free to all.

The granite in Little Cottonwood cañon, used for the new temple in Salt Lake City, is taken from large bowlders which have rolled down from each side of the cañon, and are split up and loaded upon the cars. When the supply gets short, more are rolled down to a convenient place for working. The stone is a very handsome gray, and does not rust on exposure, but there are large, almost black, knots called "nigger-heads", through the bowlders, and care has not been taken to have these come on the inside of the walls of the temple, thus marring what would otherwise be a very handsome building. The supply is unlimited, for when all the bowlders are used the solid ledge may be taken; the formation extends about 3 miles up the cañon on each side. At Red Butte, near Salt Lake City, in the foot-hills, is a red Triassic sandstone, which may be had in several different shades. It has been used for the walls of several buildings, the piers of the old Mormon tabernacle, and for the foundations of many buildings. It is easily obtained, as it lies on the crest and sides of quite steep mountains and can be quarried and rolled down into the cañon below. The supply is so great that there will be no need of deep working for many years. The United States government has used about 7,000 cubic yards of this stone in the construction of the officers' quarters, barracks, storehouses, etc., at camp Douglas. The buildings made of this rock are all of rubble work. A few sample grave-stones have been cut from it, and blocks of the same are used for bases to monuments made of other stone. As all help themselves as they wish, I was unable to get any idea of the amount used each year or the expense of quarrying per ton or per yard.

In Echo cañon, near Croydon, there is a quarry of red sandstone similar to the Red Butte, and probably of the same age, owned by the Union Pacific Railroad Company, and is worked by it for stone to put in bridge piers all along the road. It is considered very good for this purpose, as it does not shake to pieces with the jar of the trains. The company has allowed other parties to take stone for use in the vicinity and at Ogden, but the amount used in that way is small.

From 80 to 150 miles south of Great Salt lake, marble specimens have been found, and also the rock in place, though not of a very good quality, owing to the beds being so twisted and shattered that it is impossible to obtain clear pieces of any size. Payson and San Francisco are the localities where most of the specimens have been obtained.

At Manti, in the Sanpete valley, the Mormons have built a temple of oolitic limestone quarried on the ground. It has a very warm, rich, light brown color, cuts very easily, and yet holds its surface well.

At Ogden the Episcopal church is built of a fossiliferous limestone. I was unable to get samples, as there is no regular work done.

The state of Nevada has quarried some stone in the state-prison grounds at Cañon City by convict labor. The stone is of very coarse sand, and contains fossils of both mollusks and vertebrate animals; also the tracks of some animal with three toes, like a bird, very plain in the surface of the stone which forms the floor of the prison-yard. The tracks are 11 inches long from heel to toe, and are 22 inches apart. The United States mint at Carson, the city hall and county buildings, are all built of this stone, and some was taken to Reno to form a portion of the walls of the state prison. The Carson sandstone is not fit for steps, floors, or any place where there is much wear, as it is coarse-grained and soft, and in such positions has to be replaced often. It also absorbs a large quantity of water, making it unfit for foundations or places where it is likely to be exposed to moisture.

At Virginia City a volcanic rock is used for engine beds at the hoisting-works, and in other places where heavy solid foundations are required. The rock will not take a polish, but makes fine rubble work or stone face. It is quite easily quarried, and when freshly taken out cuts well and grows harder on exposure to the weather. There is no regularly-worked quarry. Granite is also plentiful in the vicinity of Virginia City, but it is not much used owing to cost of working and transportation. A slab is being cut for the Washington monument. The stone is very heavy and of the best quality, but there is no market to encourage any one to open a quarry. The main part of the walls of the old state prison at Reno is of andesite, taken from a large body of this rock which lies about 2 miles north of the city, very easy of access. The rock forms the top of two low hills, which can be connected very easily by a side-track with the narrow-gauge railroad now building from Reno to Oregon. Reno has a few buildings, such as storehouses, built of it.

The building-stone resources of California are immense in both quantity and quality. The granite quarries of Penryn, Pino, and Rocklin are worked extensively and with system. All the granite used in Sacramento and San Francisco, except a little from New England, comes from these quarries.

Around the northern end of the bay of San Francisco, at Napa, Petaluma, Bridgeport, etc., are immense beds of basalt of several different qualities available for the construction of buildings in the future, but now only used for paving stone in San Francisco, Sacramento, and neighboring cities. A few small buildings have been put up in the vicinity of the quarries. Rhyolite is found near Mokelumne Hill in Calaveras county, of several different colors. It is used so far only in the immediate neighborhood; none has been shipped. Lake and Plumas counties each has many varieties of volcanic rocks, but they have not been sufficiently investigated to determine their value as material for construction. On account of want of means of transportation, it will probably be some time before it is used except locally.

The sandstones are also well represented, both in color and texture, all around the bay of San Francisco. At Armory point, just east of Benicia, the United States government has built a large arsenal of light brown sandstone quarried on the spot. This is all that has been used of it, though the color is handsome and the stone is very durable. Angel island, in the bay of San Francisco, now government property, has furnished a bluish sandstone which was used for the Bank of California building; and as far as I can learn, that is all of any account.

Near Alameda, Livermore, Haywards, and a number of other small places, quarrying has been carried on in a very small way in sandstones of various shades of light brown and blue, mostly for the San Francisco market. At San José, near the southern end of the bay, is a quarry of light brown sandstone of several degrees of coarseness, unlimited in extent, and of very even color. The quarry has only lately been opened, and is now used in the trimmings of the new city hall in San Francisco, and for foundation and trimmings of the State Normal School building, San José, and that is all. It is almost pure silica, and stands fire so well that it is used for lining blast-furnaces and for cupolas, forges, etc.; it cuts very easily, when first quarried, into either ornamental, statuary, or faced stone, and grows very hard on exposure to the weather.

California marbles are so bent and fractured by upheavals that it is hard to get pieces of any size without cracks and cavities.

Thousands of dollars have been spent at Colfax in an attempt to open a deposit of drab marble and get it into market, but the parties failed; some of the material was used for mantels, fireplaces, floor-tiles, etc., but the quantity was small and the stone not much liked, so no work has been done for some years.

The so-called "California onyx" is the most beautiful of the marbles, and a small quantity was found at Suisun. This has now all been worked out. Kessler Brothers own another body of it near San Luis Obispo, and are now doing some very handsome work, such as counters for stores, mantels, fireplaces, vases, table-tops, etc. The quarry has not been opened long, and being far from market little has been used, and the quarry is not regularly worked. The owners are going to try and introduce it into the eastern cities.

In Kern county there are marbles of many shades, but all are more or less broken and shattered, making them very hard to work. At Indian Diggings, Eldorado county, a marble has been quarried with almost white ground and blue streaks running through it, used a little for grave-stones, but not much liked, and is not now quarried.

Arizona and New Mexico at the present time use very little stone for building purposes; the climate does not require it, and "adobe" is much cheaper. The Pueblo Indians once used cut stone in the construction of their dwellings, which are now in good preservation in many places.

Chapter VII.—STONE CONSTRUCTION IN CITIES.

AKRON, OHIO.

Akron has ready access to the celebrated quarries at Amherst, Berea, and other localities. The greater part of its stone construction is of the sandstone quarried from local quarries, while Berea sandstone is also largely used; for foundations and underpinnings the local sandstone is exclusively used. The Akron sandstone, when carefully bedded, makes a very durable building stone, but its strength is not very great when the pressure comes unequally upon it. Memorial Chapel building is of sandstone from Marietta, Ohio. Stone has been but little used in paving the streets, and sandstone from Medina, New York, is the material used for this purpose. The sidewalks are largely paved with Berea sandstone.

ALBANY, NEW YORK.

Stone fronts in Albany are mostly of Connecticut brownstone. Ohio sandstone is used in trimmings. Granite from Maine has been used in some of the finer structures, such as the state capital, city hall, United States court and post-office buildings, and the state hall. Among the buildings in which Connecticut brownstone has been used are the Albany academy, cathedral of the Immaculate Conception, Saint John's Roman Catholic church, Saint Peter's church, Second Presbyterian church, Protestant Episcopal church, and Emanuel Baptist church. As in all the towns and cities on the Hudson, Albany is largely of brick; stone is used for large public edifices and in dwelling-house fronts to a limited extent. The cheapness of brick enables them to compete successfully with stone, even in foundations and cellar walls. A great variety of stone has been used in the new capitol building; the mass is Maine granite. In the interior decorations Mexican marble, Bellville sandstone, Ohio sandstone, and Lake Champlain marbles have been used.

Saint Joseph's Roman Catholic church is trimmed with Caen stone; this material weathers badly, and does not stand the severe winters. The Episcopal church, State street, is trimmed with Hudson River sandstone from Schenectady. This material comes out with natural faces, and these are weathered to brownish and greenish-yellow shades of color, giving the front a highly-variegated aspect. The weathering or fading on exposure is seen in different shades of color between the stone of the building proper and the tower; the latter, of later construction, is the darker shade. The Second Reformed church, a large edifice of a composite style of architecture, is of limestone of Trenton age. The foundations and underpinnings are built of limestone from Amsterdam, Howe's cave, Kingston, and Glens Falls; also sandstone from Schenectady, Highland, and other places in Ulster county is used for this purpose. The streets are largely paved with stone, and the materials used are bowlder or cobble-stone and granite blocks from New England; the dimensions of these blocks are usually about 14 by 4 by 8 inches. The following is an approximate statement of the number of miles of pavement of the different materials: 38½ miles of cobble-stone pavements, 4 of granite block pavements, and 1¼ of macadamized pavements; total number of miles, 43¾. Number of miles of unpaved streets, 89¼.

The sidewalks are largely paved with stone, and the materials used for this purpose are the Hudson River blue flag-stone, and blue flags from the Helderberg mountain; also some Potsdam sandstone; the curbstones are of the same materials.

ALLEGHENY, PENNSYLVANIA.

What is true of stone construction in Pittsburgh is also true of it in Allegheny, as the two places are separated only by the Allegheny river, and the sources of their building materials are precisely the same. In rare instances Connecticut brownstone is used, and a very little of New England granite, principally for cemetery work, but nearly all the stone construction is of sandstones and limestones of sub-Carboniferous and Carboniferous age quarried west of the Alleghany mountains, in Pennsylvania and Ohio.

ALLENTOWN, PENNSYLVANIA.

The stone used for foundations and other ordinary purposes of construction in Allentown are limestones and hard sandstones from small quarries in the mountains near the city. Sewers are constructed entirely of brick. The building stone used here is limestone and the mountain sandstone, and is of the most durable quality. The city engineer reports that the ground in some portions of the town is unfavorable to heavy buildings on account of being cavernous. The bridge abutments and arches are built of limestone and quartzite from the mountains near the city. The streets are but little paved with stone, and the material used is cobble-stone from the river. Some of the streets are macadamized with limestone from the vicinity. There is but little stone sidewalk paving, and the material is the North River and Wyoming blue-stones, but the native limestone from the Lehigh valley is used to some extent for this purpose.

ALTOONA, PENNSYLVANIA.

The sides of the mountains near Altoona are thickly strewn with surface rocks of different geological formations which furnish nearly all the building stone for cellars, foundations, terrace walls, and other ordinary building purposes in the town and vicinity. These surface rocks are durable and very hard from long exposure to the weather. On breaking them up numerous cracks are found, owing probably to the effects of the frequent fires that pass over the mountains. The material is so rough and hard as to make it extremely difficult to dress, and it is therefore not found practicable to use it for any other than the ruder purposes of construction, where dressing is not required. Material from a quarry of what is probably sandstone of Pocono (sub-Carboniferous) age, 2 miles from Altoona, is being introduced to a limited extent for cellar work and foundations. It breaks irregularly and with a conchoidal fracture. The supply of the material which is available is not large, owing to the amount of dip (about 45°) into the hill. For finer cut work some sandstone from Gallitzin, on the Pennsylvania railroad, west of Altoona, and in Cambria county, is used. It has a local use for caps, sills, bases, etc., as far east on the Pennsylvania railroad as Huntingdon, a distance of 60 miles. Amherst and other northern Ohio sandstones are employed to a limited extent for trimmings. The stone work in Altoona is confined chiefly to cellar and foundation work and a few terrace walls, the ground on which the city is built being somewhat uneven. There is scarcely any stone work in the shape of caps, sills, and columns, brick being used, as there is no stone in the immediate vicinity which would be very suitable for these purposes. The streets are paved with cobble-stones from the streams in the vicinity, but there is very little stone sidewalk paving. In front of the Logan house there was formerly considerable pavement, constructed of hard blue slate, which has a smooth, even surface, and presents a pleasing appearance when first put down, but is not durable.

ATLANTA, GEORGIA.

The stone chiefly used in this city is from local quarries. Some is brought from Dixon, Alabama, and Bowling Green, Kentucky, for trimmings. The Stone Mountain granite is shipped west to be dressed, polished, and carved, and then returned. The only buildings constructed entirely of stone are the warehouses. The usual style of building is a foundation and superstructure of brick with stone trimmings. The United States post-office and court-house is built of granite from Vermont. The foundation is the Stone Mountain granite. The new county court-house is to be trimmed with Bowling Green limestone. Several stores are trimmed with Dixon, Alabama, stone. The brick is of very superior quality; stucco is used to some extent; the use of stone is increasing. The city has 133 miles of streets; of these 10 miles are macadamized, and only 7 miles have brick and stone sidewalks; 11 miles of the streets are sewered, and of the sewers about one-third are constructed of stone. The city prisoners work the quarry, and they are employed a portion of the time in macadamizing the streets and roadways.

The city of Atlanta has an abundant supply of rock and good granite accessible. The soil is red clay and furnishes secure foundations. The most durable stone is gneiss, locally called "blue granite". The Stone Mountain granite wears away under attrition, and has not been long enough in use to determine its wearing qualities. The best granite at present known in the state is in Oglethorpe county, but it has not been used much as yet; it resembles very much the Quincy granite of Massachusetts. The growth of Atlanta has been very rapid of late years, and the macadamizing of the streets has proceeded at an average rate of only one mile a year. Granite, chiefly from Lynch's city quarry, is used by the railroads for bridge piers and retaining-walls; the railroad cut in the city is braced in this way.

BALTIMORE, MARYLAND.

The rocks exposed in the immediate vicinity of Baltimore are gneiss of Archæan age, and it was this material that was first drawn upon for the ordinary purposes of stone construction, it being the most convenient. Baltimore has, since its foundation, had ready access to all the important quarries on the eastern sea-coast, and it has drawn largely from this source. There is much of the Connecticut and New Jersey sandstone used; and of late years granite from the quarries on the coast of Maine has been largely employed. In the early times of the city, stone brought as ballast in the numerous ships arriving was used for ordinary purposes. Another important source of supply in later years and at the present time is the marble quarries at Cockeysville, a short distance north of the city. Granite from various points in the state of Maryland has been largely used, especially that quarried at Ellicott City, on the Patapsco river; at Woodstock, in Howard county, and at Jones' falls. Since the city has had railway communication with all points in the interior, serpentine from Chester county, Pennsylvania, and Ohio sandstone have been largely used.

The following are some of the most important stone structures in the city: The Eutaw Place Baptist church, which has a tower 187 feet in height; the Brown Memorial Presbyterian church, corner of Park and Townsend streets;

the Franklin Street Presbyterian church; the city hall, and the Peabody Institute. These are all built of marble chiefly from the Texas and Cockeysville quarries, north of Baltimore. The Peabody Institute exhibits the Maryland marble to good advantage, as care was taken in selecting the material. In several buildings a very few defective stones injure the effect of whole structures. The First Presbyterian church, corner of Madison and Park streets, is built of New Brunswick, New Jersey, sandstone. The city prison is built of gneiss from Jones' falls, with marble trimmings. The Catholic cathedral is built of gneiss from Ellicott City; the foundation-stone of the building was laid on July 6, 1806. The older monuments were erected before marble had been quarried to any great depth, hence the best material was not obtained. The corner-stone of the Washington monument was laid July 4, 1815, and that of the Battle monument September 12, 1815; the lettering upon the latter remains quite distinct, showing that this material, even when not selected with any care, stands the test of time quite well. The Rialto building, Second street; the Kilby building, Baltimore street; the Franklin Bank, Citizens' Bank, Union Bank, and the Farmers' and Planters' Bank buildings are constructed in part of marble from Cockeysville. The foundations and underpinnings are built of gneiss quarried in the vicinity and at Jones' falls, Ellicott City, and Port Deposit; all of these places are readily accessible by water. Granites from Woodstock, Richmond, Virginia, and from the coast of Maine are employed to some extent for the same purposes. In the construction of the Young Men's Christian Association building, the Normal School building, and the Traders' National Bank building, Berea, Ohio, sandstone was used. About three-fourths of the streets are paved with stone, the material chiefly used for this purpose being cobble-stones and gneiss from Jones' falls and Port Deposit, and granites from Woodstock, and from Virginia and Maine; although brick is the material chiefly used for sidewalk paving, yet much of the North River blue-stone shipped from Rondout, New York, is used for this purpose. Granite from Woodstock, Maryland, and from Richmond, Virginia, and gneiss from Port Deposit, Maryland, are also used for this purpose; the curbstones are of gneiss from Ellicott City and Port Deposit and the granite from Woodstock. The bridge abutments, sea-walls, and the walls of fort McHenry are constructed chiefly of gneiss from Jones' falls and Port Deposit.

BANGOR, MAINE.

The material used for the better class of stone construction in Bangor is granite exclusively, brought chiefly from Frankfort, Maine, and the islands of the Penobscot bay. Underpinnings are of granite. The post-office and custom-house buildings are of granite, chiefly from Musquito mountain, Frankfort. The light granite is largely used in the city for sills, steps, and trimmings generally. The streets are but little paved with stone, and the material is cobble from Mount Desert island and other islands in Penobscot bay, and some also from the vicinity of the city. The sidewalks are paved with brick and concrete, no stone being used for this purpose. Curbstones and crossings are of granite.

BINGHAMTON, NEW YORK.

There is little stone construction in Binghamton, and the material used almost exclusively is limestone from a quarry in the vicinity of Syracuse. A little stone for railroad work comes from Nineveh. The streets are not paved; sidewalks are largely paved with sandstone from the Wyoming blue-stone region in Pennsylvania, and curbstones are of the same material. Some stone from Oxford, Chenango county, is also used for sidewalk pavements.

BOSTON, MASSACHUSETTS.

By JOHN ELIOT WOLFF, *Assistant in Geology in Harvard University.*

HISTORICAL ACCOUNT.

When the first settlers came to Boston, over two hundred and fifty years ago, they probably found the land on which the city now stands covered with an abundant supply of our New England bowlders, which were at once useful in the construction of buildings, just as they are now used in the country; but it seems probable that no ledge of rock was found in the old town, outcropping through the thick clay covering, although there has been some difference of opinion on this point.(*a*) That they began at once to use stone for houses is shown in the following record: "Oct. 30th, 1630. A stone house which the governor was erecting at Mystick was washed down to the ground in a violent storm, the walls being laid in clay instead of lime." (*b*) "A few houses were built of stone and some of brick, but these were exceptions to the general rule, until Boston had become over twenty years of age." (*c*) About 1650 Johnson says of the city, " * * * the buildings, beautiful and large, some fairly set forth with brick, tile, stone, and slate."

There existed until 1864 a stone house built about this time (1650), which was early known as the "Stone house of Deacon John Phillips". * * * "It was built chiefly of stone, the common rocks found in the native soil of

a Cf. *Mem. Hist. Boston*, Vol. I, p. 554, note. S. Godon: *Mem. American Acad.*, Vol. III, 1809, and others.
b Snow's *History of Boston*, p. 40.
c Shurtleff's *History of Boston*, p. 589.

the peninsula having been broken into various shapes and sizes, and laid into place in the rough form left by the maul of the workman, the massive chimneys, with their spacious fireplaces, constructed of large coarse bricks and stones of uncommon size, were, as far as practicable, on the outside of the building, and portions of the house were covered with thick slate stones at the top of each of the stories." (*a*) Another writer, however, says that "the foundation walls were four feet thick or more; the walls above ground were two feet in thickness, and built entirely of small quarried stones, unlike anything to be seen in this neighborhood, and were probably brought as ballast from some part of Europe." (*b*)

When Josselyn visited Boston, in 1663, he found many large streets largely paved with pebble, and, near the common, some fine buildings constructed of stone; and Ward said in 1699: "The Buildings, like their Women, being Neat and Handsome, and their Streets, like the Hearts of the male Inhabitants, are Paved with Pebble." In fact for some two hundred years the streets were paved almost exclusively with cobble-stones obtained from neighboring beaches, and perhaps from gravel-pits, until granite blocks began to be used. Drake says that the paving of the public streets began very early, and was made of importance after 1700; the sidewalks were also early paved with cobble-stones and flags. (*c*)

The red Connecticut sandstone was shipped to Boston very early. In 1665 ordinances were passed in Portland, Connecticut, relating to the use of this stone by outsiders, which seems to have been used in Boston within the first hundred years; thus the Old Province house, erected in 1679, is described as having a flight of twenty massive red freestone steps; the freestone used in 1737 in the Hancock house came from Middletown, Connecticut. In consequence of extensive fires, laws were passed in 1692 and 1699 concerning the construction of stone houses—that of 1692 decreeing, "that henceforth no dwelling-house in Boston shall be erected and set up, except of stone and brick, and covered with slate or tile". It could not, however, be enforced. The old triangular warehouse which stood near North Market street, and was built about this time, had three turrets covered with slate, and slate was used for roofing very early; this was probably in part imported from Wales, in part obtained in Massachusetts. Professor Shaler says on this point:

> From the slates and conglomerates of the Cambridge and Roxbury series the first quarried stones of this colony were taken. The flagging slates of Quincy, at the base of Squantum Neck, were perhaps the first that were extensively quarried. A large number of the old tombstones of this region were from these quarries. The next in use were the similar but less perfect slates of Cambridge and Somerville; and last to come into use were the conglomerates and granites that require much greater skill and labor on the part of the quarrymen to work them. At first the field-bowlders supplied the stone for underpinning houses and other wall work; so that the demand for grave-stones was, during all the first and for most of the second century of the existence of the town, the only demand that led to the exploration of the quarry rocks of this neighborhood. Indeed, we may say that the exploration of the excellent building and ornamental stones so abundant here has been barely begun within the last two decades. (*d*)

In the Massachusetts records there is a letter dated 1721 describing a visit to Hangman's island in "Braintry" bay, and to Hough's Neck near Squantum, and a return with a cargo of 20 tons of split slate, showing how extensively it was used even then. The use of stone for walls, steps, and underpinning was constantly increasing, and we find that the inhabitants of Quincy were alarmed at the rapid manner in which the bowlders disappeared from their fields, for in 1715 and 1729-'30 the town passed laws regulating their use. (*e*)

In 1737 the old Hancock house (taken down twenty years ago) was built of Braintree bowlders, squared and hammered, with red freestone trimmings from Middletown, Connecticut, and it was slated (probably at some later date) with slate from Lancaster, Massachusetts.

From 1749-'54 was built King's chapel, now standing on Tremont street—at that time the greatest stone construction ever attempted in Boston, if not in the whole country. It was built of coarse bowlders dug out of the ground at both the north and south commons, Quincy (Braintree), and then split and hammered. The bowlders were split up for this building, it is said, by heating the stone (by building a fire upon it), and then splitting it by letting heavy iron balls fall upon it; in fact squared and hammered granite had only been used a short time before this in Boston, as the art of working it to a smooth surface is said to have been introduced about this time by German immigrants who settled at Quincy. Of course granite obtained in this way was very expensive and the process could best be applied only to bowlders having a free side.

> When this work was finished it was the wonder of the country round. People coming from a distance made it an object to see and admire this great structure. The wonder was that stone enough could be found in the vicinity of Boston fit for the hammer to construct such an entire building. But it seemed to be universally conceded that enough more like it could not be found to build such another. (*f*)

In 1774 the old powder-house was built of Braintree granite, with walls 7 feet thick; and in 1793 the stone light-house was built on Light-house (or Beacon) island.

About this time marble began to come into use for building, corresponding to the opening of the Berkshire, Massachusetts, marble quarries (1790), for the state-house, built 1795-'98, is described in old books as having keystones, imposts, etc., of white marble; part of this came from Boynton's quarry in West Stockbridge, Berkshire county. (*g*) Thus the "new almshouse", erected in 1800, had marble trimmings; and the Exchange coffee-house,

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a Shurtleff, *loc. cit.*, p. 666.
b Savage, *Police Record.*
c *Old Landmarks*, p. 21.
d *Mem. Hist. Boston*, Vol. I, p. 5.
e Pattee's *Hist. of Quincy*, p. 599.
f Chief Justice Shaw, *Proc. Am. Acad.*, 1859, IV, p. 353, etc.
g D. D. Field's *History of Berkshire County*, p. 275.

erected in 1805–'08, had six large marble columns or pilasters upon a rustic basement, supporting an architrave and a cornice of the same stone. The base of the building was of hammered granite and the basement of white marble. The old custom-house, built in 1810, had also marble trimmings.

About the beginning of this century came a turning point in stone construction in Boston and the country generally, coincident with the changes in the method of splitting granite. According to Chief Justice Shaw (*loc. cit.*) this was determined by the introduction of the method of splitting granite by drilling holes and then driving in small wedges. The construction of the first part of the Massachusetts state prison in Charlestown, finished in 1805, seems to have been the cause for the introduction of this method of splitting granite by drilling holes and driving in small wedges, now universally used; so that this building, together with Bunker Hill monument and King's chapel, must be regarded as of great historical importance in the development of granite construction in the United States.

Shortly after the beginning of this century, then, granite began to be used extensively in Boston, and of two varieties; white granite (the so-called Chelmsford) from Tyngsborough and Westford, near Lowell, Massachusetts, and perhaps some from Pelham, New Hampshire, and other places—quarried generally, if not entirely, from loose bowlders for many years; and the dark Quincy granite, mostly from bowlders, but a little from ledges. Thus in 1810 the court-house (old city hall) was built of white Chelmsford stone on the site of the present building, in the walls of which some of the old stone has been retained; in 1814 the New South church was built of the best Chelmsford granite. About the same time, what is now the Congregational house, on Beacon street, was built; the old Parkman house on Bowdoin square, University hall in Cambridge, and others, all of Chelmsford granite; and from 1818 to 1821 the main part of the Massachusetts general hospital, with several large granite columns, was hammered at the state prison—also of Chelmsford stone—probably from bowlders.

The completion of the Middlesex canal to Chelmsford (30 miles) in 1803, itself a great work, with sixteen locks of hewn granite, opened the way for the easy transportation of granite from the vicinity of Chelmsford, so that it could be delivered in the very streets of the city, and great quantities were landed at the state's prison in Charlestown and cut by the convicts. All, or nearly all, of this stone came from surface bowlders, as is stated, as late as 1820, (*a*) and were split as at Quincy; in 1818 a church was built of this stone in Savannah, Georgia, and $25,000 worth was sold.

In 1818–'19 there was built of this material the first stone block in Boston, still standing on Brattle street, and forming originally a block of fourteen buildings, part of which now form the old part of the Quincy house. Stores erected on Cornhill in 1817 were the first erected in the city on granite pillars, and in 1820 these were first substituted in brick buildings already standing. (*b*) In 1820 Saint Paul's church on Tremont street was built of Quincy granite with large columns and portico of yellow sandstone from Acquia creek, Virginia. Some yellow sandstone from England was used in buildings on Cornhill in 1817.

The mill-dam connecting Boston with Brookline and Roxbury, and built from 1818 to 1821, was considered one of the greatest constructions of the kind in the world. The sides of the dam are built of solid stone for 8,000 feet in length, from 8 to 3 feet thick, and 12 to 17 feet high, while the width between the walls varies from 50 to 100 feet. The stone used was Roxbury pudding-stone and stone from Weymouth.

In 1824 the United States branch bank was built on State street of Chelmsford granite, and has been called the first building constructed of large stone (the state's prison, however, should be noted); a part of this building still remains in its successor, the Merchants' Bank building, and the two columns in the present front were taken from the two in the original building, but reduced in size. These two columns were originally 24 feet high, including the cap, and 4 feet in diameter at the base, and were cut from a large bowlder of granite in Westford, Massachusetts.

The next year the construction of Bunker Hill monument began (1825–1842), the greatest monument of its kind in the world, and marking a most important step in stone construction in this country. The architect was the well-known Mr. Solomon Willard, and the master mason Mr. Gridley Bryant. To these two men is largely due the development of stone construction in Boston.

After his appointment as architect, Mr. Willard spent considerable time in looking up a quarry, and finally decided on the Bunker Hill quarry in Quincy, from which the stone was accordingly taken, and it was for the purpose of transporting to tide-water the stone for the monument that Mr. Bryant built the first railroad in America.

From the *Memoir of Solomon Willard*, by William W. Wheildon, we quote as follows:

The opening of the Bunker Hill quarry led to the discovery and opening of other quarries, caused the building of the first railroad in the country, and gave an impulse to business which has adorned our cities with a class of splendid and substantial buildings, both public and private, which for durability and beauty are wholly unsurpassed.

Mr. Willard felt persuaded that an improvement in the material for building purposes so decided as that which he, in fact, had introduced would gradually effect a change in the style of building and in the general architecture of the times. Granite, as a building material, excepting in a few instances, and these mostly under Mr. Willard's superintendence, had been used in small pieces or blocks of

a W. Allen's *Hist. of Chelmsford, Mass.*

b Snow's *Hist.*, p. 328, note.

moderato size for cellar walls, underpinning, posts, lintels, etc., and his first measure was to introduce the material in large blocks, such as were in themselves massive and durable, which, as he saw at once, would absolutely necessitate changes in the style of architecture and in the character of public buildings, stores, and other substantial structures.

In 1825–'26 the Quincy market was built of Chelmsford (and Hallowell) granite, with large columns of the same at each end of the building. Soon large buildings were put up of Quincy granite, and the construction of stone buildings went rapidly forward after 1830 to the present time, so that only a general mention is possible:

The Tremont house, 1828–'29, granite; dry dock at navy-yard, 1827–'34; old Trinity church, 1828; Masonic temple (United States court-house), 1830–'31; Suffolk County court-house, 1833–'36; and the United States custom-house, 1837–1848, may be mentioned as opening the great development in the construction of Quincy granite buildings, and as showing how the Quincy granite supplanted the Chelmsford. In 1848 we find already thirty or forty blocks of granite mentioned in the city. The eight stone columns put in the county court-house (1835) were of importance, each one requiring 65 yoke of oxen and 12 horses to transport it; and also those put up in the Merchants' exchange, in 1842—the largest in the city—may be mentioned. About this time there was a considerable use of the Somerville diabase for basements of brick buildings and of red sandstone for trimmings. About 1845 the red sandstone came in for fronts, and several churches, the Boston Athenæum, etc., were soon erected. The *Times* building on State street is said to have been the first building with a red-freestone front. Rockport granite began to be used from the quarries about 1830, and was at first put into cellars for brick buildings, and then for posts in North and South Market streets. The first building of hammered Rockport stone was that of Terice How & Co., about 1846, and the Beacon Hill reservoir, a little later, of Rockport stone, was a very extensive undertaking. The Parker house, erected in 1854, was the first marble building in the city. Concord granite was first used in columns in the Boston and Albany depot; the Merchants' Bank building was perhaps the first front (1856) of Concord granite. The Washington building at the head of Franklin street is said to have been the first building of Nova Scotia freestone (1858). Within the last twenty-five years various other building stones have been introduced: the Roxbury pudding-stone for churches, the different marbles and sandstones, and lastly the red granites. The building up of the Back bay has been very extensively done with sandstone fronts. The great fire in 1872 wiped out hundreds of stone buildings and blocks which had been erected during forty years in the business portion of the city. The buildings were very largely Quincy granite, Rockport, Concord, Hallowell, etc., and in their places have sprung up buildings of lighter-colored stone, Concord and Rockport granites, and a great proportion of buildings of the yellow sandstones of Ohio and the provinces, together with many marble buildings.

STATISTICS.

According to the assessor's list for 1880 there are about 51,000 dwelling-houses, stores, and other buildings in the city of Boston. The following figures can be compared with those above only approximately, on account of the probable differences in making the count; for in the figures for stone buildings, what appeared to be separate constructions were counted as units, and several dwelling-houses may make up one stone building. There are in the city limits of Boston, by actual count: (*a*)

	Buildings.	All stone.	Fronts, one to three sides.
Total	752	93	659
Quincy syenite (granite)	162	28	134
Concord granite—two or three from Fitzwilliam, New Hampshire	79	2	77
Cape Ann granite	40	9	31
Chelmsford granite	16	5	11
Hallowell, Maine, granite	5	0	5
Rollstone Hill granite, Fitchburg	1	1	0
Jonesboro', Maine, red granite	5	0	5
Vinal Haven, Maine, granite	1	0	1
Somerville diabase (granite)	1	0	1
Frankfort, Maine, granite (?)	1	0	1
Unknown granite	1	0	1
Total granite	312	45	267
Marble (Vermont, etc.)	58	0	58
Tuckahoe, New York, dolomite (marble)	10	0	10
Total marble	68	0	68
Connecticut valley, New Jersey, and the provinces, red sandstone	211	3	208
Connecticut valley, New Jersey, and the Ohio, part red, part yellow sandstone	116	2	114
Total sandstone	327	5	322
Roxbury pudding-stone	35–40	35–40	0
Cambridge slate	3	2	1
Dedham porphyry	1	1	0
Unknown quartzite (?)	1	0	1

a This is a close approximation, but cannot of course pretend to be accurate to a single building.

Therefore between $1\frac{1}{2}$ and 2 per cent. of the buildings of the city are of stone. Some of the more important constructions of the different kinds of stone are:

QUINCY GRANITE.—United States custom-house (1837–'48) is constructed in the form of a Greek cross. It is surrounded by 32 massive stone columns, each of which is 5 feet 2 inches in diameter, 32 feet high, and weighs 42 tons. The roof and dome are covered with granite tiles worked at Quincy; there is said to be about the same amount of stone in this building as in Bunker Hill monument—6,700 tons. The county court-house (1833–'36); there were originally eight stone columns 25 feet 6 inches high and 4 feet 6 inches in diameter, weighing 50 tons each. Suffolk County jail (1851); there is also some stone in the building from the Rockport Granite Company. Charlestown state prison (1805, 1828, and 1850); the old part was probably in large part from bowlders; some of the blocks were 9 feet long and 20 inches thick (1805). United States court-house (1830–'31); Masonic temple; Tremont house (1828–'29); King's chapel, 1754—bowlders; Saint Paul's church (1820); the yellow sandstone columns, etc., from Acquia creek, Virginia; Howard Athenæum (1846); Merchants' exchange (1842), Wigwam quarry. The pilasters in front of this building are the largest in the city; the large ones are 41 feet 8 inches long, 6 feet wide, and weigh 50 tons; Boston Museum (1846); Merchants' National bank (in part); Suffolk National bank; State Street block; State Street wharf building; United States warehouse, Union wharf; Lewis wharf building; Commercial wharf building; Commercial block; Long wharf building; the buildings of Hovey & Co. and of Hogg, Brown & Taylor; Mount Vernon church; Unitarian church, Jamaica Plain; Bowdoin Square Baptist church; Catholic church, Broadway, South Boston; many of the buildings in the navy-yard, Charlestown; United States dry dock; basements of Equitable Life Insurance and New England Mutual, and many other large buildings; lastly, Bunker Hill monument, from the Bunker Hill quarry. The monument has two parts, an inside and an outside; the outside part is in form a square pyramid or obelisk, 30 feet square at the base, and tapering gradually. A pyramid of stone 13 feet high tops this, so that the total height is 221 feet 5 inches. Inside the pyramid there is a hollow cone of stone with a circular section (diameter at base 10 feet), and between the outside wall of the cone and the inside wall of the pyramid are placed the stone steps. There are, therefore, four wrought stone surfaces in the monument extending from top to bottom. There are said to be 6,700 tons of granite; a little of the stone inside is said to be Chelmsford granite. Height of monument to the apex, 221 feet 5 inches; height of obelisk to base of pyramid, 208 feet 5 inches; sides of the square, first course, 30 feet to 15 inches; height of the cone, 196 feet 9 inches; diameter, 10 feet to 6 feet 2 inches; pyramid 13 feet high; sides of base 15 feet.

CAPE ANN GRANITE.—The United States post-office (1869–'82) is the finest granite building in the city. The stone was all furnished from Gloucester, the basement of darker stone from the Blood quarry, and the superstructure from the "Old Pit" quarry. The superstructure of that part of the building first erected was taken essentially from one immense sheet in the quarry; the stone is syenite. The pavement on the floor is from Swanton, Vermont. Lake Champlain, Sicilian, and Sienna marbles have been used in the interior; the roof is slate, from western Vermont. The Boston water-works is an immense granite structure on the side of Beacon hill; the basin is of Westford granite. Lawrence building, Fremont street; the building of Bigelow Kennard & Co., Washington street; Wesleyan hall; Commonwealth building, Water street; Saint Vincent de Paul church, South Boston; church of Our Most Holy Redeemer, East Boston; the rope-walk at the navy-yard, 1,360 feet long; South Boston Savings bank, and many stores on the business streets.

CONCORD GRANITE.—*Herald* building; *Transcript* building; Wentworth building; Emigrant Savings bank; city hall; Massachusetts Historical Society building; Suffolk Savings bank; Horticultural hall; Masonic temple; the *Advertiser* building; Merchants' National bank; National City bank; Lawrence building, Devonshire street; Rialto building; New England Mutual Life Insurance Company's building; building corner Summer and Bedford streets; building on Winthrop square; Brooks estate, Pearl street; Union Institute for Savings, Bedford street; Bowditch block, South street; Odd Fellows' Memorial hall (in part), 27–50 High street; and Cruff's block on Pearl street, from Fitzwilliam, New Hampshire.

CHELMSFORD GRANITE (WESTFORD, etc.)—Massachusetts general hospital, the original part (1818–'21) from bowlders, probably hammered at the state's prison; addition of 1846 from Westford. Quincy market (1825–'26) with some Hallowell granite; two blocks of stores, north and south of the market; church of the Immaculate Conception; Congregational house; Somerset club, Beacon street; Quincy house (old part); Parkman house; part of the Merchants' National bank and new city hall; basin of Boston water-works.

HALLOWELL, MAINE, GRANITE.—Equitable Insurance Company's building; Odd Fellows' Memorial hall (part Concord); some in Quincy market; Mutual Life of Maine, Tremont street; National Bank of the Republic; large block in Winthrop square (in part).

ROLLSTONE HILL, FITCHBURG, MASSACHUSETTS.—Fitchburg depot (1847).

JONESBORO', MAINE (Bodwell Granite Company), RED GRANITE.—Wellington Brothers' building and Nevin Brothers' building, on Chauncey street; the Morse block, South street; and the Preston building, Summer street.

SAINT GEORGE, NEW BRUNSWICK, RED GRANITE.—Bedford building, Summer and Bedford streets.

VINAL HAVEN, MAINE, REDDISH GRANITE (Bodwell Granite Company).—Building corner Kingston, Bedford, and Columbia streets.

Medford or Somerville black granite (diabase).—Front, corner Harrison avenue and Way street.

Porphyritic granite from Frankfort, Maine.—Gerrish block (1849).

Marble.—Goldthwaite & Co.'s store, Washington street: from Sutherland Falls, Vermont; Commonwealth hotel, Continental block, Washington street, Boston Penny Savings bank: from Pittsford, Vermont; Parker house, on School street (1854): from Rutland, Vermont; Blackstone National bank, Commonwealth Insurance Company: from Pittsford, Vermont; Bowdoin building, Bedford building, Summer and Bedford streets: from Sutherland Falls, Vermont; Rogers' building, hotel Comfort: from Rutland, Vermont; building corner Franklin and Pearl streets: from Sutherland Falls, Vermont; Saint Cloud hotel, hotel Dartmouth: from Rutland, Vermont; old part of hotel Vendôme, Italian marble; Richardson building, Devonshire street: from Lee, Massachusetts; block of stores on Pearl street (Nos. 113–151): from Alford, Massachusetts.

Tuckahoe, New York, marble (dolomite).—Sears' building; McCullar & Parker's building; Mason & Hamlin Organ Company's building; Chandler's building, Devonshire street; large building corner Devonshire and Franklin streets; New York Mutual Life Insurance Company's building, one of the finest stone buildings in the country: from the quarry at Tuckahoe, New York; Montgomery building, Summer and Chauncey, hotel Vendôme (new part): from Tuckahoe, New York.

Red-sandstone from Connecticut valley and New Jersey.—Church of the Messiah, Florence street (1848): from New Jersey; 681 Washington street: from Longmeadow, Massachusetts; Evans house: from Portland, Connecticut; hotel Pelham: from Portland, Connecticut, and New Jersey; Brewer building: from Connecticut; Boston Athenæum: from Little Falls, New Jersey; Second Unitarian church, Boylston street: from Newark, New Jersey; Arlington Street church: from Belleville and Little Falls, New Jersey; five houses on Mount Vernon street: from Portland, Connecticut; and great numbers of fronts in the Back bay and elsewhere.

Red sandstone from the Provinces.—Wilde buildings, New Washington street: from Mary's Point, New Brunswick; buildings of Palmer, Batchelder & Co., Jordan, Marsh & Co., Boylston bank, Young Men's Christian Union, Boylston street; Channing building, Franklin street; Howard buildings, Arch street; Richardson's building, Federal street: from Bay View, New Brunswick; Bristol building, Boylston street: from Wood's Point, New Brunswick; bank building in Charlestown: from Bay View; Liberty building: from Wood's Point; buildings of Currier & Chamberlain, Washington street, and Minot, Hooper & Co., Kingston street: from Mary's Point; many fronts in Back bay and elsewhere.

Yellow to white sandstone from Berea and Amherst, Ohio, and from Nova Scotia and New Brunswick, etc.—Saint Paul's church (1820), columns, etc.: from Acquia creek, Virginia; Wilde buildings: from Caledonia, New Brunswick; Associates' building (Leopold Morse & Co.): from Berea, Ohio; buildings of Palmer, Batchelder & Co.: from Caledonia, and Mary's Point; Shreeve, Crump & Low: from Amherst and Berea, Ohio; R. H. White & Co.: from Amherst, Ohio; Boylston Bank building: from New Brunswick Freestone Company; Dobson's building: from Amherst, Ohio; Call & Tuttle, 459 Washington street: from Caledonia, New Brunswick; hotel Boylston: from Amherst and Berea, Ohio; Young Men's Christian Union: from Amherst, Ohio; Tremont National bank: from Bay View; Simmons' building: from Berea, Ohio; Metropolitan National bank: from Amherst, Ohio; Angelo building: from Ohio; Minot, Hooper & Co.: from Bay View; Harvard College building, Arch street: from Amherst, Ohio; Richardson's building, Federal street: from Bay View; Rice, Kendall & Co., Federal street: from Berea; Alexander building, Washington street, and Sargent's block, Lincoln street: from Mary's Point and Caledonia, New Brunswick; extension Young's hotel: from Caledonia, New Brunswick; Rand, Avery & Co., Mason building (trimmings): New Brunswick freestone.

Roxbury conglomerate or pudding-stone.—First church, Marlborough and Berkeley streets; Brattle Square church; Central Congregational church, Beilseley and Newbury streets; Emanuel church, Newbury street; new Old South church; Second Universalist church; Tremont Street Methodist Episcopal church; cathedral of the Holy Cross; Saint James (Episcopal) church; Mission church, Tremont street; Saint Peter's church, Dorchester; Saint Columbkille church, Brighton; Saint John's church and the Bussey institution, Jamaica Plain, and several others.

Somerville or Cambridge slate.—Saint Francis de Sales church, Charlestown.

Dedham porphyry or felsite.—Trinity church, from Mr. Bullard's quarry, Dedham.

The city has been very fortunate in having close at hand such an excellent stone as the Roxbury conglomerate for certain purposes. It has been used almost entirely for churches, the stone being so laid up that the exposed surface is that of a natural joint, the rusty-brown color of which is very effective in massive buildings; but of course this use of joint surfaces adds to the expense.

In the trimmings of buildings the red sandstones of Connecticut valley, of New Jersey, and of the provinces have been universally used with brick, and also the yellow sandstones to a considerable extent, while the granites have been used somewhat, especially in the large brick buildings. With the Roxbury conglomerate red and yellow sandstone are used, but the Catholic churches seem to prefer Rockport granite. The new Old South is trimmed with yellow sandstone from Amherst, Ohio, and red sandstone from Longmeadow, Massachusetts. Quincy, Rockport, and Concord granites are the most used for trimmings and supports; also granite from Spruce Head and Hallowell, Maine. The new Boston and Albany depot is trimmed with two shades of the gneiss from Monson, Massachusetts. The

Mechanics' Charitable Association's new building has steps, etc., from Sullivan, Maine. The Boston and Albany Railroad round-house, East Boston elevator, etc., are trimmed with granite from Braggville, Massachusetts. In Gilman & Cheney's building, Charlestown, granite from Deer Isle, Maine, has been used. Red granite from Westerly, Rhode Island, has been used in some churches. Coarse porphyritic granite (Frankfort, Maine) has been used in houses on Harrison avenue.

Marble has been used for trimmings in some large buildings, and the Tuckahoe dolomite a little, *e. g.*, in a house opposite the state-house. The blue or dove marbles have been used in several buildings of white marble; that in the Sears and Montgomery buildings is from Dover, New York; another dove marble (Rogers and other buildings) comes from Rutland. The gray marble from Isle La Motte, lake Champlain, has been used for trimmings in a few buildings (Summer and Pearl streets). In the Richardson building on Federal street the beautiful green serpentine from Chester, Pennsylvania, has beon used with marble, but it has crumbled badly with the exposure; the same stone used in Philadelphia has stood well (University of Pennsylvania buildings). The Hudson River blue-stone has been used for trimmings with Tuckahoe marble in the building corner Devonshire and Franklin streets. The bright red sandstone from Potsdam, New York, has been used a little (columns and trimmings of house Myrtle and Hancock streets, and in Raynor block, in Union street).

For polished granite ornamentation there has been a considerable use in columns on the exterior of buildings (red Scotch, Saint George, New Brunswick, Red Beach, and Jonesboro', Maine); dark red and pink Quincy and gneiss columns (new Old South church). In Wellington Brothers' and Nevin Brothers' buildings are polished columns of Vinal Haven, Maine, granite. In the Wentworth building are columns of the porphyritic Shap granite (English); in the hotel, Boylston avenue, some very beautiful columns of red Quincy; the dark may be seen in the Tremont National bank, Providence depot, and many other buildings. In the *Herald* and Bedford buildings may be seen polished Saint George granite, Scotch and Jonesboro' in many others. At No. 55 High street, in the Mason building, the Bedford building, and elsewhere the underpinning or granite supports are of polished work.

For foundations the granites of Quincy and cape Ann, together with Cambridge slate and Roxbury stone, are used. The Somerville diabase was extensively used forty years ago, and about forty-five years ago the rails of the Lowell railroad from Boston to Medford were laid on a foundation of this stone from Dane ledge, Somerville.

For underpinning, Quincy, Rockport, and Concord granites are generally used; red and yellow sandstones also very extensively in dwellings. In Charlestown the Somerville slate and in Roxbury and Jamaica Plain the conglomerate are largely used, on account of the proximity to the ledges. Hallowell, Spruce Head, Vinal Haven, Deer Isle, and other granites have been used. In the very old houses one sees generally the white Chelmsford granite, looking very rough, as the bush-hammer had not been invented forty years ago. At that time the Somerville diabase was very extensively used for underpinning in Tremont and Hanover streets, Harrison avenue, and in the neighborhood of the Charles Street jail. In many of these old streets the Connecticut sandstone was profusely used, and, being of poor quality then, shows the effects of the frost very plainly. Marble and Hudson River blue-stone have also been used. The handsome granite basement of the Art Museum building is from Mr. Corliss' quarry at Randolph, Massachusetts.

Posts and walls are made generally from the varieties of granite—Quincy, Rockport, and Concord; mainly for posts, Spruce Head diabase, etc.; the granites and sandstones for steps; for walls, Quincy, Rockport, Concord, and Chelmsford sandstone, conglomerate, and slate.

As mentioned before, the streets were early paved with the cobble-stones from the beaches, and these were generally used until about 1840, when Mr. Willard laid the first paving blocks of Quincy granite in front of the Tremont house; they were very large at first—18 inches by 14 feet—but became smaller until about a foot square. For a while (1856) blocks of trap from Bergen hill, New Jersey, were used, until in 1858 Mr. Henry Barker, of Quincy, introduced the small granite pavers which have since been universally used. At present the paving stones come from Rockport, Quincy, and the Maine quarries—all of granite. Granite curbs were used long ago; at present Quincy and Rockport furnish most; some are of Hudson River blue-stone. There are 355 miles of public streets and about 410 miles in all; of these 67 miles are paved.

Sidewalks were flagged or paved in this century. Before the North River flagging came into use in the city, quantities of the Bolton, Connecticut, flagging (a mica-schist, wearing down easily) were laid down. Pemberton square is still largely flagged with these, and many other places in the city, where it still lingers. At present, while brick is generally used, the business streets are flagged with North River stone and granite flags, the granite principally from Rockport and Quincy. Red sandstone flagging is used once or twice. For crossings, North River stone and granite; a great deal of the granite comes from the old-fashioned paving blocks. For the catch-basins of the sewers Rockport granite is largely used. In some of the old city sewers pudding-stone has been used for side walls, and especially for culverts; in some cases the old brick sewers were covered on top with slate. In the improved sewerage construction at Moon island considerable masonry has been used in the pumping station—the granite from cape Ann, Quincy, and Mount Desert.

The reservoir of the Boston water-works on Beacon hill has been described. At the Chestnut Hill reservoir the lining is trap and pudding-stone with a cap of Douglass mica-schist. The East Boston and South Boston reservoirs are lined with Quincy granite. The Parker Hill reservoir has a pudding-stone wash-wall with cap of granite from Graniteville, Massachusetts. The Mystic reservoir has a granite cap. The Sudbury River conduit crosses Charles river over a bridge 475 feet long, of granite from the Cape Ann Granite Company; and the Waban Valley bridge of the same, 536 feet long, is from Spruce Head and Deer Isle, Maine. Three dams are built of Farmington and Cape Ann granite, etc.

The abutments of the Boston bridges are of granite from Quincy, cape Ann, and various other places; the West Chester Park bridge, for instance, is of Milford, Cape Ann, Deer Isle, and Mount Desert granite. For the walls and abutments and other stone-work of railroads, granites, pudding-stone, diabase, slate, etc., are used; the Braggville granite was used quite largely by the Boston and Albany railroad.

For the sea-walls surrounding the city, Rockport and Quincy granites, Somerville diabase, pudding-stone, etc., have been used. In the sea-walls built extensively in the harbor on Galloup island, Point Allerton, Long island, etc., granite has been used—a great deal from Biddeford and Bamebrush, Maine.

Forts Winthrop, Warren, and Independence, in the harbor, are of granite from Quincy, Rockport, and other quarries. Boston Light and Minot's Ledge light-houses are of stone.

ROOFING.—The John Hancock house and old state-house were slated from Lancaster; but the Welsh slates were used in Boston probably two hundred years ago. The Lancaster quarry furnished great amounts of slate to the city after the Revolution, and the slate quarries near Brattleboro', Vermont, furnished slate early in this century. About thirty-five years ago the slates from western Vermont and the Maine slates came into use for roofing, and their use has steadily increased until very little Welsh slate is now used. At or after the time of the war, slate from Buckingham county, Virginia, was used in many buildings of the city. At the present time the roofing slates used come from Piscataquis county, Maine, and from Vermont, Pennsylvania, New York, and Wales. The green, red, and purple slates of western Vermont, and New York state, etc., are extensively used. We may mention the following examples: Trinity church (in part), Clarendon Baptist church, and Saint Mary's cathedral: from Brownville, Maine; new Latin school: from Monson, Maine; cathedral of the Holy Cross, Park Street church, and Bowdoin Square church: Welsh-Penrhyn; navy-yard buildings: Maine and Welsh; Lowell Railroad station and city hall, Charlestown: Pennsylvania slate; post-office, and Eastern Railroad station: Vermont slate; Baptist church in Cambridge: Virginia slate.

The use of slate by marbleizing for mantels, chimney-pieces, tables, etc., began about thirty years ago; and it is used for tiling, slabs, etc., as elsewhere in the country.

Ornamental marbles were in use at least thirty-five years ago in Boston; the "black and gold", Bardillo, and Italian dove were most used then, and the others gradually came in—the German marbles last. The use of the blue marbles of Dover, Pittsford, and Rutland in the exterior trimmings has been mentioned; some of the other veined marbles have been slightly used (Sears building), and the Winooski Vermont marble in columns (Masonic temple), and black marble (Parker house). In the interiors of buildings the ornamental marbles have been frequently used, and in great variety, *e. g.*, the Art Museum, New York Mutual, *Herald*, Marlborough, and many other buildings; and of course considerably for mantel-pieces, soda fountains, etc. The following have perhaps been most used in the city:

Yellow Sienna: Italy; Saint Baume, Jaune Fleuri, and Lumachelle, France.

Black: from Glens Falls, New York, and elsewhere.

Red: Lisbon, Portugal; Victoria or Irish red; Griotte, France and Spain; Echaillon, France; Formosa and Bougard, Germany; Brocatello, Italy; East Tennessee, red, brown, chocolate, and pink; rouge and garnet, France; Larancolin, France; red and pink, etc., from lake Champlain.

Green: Geneva, Alps, Campagna, and the Marie, New York, marble (columns in entrance to Art Museum). The red slate is used with the colored marbles.

Blue: Dover, Rutland, and Pittsford. In tilings, slate, red slate, Italian and Vermont white marbles, Lake Champlain black marble, and the Swanton red marble are largely used.

The monuments and statuary distributed through the parks and squares of the city have necessitated a considerable employment of stone. The Hamilton statue on Commonwealth avenue, of gray granite, is said to have been the first in the country made of granite (1865).

The soldiers' and sailors' monument, on the common, and that of Charlestown, are of granite from Hallowell, Maine. The Dorchester soldiers' monument, on Meeting-House hill, is of Gloucester red granite.

The Ether Monument group of statuary in the public garden is of Concord granite, as is also the Good Samaritan group of statuary; the figures on Horticultural hall are of Fitzwilliam, New Hampshire, granite; the pedestal of the Franklin monument, city hall, and the Warren statue, Bunker hill, are of Roxbury, Vermont, serpentine; the polished bases of the Winthrop and Prescott statues are of Jonesboro', Maine, red granite; also that of the Emancipation group. Quincy granite is used for the Adams, Washington, and many other bases; the soldiers' monument in Jamaica Plain is of Clark's Island, Maine, granite, with Quincy base; and the statue of Josiah Quincy, city hall, has a green verd-antique base.

One of the earliest applications of stone was in the city cemeteries. The principal old burying-grounds, those of King's chapel, Copp's hill, the Granary, Charlestown, and Roxbury, are much alike in the kinds of stone used. Some of the oldest tombstones are of porphyritic greenstone taken, presumably, from bowlders. The Welsh slate was extensively used (often to be told by lines of color crossing the slabs) with American slate, foreign and American marble, and sandstone. In the King's Chapel ground may be noted the apparently early use of marble: a small tomb of shell marble reads 1702; the Winthrop tomb is supported by four marble columns. The Granary burying-ground is much similar; red, green, and blue slate tombs have been used principally. The Franklin monument is of Quincy granite. At the large cemetery of Copp's hill we find much the same stones—red and greenish, Welsh, bluish American marble, yellow and red sandstone, and Vermont slate. In the Charlestown cemetery the John Harvard monument is of Quincy granite (1828).

The weathering of the stone in these old places is noteworthy. The Welsh slates, some of which have stood two hundred years, are often almost unaltered, looking very fresh; the greenstone tombs have also stood the weather well. In a slate slab at Copp's hill, having alternations of sandy layers parallel to the surface of the slab, one of these sandy layers has been eaten out, leaving the unsupported thin layer of slate to cave in; the slates are occasionally cleaned by the weather. The red and yellow sandstones, when standing upright, have almost always crumbled or scaled off, and the marbles have suffered. One case of this is a vertical slab at Copp's hill, about forty years old, of a coarse marble; below the ground it retains largely its original smoothness, but above the ground, on the northeast exposure, the action of the rain and atmosphere has dissolved out the cement of the grains of the marble, leaving the isolated grains sticking out like sandpaper; on the sheltered side there is a marked difference. Another large imported marble monument, some seventy years old, has weathered so that the shells embedded in the marble stand out in relief, and the stone is also covered with fine cracks, which, widening and admitting the black soot from the air, give it a peculiar appearance.

In the recent cemeteries of the city there has been an immense consumption of stone for monuments and curbing.

In Mount Auburn, in Cambridge, marble has been most used for monuments, and there are many fine pieces of statuary made from it; the Italian marble for the finer pieces, Vermont marble somewhat, and the pink Tennessee marble. Since the introduction of granite-polishing at our quarries there has been a great increase in the proportion of granite monuments. Quincy granite has been used since the opening of the cemetery, and there are many polished monuments of this stone. The light Mason, New Hampshire, granite is abundantly used here in polished monuments and curbing; also the Rockport granite and that of Concord. There are some fine monuments and tombs of Hallowell granite (the Sphinx and the Charlotte Cushman monument). Westerly granite has been somewhat used. Polished red-granite monuments are plentiful—Scotch, New Brunswick, and Maine. The Shap granite is used in a few cases; also some other granites. There are several tombs and monuments of the Somerville diabase, and a recently-polished one of diabase from Maine (Addison Point?). Both yellow and red sandstones have been used. The Winter monument consists of a large shaft of soap-stone coming, I believe, from a quarry in the east part of Andover forty years ago.

The weather shows its effects at Mount Auburn as elsewhere. Some of the old marble tombs have the roughened surface (by solution of the lime) previously mentioned; others, however, have stood as long without the same evidence of changes, especially the fine-grained marbles. In one tomb of a medium coarse white marble, in a course at the top part of the structure, the marble has disintegrated as follows: On the corner pieces and sides the marble cracks almost imperceptibly; along these cracks the cement of the grains (or some of the grains) is slowly dissolved out, leaving the coarse grains, and these finally crumble off in powder. As this continues, whole lumps are loosened and fall off, breaking into powder; in this way one of the corners has entirely crumbled to loose grains which may be taken up by the handful. The tombs made of the different granites have been slightly affected by the weather, consisting in a change of color; this is most marked in the Quincy; the light granites occasionally show a rusting of the feldspar. The diabase tombs have turned a rusty brown, the change apparently occurring in the black minerals (augite, mica, etc.), while the feldspar whitens. It is very noticeable here that grains of pyrite in the stone are generally bright, without patches of rust about them; one large shaft of the stone, finely bushed, has been little affected by the weather. Many of the red-sandstone tombs have exfoliated considerably; there is one curious case of a large tomb of this stone in which ivy had been trained up the face of the stone, but the continual peeling off of the layers afforded the tendrils no support.

Forest Hills cemetery.—The marbles are generally white Italian, bases often of Vermont marble. There are some very large tombs of marble; in one of them the Tuckahoe, New York, marble is used. There are a number of very beautiful monuments of the polished white Westerly, Rhode Island, granite; many of Concord, Quincy, and Rockport granite. The Randolph, Massachusetts, granite, with greenish spots, has been used in several polished monuments, and a gneissoid granite also. There are many fine examples of red granites—Scotch, Saint George, and Maine. A black granite (diabase) from Addison Point, Maine, has been recently used in a polished monument. The brownish-red Quincy is used in some beautiful shafts; also Shap granite; occasionally red and yellow sandstones; Rockport, Concord, Quincy, and other granites for curbing.

In Mount Hope cemetery there has been nearly a similar use of stone. The Odd Fellows' monument, with large carved granite figures, is of Hallowell granite with two courses of polished red granite; on the posts in front are two polished spheres of Quincy. The Army and Navy monument is a large structure of Concord granite; marble is used extensively as before—Quincy, Rockport, Concord, Mason, New Hampshire, Westerly, Randolph, etc. There are several monuments of Aberdeen granite, New Brunswick red, etc. The Vinal Haven, Maine, reddish granite has been used in polished work, and Hallowell granite also. For curbing, Quincy, Rockport, Hallowell, Chelmsford, Milton, and Randolph granites. The red Tennessee marble in a few monuments.

At Woodlawn cemetery, in Everett, besides Italian, Vermont, and Tennessee marbles, Quincy, Hallowell, and others are used. There is considerable use of Vinal Haven granite; in one tomb there is the combination of Vinal Haven red, Spruce Head white, and black granite (diabase), all from Maine. Shap granite and the red granites are frequent. There is a shaft of dark soap-stone, probably from Andover.

WEATHERING OF STONES.—The climate of Boston must be one of the most trying ones in the country for building stones, as far as natural atmospheric causes are concerned; for in the winters there is a more or less frequent alternation of damp, rainy, and warm days with those of intense cold, while the rain-storms are violent; yet the deleterious effects of smoke and other products of certain manufactories are largely wanting; the changes in the stone are hence due to the character of the stone itself, and to the defects in it; at the same time most of the stone buildings have not stood long enough to develop a marked change in the stone.

The granites have generally been affected by chemical change alone in some of the constituent minerals, as is evidenced by a change of color—an effect of a higher degree of oxidation of the iron; but they have generally not crumbled. The Quincy granite, since it is found in the buildings that have stood longest, and since it contains a dark feldspar, shows often the signs of change. The stone is of many shades: blue, greenish-blue, pink, reddish, brown-gray, and grayish-black, these being the colors of the feldspar, the mineral in which is found the change, if there be any. This turns liver-brown, rusted-red, yellow or white; often the whitening of the feldspar, with the white look of the quartz, causes the bush-surface to appear almost white. The hornblende seems less frequently affected, turning green and rusty brown. Some of the Quincy stone has stood for years without any very noticeable change of color. Perhaps the Boston custom-house shows best in one building the differences in the weathering, the color remaining unchanged in some cases, in others having become a deep brown, differing in the separate blocks, and even in different ends of the same block.

The light granites (Hallowell, Concord, etc.) have naturally not changed much in color, nor have the buildings been standing long. The principal change observed seems to consist in a dull whitening of the feldspar, and an occasional rusting of that mineral to a yellow color. The white granite from the vicinity of Chelmsford, which was used so extensively in Boston fifty to sixty years ago, shows almost universally in the old buildings a change in the feldspar to a honey-yellow; this is perhaps in part due to the fact that almost all this granite was then quarried from loose bowlders, and of inferior quality to that obtained from ledges. This can be seen in the Massachusetts general hospital, the central part of which—erected in 1818–'21, of stone derived presumably from bowlders—shows the yellow weathering, while the wings, of stone quarried in 1846, are almost unchanged (the garnets scattered through some of the old stone have not changed); part of this difference may be due to the difference in the date of erection.

A red granite from Gloucester has not rusted and faded, but it has been but little used in the city.

The marble buildings have not been standing long and do not generally show a perceptible change, except in the blackening and roughness of the surface. The veined ornamental marbles when exposed out of doors have generally suffered by the removal of the softer parts of the veins. This is notably shown in the pedestals, of veined serpentine marble, of the two statues in front of the city hall—one erected only four the other some twenty-five years ago. The calcite veins in the serpentine have become roughened by the weather, and cracks, which widen so that pieces fall out, often form along them; this is much more marked on the flat surfaces. The green Roxbury, Vermont, serpentine, in consideration of its twenty-five years' exposure, has stood the weather well. The green serpentine used in one building has crumbled on the surface like sand.

The red and yellow sandstones used so extensively in the city vary in character so greatly, even in the same building, that it is difficult to make general statements. Many years back a great amount of red sandstone from the Connecticut valley and elsewhere was brought to Boston, and can now be seen in many of the older brick houses; it was generally coarsely stratified, and, moreover, was laid up with the stratification or layers perpendicular instead of horizontal, the consequence of which has been a frequent cracking, opening, and falling off of pieces. Where sandstone pillars were thus made, it can often be seen how the split began at the bottom, where the free edges of the layers were exposed and worked up. The introduction of better and more homogeneous stone from the quarries of the valley, from New Jersey, and from the provinces, and greater care by the builder, have largely done away with this; yet still cases of scaling off are seen. The other change in the red sandstones has been in the depth of the red color.

The yellow sandstones of different shades from New Brunswick, Nova Scotia, and northern Ohio have been very variable in their character, the same quarries furnishing apparently both good and bad stones. None but homogeneous sandstones of this class have been in general use, and there have been two main changes by weathering, exfoliation, and falling off of pieces, owing to incoherency of the particles, giving the stone a rough appearance; and also rusting of the iron in the stone. The latter has been most noticeable, and occurs either by a uniform change of color in the whole block of stone or only in patches; or else there are parallel layers in the stone, some of which rust while others do not; and consequently when the face of the stone is cut across these layers we have rusty bands crossing it at intervals. This can be seen very markedly in some of the buildings of the city, and poor selection of the stone must be partly the cause. In many buildings, however, the yellow sandstone has stood unchanged; a good example of this is the Washington building, of Nova Scotia stone, erected over twenty years ago.

Occasional changes of color in slated roofs are observable in the city, especially in the green slate, which often changes to a yellowish-red. The black slates have rusted, especially in buildings where cheap slate has been used, and the purple slate changed to reddish; but these seem rare. The Bolton mica-schist, having hard quartziferous tongues in the softer rock, has worn down by the passing feet, leaving these tongues in relief in peculiar shapes.

Movements of the ground have occasionally occurred, especially in the older streets, cracking the sills, and in some cases two motions in opposite directions appear to have affected one block of stone, cracking it twice.

BRIDGEPORT, CONNECTICUT.

Portland brownstone is the material usually employed in Bridgeport for the better class of stone construction. Gneiss from Greenwich, and granite to a limited extent, are used for the same purposes. The foundations and underpinnings are of gneiss from the local quarries. A long line of wooden wharves along the water-front is backed with stone walls of very rough masonry built of the gneiss from local quarries. The west approach to the Central bridge across the harbor is faced with cut stone with a dressed granite coping. The intermediate piers and draw-pier are built of the same material. The approach is 300 feet long and 41 feet wide. The railroad draw-pier and east abutment are built of Greenwich stone. Bridgeport harbor and Black Rock harbor, both within the city limits, have each an extensive breakwater, the first of stone quarried a little north of Lyme on the Connecticut river, a quarry not now operated. There is a substantial wall, over half a mile in length, of stone from local quarries. The streets are but little paved with stone; the material used is trap-rock from New Haven. Many of the sidewalks are paved with North River blue-stone, and the curbs are of the same material, with some gneiss.

BURLINGTON, IOWA.

Most of the limestone quarried in Burlington disintegrates and exfoliates on protracted exposure to the weather and to the action of frost. It appears, however, to be tolerably durable when protected as in underground work. This imperfection of the stone, the cost of transporting better building stone, and the cheapness of lumber and brick—the city having access to extensive lumber regions on the Mississippi river, which is the natural route of communication with the northern pineries—have very much restricted the use of stone. The banks of the Mississippi in this region are covered with löess or reärranged drift material suitable for the manufacture of brick. This has also had its effect in preventing the use of stone as a building material. There are no natural obstacles to the use of heavy building materials. The substratum which is found at a limited depth being formed more or less with compact limestones, the glacial drift and calcareous clays forming the superficial soil are themselves so compact and firm as to largely obviate the necessity of paving the streets. The city sewers are the most important works in which stone is employed. They are mainly constructed of limestone quarried within the city limits, either by quarrymen in temporary quarries, or by contractors in grading streets. There are some sidewalk pavements of limestone flagging from Sagetown, Illinois, and Mount Pleasant, Iowa.

CAMBRIDGE, MASSACHUSETTS.

The materials employed for the better class of construction in Cambridge are Quincy, Rockport, and Concord granites, Somerville diabase or trap, Somerville slate, and Roxbury conglomerate. The foundations are of slate from the Somerville quarry, and diabase from the same place, with some granite from Rockport and Quincy. The underpinnings are built of granite from Rockport, Concord, and Spruce Head, in Maine. The soldiers' monument on the common is built of Mason, New Hampshire, granite. For posts, the Somerville diabase, and Rockport, Quincy, and Concord granites have been extensively used. In the sewers the Somerville slate has been employed for the sides, and slate and granite for the top. For the stones at the entrance to the catch-basin Rockport granite and North River blue-stone have been used. There are no stone bridges of large size. In the sea-walls about East Cambridge the Somerville diabase has been largely used. There are about a hundred miles of graded streets in this city, and about 2 miles are paved with granite chiefly from Quincy; three-quarters of a mile is paved with cobble-stones. A few of the sidewalks are paved with the North River blue-stone; the curbs are of Rockport granite with a very little blue-stone.

CAMDEN, NEW JERSEY.

The materials used for stone construction in Camden are, for foundations and underpinnings, gneiss from the quarries near Chester, Pennsylvania, and sandstone from Greensburg, New Jersey. For the better class of stone construction serpentine from Delaware county, Pennsylvania, Vermont marble, Trenton freestone, Connecticut brownstone, and Ohio sandstone are used. Philadelphia pressed bricks are the material chiefly used in the walls of buildings. The Ohio sandstone, used to a limited extent, is well esteemed here. Berea, Ohio, stone was used in the construction of the court-house. The serpentine tends to crumble and split in winter, and breaks under heavy pressure. The streets are largely paved with stone, and in the portions which are paved with rectangular blocks Connecticut stone is used. Much of the pavement is cobble-stone from the Delaware river above Trenton, but there is but little stone sidewalk pavement, brick being the material mostly used for sidewalks. Slate from Lehigh county, Pennsylvania, is used to some extent for this purpose, and also trap-rock quarried near Lambertville; the curbs are of Connecticut granite.

CANTON, OHIO.

Canton is situated but a few miles from the important and extensive stone quarries located on the Massillon sandstone at Massillon. It is almost the only material used in stone construction in this city. In a few instances, where very fine carving and finishing were desired, Berea and Amherst sandstones were used, as the Massillon stone is too coarse-grained to answer well for these purposes. There are but four or five buildings in Canton entirely of stone; a few have fronts of stone as high as the second story, and quite a number have much stone in their composition in the way of corners and heavy caps and sills. The stone sidewalk pavement is almost entirely of Berea sandstone. The Massillon sandstone is not often found in layers of convenient dimensions for paving flags. The streets are largely paved with stone, cobble-stones from the drift near the city being used.

CEDAR RAPIDS, IOWA.

The stone from the local quarries is practically worthless for purposes of construction, and the freight is such on the Anamosa limestone as to render it too costly to compete with brick and timber. Much of the Anamosa material is objectionable on account of lack of strength and durability. The Farley stone is better, being more uniformly good, but the cost of shipment prevents its extensive use. Some stone has been moved from near Mount Vernon to Cedar Rapids within the last year or two. In some cases builders have placed Anamosa limestone on edge in caps, sills, corners, etc., of brick buildings with the result, which might have been foreseen, of causing its gradual exfoliation and separation into extremely thin laminæ. Much of the stone is indeed unfit for curbstones on account of its tendency to exfoliate on exposure. The piers of one or two bridges across the Cedar river are of limestone from Anamosa. Magnesian limestone of Niagara age, quarried at Stone City, Jones county, Iowa, was used in the construction of the Carpenter block, Third Ward school-house, city jail, and post-office. There are no other important stone structures. Caps, sills, water-tables, etc., are of Anamosa limestone; the bases for monuments, and a few curbstones, are from Farley, although the Anamosa limestone is also used to some extent for these purposes. The streets are not paved; there are a few blocks having stone sidewalk pavements of Anamosa limestone; curbs are of Anamosa and Farley limestones.

CHATTANOOGA, TENNESSEE.

In the city of Chattanooga stone is just coming to be used to a considerable extent for purposes of construction. In the valley where the city is located there are two formations of Lower Silurian age, the Nashville and Trenton, and the Knox or Quebec dolomite. The latter has been used to some extent, but is rather cherty, though some of its courses approach marble in quality. The stone chiefly used is that classed by Professor Safford as the Maclure limestone, from its large fossil, *Macluria magna*. There are several quarries of this stone in the vicinity of the city. The old quarry near the Chickamauga station, of what was called by the soldiers Chattanooga marble, is in Georgia, and is objectionable on account of having seams in it which cause it to disintegrate by the action of frost.

The pillars of the Union depot are built of this stone, but in additions which were made to the building the material was rejected and that from a local quarry was used. The growth of Chattanooga has been very rapid, and brick has been chiefly employed for fronts, but stone is growing daily more and more important as a material for construction. The pillars and ornamental parts of the court-house are of Knoxville marble, the basement of local stone. The only private residence entirely of stone is of a common limestone from local quarries. This stone is largely used for steps, caps, sills, and other trimmings; it is also much used for foundations. The front of the old post-office, now occupied by the offices of the Cincinnati Southern Railroad Company, is of a yellow sandstone from the line of the Alabama Southern railway. It is soft when first quarried, and easily wrought, but becomes hard on exposure and resists the action of the weather quite well.. It is easy to get good foundations in Chattanooga, as limestone usually lies near the surface. There are, however, marshy places that have been filled in, but a few feet of digging reaches the stone. Rolling-mills and blast-furnaces all have solid foundations of stone. The front of the First National bank is built from stone from a local quarry. The quarries from which material for foundations and underpinnings are obtained are situated from 2 to 8 miles from the city. The streets are macadamized with this same material, and there is some stone sidewalk pavement of limestone from local quarries, with curbs of the same material. Piers of all the bridges in the vicinity are constructed of this limestone.

CHELSEA, MASSACHUSETTS.

There are only two buildings in Chelsea entirely of stone (the material used is what is called "mortar-stone"), and two have stone fronts. Those entirely of stone are built of a calcareous rock found in the vicinity. There are two fronts of Cape Ann granite. The foundations and underpinnings are of Cape Ann and Quincy granite. But few of the streets are paved with stone, and the material used is Cape Ann and Quincy granite. The sidewalks are not paved with stone; curbs are of Cape Ann granite.

CHESTER, PENNSYLVANIA.

The only stone exposed in the vicinity of Chester is the gneiss, on which there are several quarries of considerable importance; these quarries furnish almost all the stone for building purposes in the city. In the bridge abutments, however, some Port Deposit gneiss is used in combination with the gneiss quarried in the vicinity. The streets are paved with stone to a limited extent, the material used being cobbles from the Delaware river and rubble from the gneiss quarries in the vicinity. Stone is but little used for sidewalk pavements, brick being ordinarily employed for this purpose. In such sidewalks as are paved with stone the North River blue-stone is used.

CHICAGO, ILLINOIS.

By J. S. F. Batchen.

LIMESTONE.

The principal stone used in construction in Chicago is the Niagara limestone. The city is supplied with this stone from the various quarries located around Lemont, Cook county. It is brought to the city by means of canal-boats and is unloaded at the docks of the various quarry companies by means of horse- or steam-power derricks. It is also brought from Bedford, Indiana.

The material is used as building, dimension, and rubble stone. The first is used in buildings as cut stone, and is of the best quality. The dimension stone is of an inferior quality, yellowish, and generally harder than that used for building purposes, and is used for vault covers, flagging, curbing, and sawed window-sills; roof-coping is made from a variety of this stone varying from 1½ to 3 inches in thickness. This quality of stone frequently contains nodules or layers of flint, which occasion some trouble in working; in other places it assumes a siliceous, even flinty, character. This and its yellowish color do not, however, lessen its value for the above-named purposes.

The stone used for rubble is generally of the second class, although frequently first-class stone too small for building purposes is used. This quality is the only stone used in the city for foundations. The stone when sold to contractors is in large blocks or slabs; these are broken into suitable pieces for cutting by means of hand-churn drills, with which holes 3 or 4 inches in depth and from 4 to 5 inches apart are made in the stone, and the separation is made by use of wedges and feathers. Frequently the stone is stunned here and there by the pressure of the shoulder of the steel wedges. This part, although generally seeming as perfect as the rest of the stone, under atmospheric influences frequently scales or drops off and is condemned, when it is really the fault of the handling.

The Lemont limestone is known to some architects as Joliet limestone, but with no valid reason, as, although there are a number of limestone quarries at Joliet, the stone which supplies Chicago is from Lemont, Cook county, excepting occasionally when cut-stone contracts are let to the state penitentiary, when the stone used there comes from that locality. In letting contracts the stone of any particular quarry is seldom specified, but is referred to as the best quality of Joliet or Lemont limestone; the stone from the different quarries differs very slightly, if at all, that from several of the quarries having a yellowish color. The stone used in the construction of the county part of the court-house is from the lighter-colored stone.

The limestones of Cook county harden upon exposure to the atmosphere for any length of time, and are easiest worked when newly quarried. The stone also becomes slightly yellowish with age, the softer varieties being always the whitest, while those which have a tendency to hardness have generally a slight yellowish or cream color. Any stones which are very hard to work are made much softer by soaking them in water for some time, or even by throwing water on the stone. The Lemont quarries furnished the first stone used in construction in this city, and for the length of time it has been in use seems to stand atmospheric influences and sudden changes of temperature very well, although the stone of some buildings has a tendency to scale off here and there, more especially the stone cut entirely by hand in structures which have been built for some length of time, which may probably be accounted for on the following hypothesis, viz: the stone when given to the workmen to dress, after being drafted is pointed, then axed, and then bush-hammered, the two latter tools weighing from 8 to 12 pounds, and when used probably striking a blow of from 150 to 200 pounds at least, so that the part on which these tools have been used, although seemingly as perfect as the rest of the stone, is probably stunned to the depth of from one-sixteenth to one-eighth of an inch, and even as deep as one-quarter of an inch, which only requires time and atmospheric influences to cause it to scale or drop off, showing a ragged surface; this theory has been strengthened by the fact that stones in which the face has been sawed by machinery never show the slightest tendency to scale, while those dressed with tooth-ax and bush-hammered generally scale off, though sometimes very slightly. There are in this city about 40 cut-stone yards, of whom about one-half use machinery, as saws and rubbing-beds.

This limestone is never polished. The slightly-yellowish color which the stone takes after years of exposure, and which the poorer varieties, those which are used for vault covers, flagging, and window-sills, have when quarried, are probably caused by sulphide of iron, this brilliant mineral being frequently found in the natural seams and crevices, and between the different strata of stone; light greenish veins are frequently noticed in the stone similar to the veins in white marble.

Quarries of this stone (Lemont limestone) at Bridgeport and along the western city limits produce large quantities of excellent quicklime.

In laying the water and sewer pipes in this part of the city the rock has frequently to be blasted to enable the pipes to be laid to a sufficient depth to protect them from the frost. About two-thirds of the stone used for sidewalks is dressed by means of steam-planers. A large amount of other stone-cutting, such as moldings on cornices, etc., is done by means of machinery.

OOLITIC LIMESTONE.—Blue oolitic limestone from Bedford, and a buff-colored oolitic limestone from Avoca, Lawrence county, Indiana, have been used somewhat in the city within the last few years. When stone was selected for the construction of the city part of the new court-house, the choice was finally awarded to this stone, and its being used in the city hall immediately led to its use in a number of other buildings in the city. The buff oolitic limestone from Avoca is not used so frequently as the blue oolitic from Bedford, in the same county, but this may be accounted for by the fact that the latter was used in the construction of the new city hall. When first built the structures in which either of these two stones (blue or buff oolitic limestone) were used looked very well, but in a short time they became dark and dirty looking, more especially the buildings in the business or commercial part of the city.

SANDSTONE.—The sandstone known by the general name of Waverly sandstone or Ohio freestone is brought to the city from the various quarries at Berea, Columbia, Berlin, Amherst, Waverly, and other places in the state of Ohio, and is used in some of the largest structures in the city. That from Berea and Amherst, of a bluish-gray color, is very largely used in the mills and factories of the city for grindstones. What is known as blue Columbia sandstone, from Columbia, Ohio, although furnishing one of the finest building stones used in the city, is remarkable for the rapidity with which it will become stained with rust (ferric oxide). In sawing the stone into slabs the greatest care is necessary; the sawing of the blocks is generally begun early in the day, so that they can be sawed entirely through without stopping; when taken from under the saw-blades the cut which the saws have made is well washed with clean water. When the stone was first used in the city, or when sawed by parties unacquainted with this peculiarity, the saws were often allowed to remain at rest between the slabs over night; when the slabs were removed and opened up, a stain of iron rust the full length and breadth of the saw blade, and which penetrated the stone from one-third to one-half of an inch, was found, which could only be removed by cutting out the part stained. The laying of a wet chisel or any piece of wet iron on the stone for a few hours is sufficient to cause a similar stain.

Sandstone from Buena Vista, Ohio, has been used in the construction of the Chicago custom-house, and for a number of other buildings in the city. In the custom-house the stone contains large numbers of spots of iron pyrites, resembling those found in Aux Sable stone. They are removed by cutting out the spot with a chisel and then filling the cavity with a mixture of stone dust and liquid shellac, which very soon falls or crumbles out, leaving the original cavity. The stone also stands exposure very poorly, splitting or falling off in large scales or flakes and crumbling away until the original sharp outline is completely lost; the scales which fall off have the peculiarity of being exactly the same on the upper and lower sides; and should the stone be what is known as droved, the scale follows exactly the depressions which the chisel has made. Several attempts have been made to coat or paint the stone with some composition which would protect it from the air, but have not been very successful.

Sandstone from Aux Sable, Grundy county, Illinois, is used somewhat for building purposes. It is of a light grayish-white color, and is very easily dressed—in fact the easiest of any used in the city. It contains large quantities of small scales of mica. The stone contains sometimes iron pyrites; the iron under atmospheric influences, and especially when wet, causes the stone to stain with iron rust wherever the pyrites appear; if the stone is protected from the action of water and air no rust stain appears.

A number of buildings have been constructed in which this stone is used, together with Lemont limestone, as, for instance, caps of limestone and the keystone of Aux Sable sandstone. The contrast afforded by the two stones has a very pleasing effect. Aux Sable stone, when crushed to a fine powder and mixed to a thick dough with water, forms a very good fire-brick lining for furnaces, etc.

Brown or mottled sandstones, from Lake Superior, Michigan, were introduced about 1870. The stone is generally of a rich, deep, reddish-brown color, and may be favorably compared with the brown freestones of Connecticut and

New Jersey. There are, however, some exceptions, the stone of some quarries being very coarse and gritty, and sometimes containing flinty pebbles varying in weight from a few grains to two or three ounces; these are generally very loose, and when struck by the chisel in cutting the stone fly out, leaving a cavity which has to be filled with a mixture of brownstone dust and liquid shellac. The variety containing these pebbles also contains numbers of cavities or pockets filled with clay, iron ore, or a reddish clay, which with water forms a reddish mud. These defects are only found in stone from particular quarries, and can be altogether avoided. The quarries which principally supply the city are those at Marquette and at L'Anse, Michigan; the stone since its introduction has been very generally used and is well liked. A peculiarity of Michigan brown sandstone is the fact that the stone from almost every quarry is spotted here and there with white spots (generally round), varying in size from the size of a small pea to 12 or 18 inches in diameter, though the latter are not very frequent. Various means have been tried to color the spots the same as the rest of the stone, but without success, as whatever is used is soon washed out when exposed to the weather. These spots appear to be of exactly the same composition as the rest of the stone, with the exception that they are uncolored and appear as if they had been touched by a drop or globule of some oil which had prevented the adhering of the coloring matter which had colored the rest of the stone; in this they resemble that which takes place in obtaining oleographs of the different oils, as in Tomlinson's cohesion figures.

Within the last two or three years stones as regularly spotted as possible to obtain have been used as a building stone, which gives the building a mottled red and white appearance, which looks very well. The spots seem to stand as well as the colored parts of the stone.

Brown sandstones from Portland and Middlesex, Connecticut, and from New Jersey, are used in a number of instances but not in large quantities. Those of Michigan are much more used. The cost of working all the sandstones used in Chicago during frost is double what it cost to dress the same stone during warm weather—as the stone which, during warm weather, is a freestone and very easily dressed, under the influence of frost becomes hard, dense, and tough, becoming like lead. Should the weather be very cold the cutting of the stone is entirely discontinued. No matter how dry it may be the advent of frost causes it to become harder and tougher in working. The frost does not appear to have any permanent effect, as on the return of warm weather it again resumes its normal appearance. Machinery is not used at all in the dressing of sandstone excepting to saw it into 4-, 6-, or 8-inch slabs.

GRANITES.—Granites are pretty generally used for ornamental purposes, as for columns, pilasters, monuments, and in one or two instances for sidewalks; but there is only one building constructed entirely of granite in the city—that of the Chamber of Commerce—and one other constructed with granite front. Those principally used are blue or grayish granite from Aberdeen, and a reddish granite or syenite from Peterhead, Aberdeenshire, Scotland; granites largely used for monuments and columns and caps from the Chicago and Wisconsin Granite Company, Waterloo, Jefferson county, Wisconsin; the Westerly Granite Company, Westerly, Rhode Island; from the quarries at Fox island and Hallowell, Maine, and from Henrico county, Virginia, and Moundville, Marquette county, Wisconsin. None of these granites are used in any large quantity, but only here and there, excepting those of Fox island and Hallowell, Maine, which are used in the Court-house and the Chamber of Commerce buildings.

MARBLES.—The marbles of Rutland, Vermont, are largely used in interior work, as mantels, tiles, etc., together with red marbles from Tennessee, Mexican onyx, Belgium black from Brussels, and several marbles from Italy.

All the prominent buildings of Chicago have been erected since the fire of October 9, 1871, and are therefore comparatively new.

In using the stone from the Lemont, Cook county, quarries it is brought to the city during the summer in large quantities, so as to be seasoned before the approach of frost. Thousands of dollars' worth of this stone are lost annually to contractors who have purchased stone which has been quarried too late (or what is known to the trade as greenstone), and which a sudden sharp frost causes to crack and burst in every direction, and making it worthless for any purpose. When the stone is once seasoned no amount of cold has any effect on it. In some instances if the stone is not disturbed till warm weather the cracks appear to close up.

STONE-WORK OF SOME OF THE PROMINENT PUBLIC AND PRIVATE BUILDINGS.—The court-house consists of two parts, the county part and the city part. The county part is chiefly constructed of Lemont limestone. The columns and other granite work are of Fox Island, Maine, granite. In the construction of the city part Bedford, Indiana, oolitic limestone was used; the foundations are of Lemont limestone; columns and other granite work of Fox Island, Maine, granite. The interior ornamental stone-work is chiefly of marble from Rutland, Vermont. Cook County hospital is constructed of Lemont limestone. The custom-house and post-office building is of Buena Vista freestone from the quarry located near the Ohio river, about 100 miles above Cincinnati; there were used 467,445 cubic feet of rough Buena Vista stone; there were used in the pier foundations 48,731 cubic feet of Lemont limestone; foundations of Lemont limestone; the stone used for vault covers and sidewalks is Maine granite. John B. Sherman's residence is of blue sub-Carboniferous sandstone from Columbia, Ohio; foundations of Lemont limestone, with polished columns of granite from Quincy, Massachusetts. The Chamber of Commerce building has a superstructure chiefly of granite; three fronts are of Fox Island, Maine, granite, and the rear wall is of Hallowell granite; foundations of Lemont limestone. The Palmer house is of Amherst, Ohio, sandstone; Lemont limestone foundations. The Mackin hotel is of Amherst, Ohio, sandstone; foundations of Lemont limestone. The Grand Pacific hotel, on the block bounded by Clark, Jackson, Quincy, and La Salle streets, has three fronts of Amherst, Ohio, stone; foundations of Lemont limestone. The Sherman house, corner of Clark and Randolph streets, is of sandstone from Kankakee, Illinois, which is injuriously affected by reason of the iron pyrites in its composition; foundations of Lemont limestone. The First National bank has marble counters and floor-tiling of red Tennessee and Rutland, Vermont, marble; in the superstructure blue oolitic limestone from Bedford and buff oolitic sandstone from Avoca, Indiana, were used; the foundations are of Lemont limestone; the granite work is of Jonesboro', Maine, red granite. Saint Luke's hospital: blue oolitic limestone from Bedford, Indiana; foundations of Lemont limestone. Saint Paul Universalist church: Lemont limestone. West Side water-works: cut stone is Bedford, Indiana, oolitic limestone; foundations of Lemont limestone. North Side water-works: rock-faced with Lemont limestone; foundations of same material. Academy of Music: Lemont limestone. Northwestern Railway depot: sandstone from a quarry belonging to this road on lake Huron was used; foundations of Lemont limestone. Haverly's theater: Lemont limestone. Depot of Chicago, Rock Island, and Pacific, and Lake Shore and Michigan Southern railroads is rock-faced with Lemont limestone; foundations of same material. The Union League club-house: brown sandstone from Springfield, Massachusetts; the underpinnings are of the Bedford, Indiana, blue oolitic limestone; foundations of Lemont limestone. Central Music hall: Lemont limestone; foundations of same material; the interior ornamentation is of Rutland, Vermont, marble and Mexican onyx; the polished columns are of granite from Red Beach, Maine, and Quincy, Massachusetts. In the Stephen A. Douglas monument the foundation and tomb, the coping, sidewalk, and terrace wall are of Lemont limestone; the pedestals and other granite work of Fox Island, Maine, granite. The armory of First Regiment, I. N. G.: Lemont limestone. Office of the Chicago, Burlington, and Quincy Railroad Company, corner of Franklin and Adams streets: Bedford, Indiana, blue oolitic limestone; foundations of Lemont limestone; sidewalks of the latter material; white Italian statuary marble, black marble from Brussels, Belgium, and red Tennessee marble were used. Calumet club-house: Bedford, Indiana, limestone; foundations, Lemont limestone. Chicago university: rock-faced with Lemont limestone; foundations of the same material. A. G. Byram's residence: Avoca, Indiana, oolitic limestone; foundations of Lemont limestone. M. L. Wilson's residence: Lemont limestone; foundations of same material. Block of residences from 1200 to 1210 State street: Amherst, Ohio, sandstone; foundations of Lemont limestone. Store 302 west Madison street: Buena Vista, Ohio, freestone; foundations of Lemont limestone. Store on Wabash avenue, near Van Buren street: Lemont limestone. Residence, Adams and Lincoln streets: Lemont limestone. Residence corner of Rush and Illinois streets: Berlin, Ohio, sandstone; foundations of Lemont limestone. Wickerson residence: Amherst, Ohio, sandstone; foundations of Lemont limestone. Residence, 549 and 551 west Van Buren street: Lemont limestone and granite from Peterhead, Aberdeenshire, Scotland; foundations of Lemont limestone. Residence, Adams street, near Lincoln street: Lemont limestone. Williams building, Wabash avenue and Monroe street, Amherst, Ohio, sandstone; foundations of Lemont limestone. Taylor building, 146 Monroe street: Bedford, Indiana, oolitic limestone; foundations of Lemont limestone. Adams building, Adams street and Wabash avenue: Amherst, Ohio, sandstone; foundations of Lemont limestone. Residence of C. P. Libby: brown sandstone from Marquette, Michigan; foundations of Lemont limestone. Residence of W. F. Storey, Chicago *Times*, in process of construction: blue marble, Pittsford, Vermont; foundations of Lemont limestone. Boise block, northeast corner of State and Madison streets: partly of Lake Superior brownstone and partly of stone from the bed of Oswego river, New York; the two kinds of brown sandstone from these localities, so widely distant from each other, are so much alike that they are used together indiscriminately; they are both of Potsdam age; foundations of Lemont limestone. B. P. Moulton's residence, Nineteenth street and Prairie avenue: brown sandstone from Middlesex, Connecticut; foundations of Lemont limestone. Potter Palmer's residence: ashlar of brownstone from Portland, Connecticut, and granite from Marquette county, Wisconsin; trimmings of Amherst, Ohio, sandstone; underpinnings of limestone from Trinity bay, Canada; foundations of Lemont limestone. Honoré block: Lemont limestone; Howland block: Cleveland, Ohio, sandstone; foundations of Lemont limestone. Merchants' building, northwest corner of La Salle and Washington streets: Buena Vista, Ohio, stone; foundations of Lemont limestone. Dore block: Buena Vista, Ohio, sandstone; foundations of Lemont limestone. Reid block: Lemont limestone. Union building, southwest corner of La Salle and Washington streets: sandstone from Au Sable, Grundy county, Illinois; foundations of Lemont limestone. Speed block, on Dearborn street, between Madison and Washington streets: Bedford, Indiana, oolitic limestone; foundations of Lemont limestone. Booksellers' row: Lemont limestone. Montauk block: Bedford, Indiana, oolitic limestone; foundations of Lemont limestone. Grannis block, Dearborn, between Washington and Madison streets: Bedford, Indiana, oolitic limestone; foundations of Lemont limestone; columns of gray granite from Quincy, Massachusetts, and red granite from Peterhead, Aberdeenshire, Scotland. Borden block, northwest corner of Dearborn and Randolph streets: Berlin, Ohio, sub-Carboniferous sandstone; foundations of Lemont limestone. Ryerson building, corner of Washington avenue and Adams street: Bedford, Indiana, oolitic limestone; foundations of Lemont limestone. Schufeldt residence, Dearborn street and Lincoln park: green serpentine from Chester county, Pennsylvania; foundations of Lemont limestone. This is the only building in Chicago constructed of Chester county, Pennsylvania, serpentine.

CINCINNATI, OHIO.

Cincinnati is built on ground of the great limestone formation which takes its name from this city, and which is sufficiently durable for foundations when kept below the surface of the earth. In some places in the city the ground is unfavorable to heavy building, as the shales in the hill slopes give way under heavy pressure. For the better class of stone construction sandstone from Portsmouth and the Amherst and Berea quarries, and limestone from Dayton from different points in Indiana, and from the home quarries, and granite from Maine and from Missouri are used. For foundations and underpinnings, beside the limestone quarried in the vicinity, some limestone from Dayton and from points in Indiana, and freestone from the vicinity of Portsmouth, are used. The abutments of bridges over the Ohio river are built of limestone from the home quarries and from Dayton, from points in Indiana, and sandstone from the vicinity of Portsmouth. The streets are largely paved with cobble-stone, but many of the streets and roadways are macadamized with the native limestone. There is considerable stone sidewalk pavement, and the material used for this purpose is the freestone from the vicinity of Portsmouth; also, to a limited extent, limestone from the home quarries and from Dayton, and of late years the remarkably even-bedded limestone of the Helderberg formation from Greenfield, in Highland county, has been largely used. The following are some of the principal structures in Cincinnati, with the stones used in their construction: In the custom-house, limestone of Niagara age and granite from Missouri and from Vinal Haven, Knox county, Maine, were used; in Pike's opera house, the Gibson house, and Shillito's block, freestone from Scioto county was used; in the Sinton building, Trust Company's bank, and Johnson's building, freestone from Rockville, Adams county, was used.

CLEVELAND, OHIO.

Cleveland is situated within easy reach of all the celebrated quarries of the Waverly sandstone in northern Ohio, and nearly all of its stone construction is of this material. The Amherst sandstone is used almost exclusively for the superstructure of stone buildings. The Euclid blue-stone has not been used in any important structures. In the construction of the city hall, sandstone from Independence, Cuyahoga county, was used; Beckman's buildings, Exchange buildings, hotel Madison, Bronson's block, and the court-house, are of Berea stone. The soldiers' monument is of granite from Woodbury, Washington county, Vermont. The Amherst stone is deemed here the best for superstructures and trimmings of buildings; the Berea stone best for bridge-building purposes; the east Cleveland building stone best for foundations and underpinnings; the Euclid blue-stone best for sidewalk paving; the Medina sandstone, from Medina, New York, is used in a few structures; foundations and underpinnings are of local sandstones. The streets are largely paved with stone, and the material used for this purpose is the Medina sandstone. The sidewalks are nearly all paved with stone, and the material used is blue-stone from Euclid and Newburgh; also to some extent sandstone from Berea. The stone commonly used for curbstones is the Medina sandstone, while bridge piers and abutments are mostly built of Berea sandstone. The stone used in the construction of the Cleveland viaduct is from the Berea quarries.

COLUMBUS, OHIO.

Columbus is built mostly on ground made by the glacial drift, which covers a considerable portion of the surrounding country. The greater portion of the site of the city is on ground well elevated above the Scioto river, affording facilities for drainage, and the drift formation furnishes cobble-stones for street pavements and gravel for roadways. That portion of the site, however, which lies west of the Scioto river is on a low, alluvial bottom, but little elevated above the surface of the river, and protected by levees which prevent its inundation when the waters of the river are high. In the extreme western portion of the city limits the Corniferous limestone forms a rather abrupt bluff, and on it are located extensive quarries, where most of the material used for all building purposes in Columbus is obtained. This material was used in the construction of the Ohio state-house, and in the colonnade surrounding the building the columns are constructed of blocks from a course of this limestone which comes from near the bottom of the ledge. The walls of the Ohio state prison are also of this stone. The sandstone from the Waverly formation is used to some extent, and the material is obtained at Berea, near Portsmouth, Black Lick, and Reynoldsburg. The Dayton limestone of Niagara age is used in a few instances, chiefly for trimmings. Saint Joseph's cathedral is built of stone from the Waverly conglomerate, quarried near Lancaster, and some of the material obtained from the Newark quarries is also used. It is worthy of remark here that there are three formations, the exposures of which pass north and south within a few miles of Columbus, all being important sources of building material. Beginning at the east, appears the Waverly conglomerate, next westward the lower Waverly. There is then an interval of several miles of Hudson shales, after which, immediately west of Columbus, the great ledge of Corniferous limestone is exposed, of good quality for general building purposes, and readily accessible to the city. Among the other prominent stone structures in Columbus are the Ohio blind asylum, built of Waverly sandstone quarried near Reynoldsburg, 10 miles east of Columbus; Trinity church and the Kelly residence are of Waverly sandstone from Piketon, Pike county; First National Bank building, McCune block, and Nuthoff block are of Waverly freestone from Rush township, 12 miles from Portsmouth; and the basement and trimmings of the Ohio state university are of Amherst freestone.

CONCORD, NEW HAMPSHIRE.

The seven stone buildings in Concord are constructed of the well-known Concord granite, the quarries of which in the vicinity of the city furnish nearly all the material for stone construction at this place. All the buildings erected of stone in Concord and in Nashua are in excellent condition—no discoloration or decomposition, though the joints in the Concord quarries carry a slight discoloration down to the lowest depth. The substratum is occasionally rock, but usually sand. Brick is the most common material used for building purposes in these cities. The fact that stone construction is more expensive than that of brick or wood rules it out of use here, except for some public buildings. The following is a list of the stone structures in Concord: The state-house, state prison, church in West Concord, Ward & Humphrey's storehouse, two dwelling-houses, and Saint Paul's school building. The street in front of the Phœnix block is paved with Concord granite. There is much concrete used for street paving and sidewalks; the curbs are of granite from the native quarries.

CUMBERLAND, MARYLAND.

The only stones used for construction in Cumberland are Medina and Oriskany sandstones, of which there is an abundant supply in the immediate vicinity, and limestone quarried at Iron's mountain, on the old town road, about 3 miles from Cumberland. The chief uses to which stone has been put in the vicinity of Cumberland have been in the construction of canal walls and locks and dams. The Erett's Creek aqueduct, below the town, is also a good specimen of stone masonry, and is constructed of the limestone from Iron's mountain. The Medina or white sandstone is an admirable building stone. It is fine-grained, easily worked, and especially adapted to situations of exposure to the changes of the weather, as it neither scales nor crumbles. One of the finest churches (Presbyterian) is built entirely of this material, which is used in foundations, underpinnings, walls, sills, curbing, street-crossings, steps, and for capping walls which are built of other stone. The Oriskany or yellow sandstone ranks next as an available building stone for use here, and several quarries have been opened within the city limits. This is quite soft and is much more easily worked than the Medina stone, but does not stand exposure so well, and is not as durable. Of it also one of the principal churches, the Episcopal, is built. Where great weight is to be sustained, as in the foundations in the city hall, the Medina or white stone has been preferred; but for underpinnings, walls, window-caps, and for nearly every purpose, the Oriskany stone has been largely employed. Dressed, for stone fronts, it has been used to decided advantage in two of the handsomest residences; and in the Rose Hill cemetery monumental shafts and vaults have been built of it.

But little limestone has been used here as a building material. The stone of which the Chesapeake and Ohio canal locks, etc., are built was procured 3 miles from Cumberland, and is very durable. The iron sandstone, so called, is an iron ore, or rather a ferruginous sandstone, containing about 18 per cent. of metallic iron. This peculiar material has been made use of to a limited degree, notably in an extended wall on Washington street, capped with white sandstone. It is extremely hard, forms a structure of great durability, and is found in the vicinity.

DAVENPORT, IOWA.

Lumber is cheap, and excellent brick may be manufactured in unlimited quantities from the löess which caps the river bluffs. The stone found in the vicinity is either of a very uniform quality or of the fine, compact, non-magnesian character of the purer strata of the Hamilton formation in Iowa; which stone is hard, closely-jointed, and refractory under the hammer, and in part liable to suffer disintegration under atmospheric agencies, chiefly from the action of frost. Stone brought from other localities is a relatively costly material. There are no local circumstances unfavorable to the use of any good building stones, and the rock substratum beneath much of the city is peculiarly suitable for the foundations of heavy structures. There are no docks, wharves, fortifications, or breakwaters, and no stone sewers. There is an iron bridge across the Mississippi at this point, the piers at the Davenport end being of stone. Trinity church is built partly of limestone from the city quarries. The streets are largely macadamized with the local limestone, and a few of the sidewalks are paved with Anamosa and Joliet limestones.

DAYTON, OHIO.

There are small isolated areas of what is called the Dayton limestone, which is of Niagara age, exposed in the vicinity, and it is on this formation that the celebrated Dayton quarries are located. The court-house and bridges over the canal and the Miami river are built of stone from the Dayton quarries. Sandstone from Portsmouth and Berea is used to a considerable extent, chiefly for trimmings. The streets are largely macadamized with limestone from the Dayton quarries, and a few streets are paved with cobble-stones. Many of the sidewalks are paved with local stone.

DENVER, COLORADO.

The Windsor hotel and the Union depot are of rhyolite, the latter trimmed with Morrison sandstone. The Union Pacific freight depot and the Denver and Rio Grande depot are of rhyolite. The only other stone used for building purposes in Denver is sandstone from Cañon City, Manitou, Fort Collins, and Trinidad. The quarries near this place lie at the foot of the mountains to both the north and the south of the city. The stones are white and red sandstone obtained from the lower horizons of the Cretaceous; some of the white sandstones are possibly from the Jura. A light pinkish-gray rhyolite which has broken through the Tertiary strata half-way between Denver and Colorado Springs is a favorite building stone in Denver; it seems to wear well, is easily worked, but will not stand fire. The streets are not paved; a few sidewalks are paved with sandstone flags from Fort Collins; curbs are of the Morrison sandstone. Bridge piers on Cherry creek and Platte are of rhyolite from Castle Rock.

DERBY, CONNECTICUT.

The material chiefly used in Derby for stone construction is the gneiss from Ansonia. Of the twelve stone buildings in the city eleven are of the Ansonia gneiss and one of rubble-stone from Birmingham. There is no other stone used here except a very small amount of North River blue-stone for sidewalk pavements and for curbstones, while the gniess before mentioned is used to a limited extent for the same purposes. The bridge abutments across the canal and the Naugatuck river are built of the Ansonia gneiss. There are no paved streets. The Ansonia gneiss is a good material for all ordinary purposes of construction, and is the only building stone to be found in the vicinity.

DES MOINES, IOWA.

Most of the building stone heretofore employed is from Earlham, all of which, except a single ledge in the Bear Creek quarry, is regarded as inferior. It is reported by the city engineer that certain stones from the Earlham quarries are durable and strong, while others undistinguishable in appearance disintegrate rapidly. It is probable that the rock is not sufficiently seasoned before using. The quarrymen think that little if any seasoning is required. Wood is a cheaper building material than stone, as the nearest quarries are so far from Des Moines that freights add very materially to the cost. Rubble, which costs one cent per cubic foot in the Earlham quarries, costs 5 cents per cubic foot delivered in Des Moines. Excellent building stones exist in unlimited quantities in Winterset, in Madison county, near Tracy and Pella, in Marion, and at Givin and elsewhere in Mahaska county, at little greater distance from Des Moines than is Earlham. The new state capitol now in process of construction, with the superstructure nearly completed, is the only important public building in the city. The following is a statement of the building stones used in the state capitol, and the number of cubic feet of each kind:

	Cubic feet.
Granite from Grundy and Marion (bowlders)	6,659
Granite, Minnesota	3,034
Granite from Iron Mountain, Missouri	1,607
Total	11,300
Sandstone from Carroll and Sainte Genevieve counties, Missouri	284,259
Limestone (dimension)	172,924
Rubble and concrete	70,136
Total	527,319

The rubble comes from Bear Creek quarries, 2½ miles north of Earlham; the dimension stone to the ground-line comes from Winterset, Madison county; the limestone dimension, constituting the basement story, comes from Northbend, Johnson county; some limestone used in the interior piers of the basement comes from Anamosa, Jones county, and some used in the interior columns and pillars comes from Lemont, Illinois, the quantity being small. A considerable quantity of limestone from Rock Creek, Van Buren county, was used in building the foundation; but it was found to disintegrate so rapidly under the action of frost that it was afterward removed. It appears from reports of various quarrymen that small quantities of stone from localities not above mentioned have also been used in the construction of the state-house. There are no sewers except temporary drains. A system of sewerage is now in contemplation, and the paving of the streets is deferred until such sewers are completed. There are no wharves; but there are two iron bridges across the Des Moines river, the piers and abutments of which are of limestone, mainly from Earlham. Of the three railway bridges across the Des Moines river, that of the Chicago, Rock Island, and Pacific railroad has piers and abutments constructed mainly from Earlham limestone. The streets are not paved with stone; there is a little sidewalk pavement, of Joliet limestone, with curbs of Joliet, Pella, and Earlham stone.

DUBUQUE, IOWA.

The city is located upon an alluvial terrace and bottom, the materials of which are sufficiently firm to support buildings of any weight, provided care is used in the preparation of the foundations. Lumber is cheap and abundant; bricks are cheap and are the principal material for buildings; but limestone from the local quarries is used exclusively in the construction of sewers. There is a cross-street (Seventeenth street) located in the course of a ravine heading in the high bluffs to the westward, and in order to prevent destructive overflows it has been graded below the ordinary level, paved, and flanked with walls of masonry, so that during freshets the street itself serves as a drainage channel. The Galena limestone from the local quarries was employed exclusively in this work. An extensive artificial embankment for a levee, used for a wharf and utilized as a site for many important buildings, is protected by riprapping, in which the same material is used. The Episcopal church is built partly of limestone quarried near Farley station. The material for the abutments of the railroad bridge across the river was largely obtained from a tunnel in Galena limestone at the Illinois end of the bridge. The building used as a custom-house and post-office is constructed of limestone of the age of the Saint Louis formation quarried at Nauvoo, Illinois. Five per cent. of the street area is paved with the limestone from local quarries, and other streets are macadamized with the same material; except on the main street there is but little sidewalk pavement, and the material used is limestone from Anamosa and Farley, in Iowa, and Joliet, Illinois, and to a very limited extent the blue limestone of Trenton age from quarries 15 miles north of the city, on the Wisconsin side of the river.

EASTON, PENNSYLVANIA.

Easton is situated on moderately uneven ground, portions of the town being located on low ground on the banks of the Lehigh and the Delaware rivers, the junction of which is here, but the greater part is built on ground considerably elevated above the rivers. The surface everywhere offers firm and secure foundations. The limestone quarried in the vicinity is the material used for all ordinary purposes of construction. It is about the lowest limestone in the geological scale within the limits of Pennsylvania, being probably the bottom of the Siluro-Cambrian formation. The brownstone quarries of Triassic age located in New Jersey are readily accessible from here, and are considerably drawn on for building material by Easton. The principal stone buildings are Pardee hall, of Trenton sandstone, with Ohio sandstone trimmings; several churches are also of Trenton sandstone, and the front of the jail is of the same material. The Wyoming blue-stone from near Meshoppen is now being introduced for trimmings. The stone sidewalk pavement is not extensive, and the materials used for this purpose are Wyoming blue-stone, and North River and Lehigh slate. Curbstones are of native limestone.

ELIZABETH, NEW JERSEY.

In the business parts of the city, in the large buildings, brick is mostly used, although there are many of wood; but private residences are almost exclusively frame buildings. Brownstone is used in trimmings and in cellar walls and foundations, but not to so great an extent as brick. Saint John's Protestant Episcopal church is a fine example of brick trimmed with stone. Dark red sandstone was formerly used for grave-stones in the cemetery of this church, and these old stones are beginning to scale off. Several bridges over the river are built of sandstone, but these are small. Of streets opened and graded the total length is 79 miles; of paved streets, 26 miles; rectangular-block pavements, part granite and part trap-rock, 13 miles; the greater part of the trap-rock is from the Hudson County quarries. Of the three stone structures the most prominent is the Westminster Presbyterian church.

ELMIRA, NEW YORK.

The materials used for stone construction in Elmira are, for foundations and underpinnings, sandstone from the local quarries; for the better class of work, sandstone from the local quarries and limestones from Syracuse. The quarries of sandstone in the vicinity supply all the railroad work, except that in which heavy stone is needed, in which case the material comes from Unionville and Waterloo. The streets are not paved with stone, with the exception of two blocks, which are paved with Medina sandstone. But few of the sidewalks are paved with stone; the material used is blue-stone from Trumansburgh.

ERIE, PENNSYLVANIA.

Three stone structures in Erie are constructed of Medina and Amherst sandstone and Sandusky limestone, with one building of marble from Dorset, Vermont. The material for foundations and other rough purposes is a sandstone of the Upper Devonian age quarried in the immediate vicinity, and a sandstone of sub-Carboniferous age quarried at Corry, in Erie county. Sandstone quarried at Lebœuf, in the same county, is used to some extent for foundations and bridge abutments, flagging, caps. and sills. The streets are largely paved with stone, the material most used for this purpose being the Medina sandstone; rubble is also used to a considerable extent. Sidewalks are but little paved with stone, and the material used is chiefly blue-stone from Euclid, Ohio; the Berea, Ohio, sandstone being also employed to some extent. The material commonly used for curbstones is the Medina sandstone. The stone from the quarries along the lake shore east of Erie, used for foundations, is a rather inferior material, but as it can be obtained at small expense, it is employed quite extensively for the underground portions of foundations; but some of it is not capable of withstanding the action of frost.

EVANSVILLE, INDIANA.

In the western part of the city the ground is unfavorable to building, as quicksand underlies the surface; but in the eastern and central parts this unfavorable condition does not exist. There is but one building entirely of stone, but ninety-nine buildings have stone fronts. The materials used in these buildings are the Bedford and Ellettsville limestones. Limestone of the sub-Carboniferous age, from the vicinity of Spencer, Owen county, was employed in the construction of the custom-house. The foundations and underpinnings are of limestone quarried in the vicinity of Evansville. The streets are but little paved with stone, and the material is the limestone from the various points in Vanderburgh county, in which the city is situated. The sidewalks of the business streets are usually paved with the Bedford limestone, with crossings of limestone from North Vernon, Indiana. Curbs are of Portsmouth, Ohio, sandstone, as in the case of most of the other important towns on the Ohio river; the wharves here are constructed of cobble-stones on the banks of the river.

FALL RIVER, MASSACHUSETTS.

About 40 structures in Fall River, mostly mills, are of stone, the material used being granite from local quarries. Among the buildings of Fall River granite is the city hall. The new post-office and custom-house building is of granite in part from Westerly, Rhode Island. The mills before spoken of are, comparatively speaking, handsome structures, and the material of which they are built was quarried by the builder as it was needed in their construction. Some of the material in these structures is surface rock taken from the fields in the vicinity and from the outcrops of granite ledges. A portion of one of the streets is paved with granite blocks from the Fall River Granite Company's quarries in Freetown, and some streets are paved with cobble-stone from the drift in the vicinity. A few of the sidewalks in the older portions of the city are paved with the North River flags, and the curbstones are granite from Fall River quarries.

FITCHBURG, MASSACHUSETTS.

There are only two buildings in Fitchburg entirely of stone; the court-house and the Episcopal church are both built of granite from Fitzwilliam, New Hampshire. There are two stone fronts built of granite from the local quarries. The Fitchburg granite comes from Rollstone hill, about half a mile distant from the railroad station. Foundations and underpinnings are of Fitchburg and Fitzwilliam granite. There is but little stone street pavement, and the material used is the Fitchburg granite; sidewalks are not paved with stone, and curbs are of granite from local quarries.

FORT WAYNE, INDIANA.

There are but five stone buildings reported in the city. Limestone from White House, Ohio, is perhaps next in importance for foundations to that of the Wabash, Indiana. Limestone from the state is used to some extent for foundations of small structures. Stone is used to a considerable extent for paving sidewalks, though brick is used to a much greater extent. The Amherst, Ohio, sandstone was formerly used almost exclusively for the different purposes for which sandstone is commonly employed in this city—monument bases, caps, sills, and trimmings in general—but the Buena Vista sandstone is used almost exclusively now, because it is obtained here at a little lower price. The sandstone from Stony Point, Michigan, is considered by some builders to be equal in quality to the Amherst stone, but its brown color is objectionable to some. Foundations and underpinnings are of the Wabash limestone, and to a limited extent, some stone from Stony Point. The streets are macadamized with Wabash limestone, and a few of the sidewalks are paved with sandstone from Berea, Ohio, and limestone from Joliet, Illinois; the curbs are of the Joliet limestone; bridge abutments are built principally of sandstone from Stony Point, Michigan.

GALVESTON, TEXAS.

A few foundations in this city are built of stone brought in ships as ballast from various parts of the world, and all that has thus far been employed proves substantial and durable. The city is built on a sand-bank, and the usual manner of preparing the foundations of the largest buildings is simply to remove the top soil, which is only a few inches thick, and, provided there is no danger of the sand wasting from under, every inch deeper is considered money thrown away. In sinking an artesian well recently silt was struck at 720 feet; all above this was sand, shell, and clay, or beds of silt in varying thicknesses. The United States government is using for the jetties the calcareous sandstone from a quarry 9 miles from Brenham, on the Gulf, Colorado, and Santa Fé railroad; also limestone from points on the East Texas railway. Both of the above stones make reliable masonry, and they are used on the railroad for bridge abutments and piers; they are rather porous. The ship ballast used so much for foundations and underpinnings comes chiefly from the northern United States, from Canada, and from Europe. There are but 20 square yards of stone street pavement in the city, and this is of cobble-stone brought as ship ballast. A few sidewalks are paved with sandstone, blue limestone, and granite from Connecticut, and from Germany and England.

GLOUCESTER, MASSACHUSETTS.

The six structures entirely of stone and the four stone fronts in this city are built of Gloucester granite. The only stone used for any purpose, with the exception of a few perches of lintel stone from New Brunswick, is granite from the quarries within the city limits. The streets are but little paved with stone, the material being the Gloucester granite; the sidewalks are not paved with stone, and there are some curbs of the granite from the local quarries.

HARRISBURG, PENNSYLVANIA.

Brown sandstone of the Triassic age is largely used in Harrisburg. Some of it comes from the Connecticut valley and some from Goldsboro', York county, but at present it is nearly all obtained from Hummelstown, Dauphin county, which is but a short distance east of Harrisburg. The climate here is rather severe on the brownstone, from whatever locality it comes. In buildings of this material it was noticed that blocks at the base, where more subject to sudden alternations of dampness and frost, are scaling off in thin flakes, while the stone higher in the wall remains unaffected. The stone-work about the base of the Pennsylvania State Capitol building is of brownstone from Goldsboro', York county, the superstructure being of brick; the brownstone is scaling off rapidly, due probably in a great measure to unskillful handling, as well as to the effects of damp and frosty atmosphere. Many of the stones are set up edgewise, instead of being laid as in the quarry. The Hummelstown brownstone is steadily increasing in use here. Front street, facing the Susquehanna river, seems to be the locality in this city most severe on building stones; the street is more exposed to rapid alternations of damp and cold weather than the other parts of the city. The material mostly used for the rougher building purposes, such as cellar walls and foundations, is the blue magnesian limestone quarried in the immediate vicinity, and most of the stone buildings are of this material. It is quite durable, the weather having apparently no effect on it, except to fade it to a light color; it is hard and brittle, and not readily susceptible of a fine dressing. Several private residences are built of blocks of this limestone of irregular shape firmly cemented together, and the effect is very pleasing. One of these, the house of Hon. Simon Cameron, was built by the founder of Harrisburg a century ago. In trimmings, curbing and steps, the Amherst, Ohio, sandstone is used in a few instances, but its use here is of recent date; the material as yet shows no sign of being affected by the elements. One building, the Dauphin County prison, is built principally of a gray, conglomeratic sandstone quarried several miles south of Harrisburg, near the Susquehanna river. The building was constructed in 1840, and the stone in the walls has been redressed several times since its construction; this is made necessary by the constant scaling off of the dressed surface in thin flakes. It was thought to be a most substantial material at first, but its vulnerable character is now so generally recognized that it is no longer quarried for building purposes. For underpinnings, steps, base courses, caps, and sills, Conewago granite, a dolerite quarried from the trap dikes which cut the Triassic formation at various places, is used to a considerable extent. The quarries which supply Harrisburg with this stone are principally those at Collins station, Lancaster county, and York Haven, York county. The material is practically indestructible, but its somber, dead color restricts it to uses in which fine effect is not desired. The abutments of bridges crossing the Susquehanna river here are constructed of the magnesian limestone quarried at Bridgeport, opposite Harrisburg; the abutments are repaired in places with patches of Hummelstown brownstone. The Dauphin County soldiers' monument is built of the trap-rock called Conewago granite; the superstructure is of Maryland marble, and the figure surmounting the column is of Carrara (Italian) marble. For curbs, base courses, caps, sills, etc., Conewago granite and Montgomery county and Maryland marbles are all used to a considerable extent. One new house is being trimmed with the Wyoming blue-stone, a handsome, fine-grained and uniform, rather light blue sandstone from Meshoppen, Wyoming county. The new post-office building, in course of construction, has a foundation of Conewago granite from Collins station, Lancaster county; the exposed part of the foundation is of Old Dominion granite, a biotite granite quarried near Richmond, Virginia, and a superstructure of granite from Bluehill, Maine; the latter two materials resemble each other very much. The streets are but little paved with stone, and that most used for this purpose is cobble-stone from the Susquehanna river. There is but little sidewalk paving; the material used is the North River blue-stone, well known through the eastern states as a paving material. For roofing, Peach Bottom slate from the slate district in York county and the adjoining district of Maryland, is most extensively used, and slate from Lehigh and Northampton counties is also used for the same purpose.

HARTFORD, CONNECTICUT.

As the celebrated quarries of brownstone in the Connecticut valley are of easy access to Hartford, this is the source from which the city draws most of its material for stone construction. A few buildings are constructed of marble from East Canaan, and granite from Westerly, Rhode Island, is employed to a considerable extent; and in one building granite from Glastonbury is used. There are three or four stone bridges across Park river, and a retaining-wall about 500 feet in length and 20 feet high along the same river, all of Portland brown sandstone. The state capitol is by far the most important of the marble structures, the others being simply the fronts of three blocks of buildings. Many blocks in the walls of the state-house are of crumbly material; flakes can be taken from them and rubbed to powder between the fingers. Limestone from Glens Falls, New York, is used in some of the inside stone-work of the state-house. In the United States custom-house and post-office granite from Saint George, Maine, was used. Light gray granite from Hallowell, Maine, was used in the construction of the monument to General Stedman. The streets are nearly all telfordized or macadamized with trap from quarries immediately southwest of Hartford. Sidewalks are largely paved with the North River blue-stone, and Bolton flagging-stone is used to some extent. The curbstones are of gneiss from quarries in Glastonbury, and of North River blue-stone.

HAVERHILL, MASSACHUSETTS.

The 15 buildings enumerated in Haverhill as having stone fronts are merely faced with Maine or New Hampshire granite for the first one or two lower stories. The one building constructed entirely of stone is a fine, large summer residence of an inferior quality of granite taken from the hill upon which the house stands. Foundations and underpinnings are of Cape Ann and Maine granite. There is a little stone street pavement of Cape Ann granite; the sidewalks are not paved with stone; curbs are of Cape Ann granite. The piers of the bridge across the Merrimack river are of Maine granite.

INDIANAPOLIS, INDIANA.

The stone most used in Indianapolis for the ordinary purposes of construction is the limestone from Indiana quarries. The sub-Carboniferous sandstone from near Portsmouth, Ohio, has been employed to a considerable extent. The Niagara limestones from Decatur and the neighboring counties may be used as ashlar in the construction of the walls without much dressing, causing a very considerable saving in mason work.

The Putnamville siliceous limestone lies in even courses from 4 inches to 2 feet in thickness. It is a silicate of lime, and resists the action of the elements admirably. Specimens exposed to extreme variations of temperature for forty-six years still retain the chisel marks as fresh as when first dressed; and a door-step of a college resisted the daily foot-wear for fifty years, with wear of less than one-sixteenth of an inch.

The oolitic limestone when soiled is quickly made bright and clean by the inexpensive process of brushing with steel or wire brushes. True, smooth, highly-colored stone tiles of the best quality are made here of this material. The piers and abutments of bridges and cell walls of jails are largely constructed of Niagara limestone from Decatur county, and Indiana oolitic limestone is used for the same purpose. The approaches to the tunnel under the railroads on Illinois street are built of Niagara limestone from Decatur county. Siliceous limestone of the sub-Carboniferous period, quarried at Putnamville, was used for foundations, curbs, and paving flags some years ago, and has shown valuable qualities for resisting the action of weather, time, and fire. Its use was discontinued by reason of a more easy access to other quarries. The new state-house, when completed, will contain 410,000 cubic feet of Niagara limestone and 520,000 cubic feet of oolitic limestone. The foundations and underpinnings are of the Niagara and Devonian limestones quarried in Decatur and Jennings counties, and the sub-Carboniferous from Owen county is used to a limited extent. Granite from Hurricane island, Maine, was employed to some extent in the stone-work of the capitol, and limestone from North Vernon, Jennings county, was used in the construction of the Indianapolis arsenal. In such streets as are paved the cobble-stones are used exclusively. Sidewalks are largely paved on the business streets with Niagara limestone from Decatur county, and artificial cement is used to a limited extent. Curbstones are of Decatur County limestone.

ITHACA, NEW YORK.

About the only material used for stone construction in Ithaca is the sandstone quarried in the immediate vicinity. Cornell University buildings are of stone from quarries near them; some in fact are within the grounds of the university. The trimmings are of Berea, Ohio, sandstone, Lockport limestone, and Medina sandstone, from Albion. The streets are not paved with stone; the sidewalks are largely paved with blue-stone from quarries near the city, with curbstones of the same material. The total amount of stone construction in Ithaca is small, only 15 buildings being reported as constructed of this material.

KEOKUK, IOWA.

The stone buildings thus far erected are among the largest of the city. The sandstone of Sonora, Illinois appears to be an excellent and durable building stone. Quarries of similar material are found on the Iowa side of the Mississippi, near the mouth of the Des Moines river, and also 5 or 6 miles above Keokuk, which have been operated only a short time. The abutments and piers of the railway bridge across the Mississippi are of arenaceous limestone from Sonora, Illinois. The stone used in the construction of the Des Moines Rapids canal is mainly from the same locality, though in part from temporary quarries of similar stone near Nashville, Iowa. The stones for foundations and underpinnings and the ruder purposes generally is limestone of sub-Carboniferous age quarried within the city limits; this material was used in the construction of the opera house (foundations) and the Keokuk Elevator Company's elevator. The streets are not paved, but some of them are macadamized with the local stone. A few of the sidewalks are paved with limestone from within the city limits.

KINGSTON, NEW YORK.

Of the stone buildings 34 are old dwelling-houses. These are generally 1½ stories high, and are built of surface rock, mostly limestone and graywacke; some few are stuccoed. As good examples of durability we may mention the old Senate house, built by Wessells & Tenbrook in 1676. The Hasbrouck and Bruyn houses are also very old. Hard surface stone used in these buildings have suffered scarcely any change such as weathering might induce. Of the more prominent buildings the Ulster County court-house was erected in 1818, and still looks bright and clean; the First Reformed church is the largest and most costly stone building in the city; it is built of a dark slate-colored grit or graywacke found in the neighborhood. The stone is thinly-bedded, but looks well. The Second Reformed Church building is of limestone; the material is much disfigured by the brown and dirt-colored stains due to the weathering of the clay seams of the mass. These stains reach in all directions through the stone. The superiority of the surface stones which appear in the old houses is evident at a glance. This limestone came from quarries near the town. Ohio sandstone has been employed in the trimmings of the new city hall; otherwise it has been scarcely used. The lower portions of the city are of brick. The aggregate length of paved streets, according to ex-Mayor James T. Lindsley, is less than one mile, and is confined to three streets. In front of two blocks the street is paved with granite blocks. For the most part foundations and underpinnings are from the blue-stone flag quarries at Kingston and Hurley, Ulster county. Some of this work, however, is of limestone, blue rock, and slate quarried within the city limits. The sidewalks are largely paved with stone, there being about 60 miles of flagging of blue-stone from quarries at Kingston and Hurley. Curbstones are of the same material. The large amount of stone sidewalk paving is due to the close proximity of the city to the most celebrated flag-quarry region in the country.

LA FAYETTE, INDIANA.

Stone used for building purposes in this city is almost exclusively limestone from the quarries of Decatur, Lawrence, and Monroe counties. It is used quite extensively for trimmings; its light color gives a fine architectural effect when used in connection with brick. The streets are not paved with stone, but the gutters are laid with bowlders gathered in the vicinity. A few of the sidewalks are paved with limestone from Greensburg, with curbs of the same material.

LANCASTER, PENNSYLVANIA.

A large percentage of the buildings in Lancaster have considerable stone in their composition, in the way of base courses, caps, sills, etc. Stone is used to bring the base of the houses to a level on the uneven ground, and brownstone from Hummelstown, from Ephrata, in Lancaster county, and from other points is used for the purposes mentioned. Connecticut brownstone is employed in a few instances. The Conewago granite, from the Kellar quarry near Collins station, is frequently used for base courses. It is apparently invulnerable to the attacks of the elements Amherst, Ohio, stone is used to some extent for base courses and trimmings.

Blue-stone from Meshoppen and other points in Wyoming county is being introduced for trimmings and is very highly esteemed. Montgomery County marble is well adapted to the construction of fronts, base courses, caps, and sills, for which purposes it is much employed in Lancaster.

In the cemeteries the New England marble is employed to a considerable extent, also Montgomery County marble; granite from the New England states and from Maryland, and some Scotch granite; Hummelstown and Connecticut brownstone to a small extent; and for lot inclosures, Conewago granite. Some houses in the city are trimmed with white marble from Sutherland Falls, Vermont. For foundations and underpinnings the material ordinarily employed is magnesian limestone, which is quarried in the vicinity, and the old houses in the city are built of the same material. The streets are largely paved with stone, the greater part, however, being simply macadamized with the limestone quarried in the vicinity. The public square and portions of other streets are paved with granite blocks from cape Ann, Massachusetts. The sidewalks are largely paved with stone, the material chiefly used being Wyoming blue-stone from near Meshoppen, Pennsylvania. The North River blue-stone is also used to some extent for sidewalk paving. Lehigh County slate is used for sidewalk paving. Bridge abutments, culverts, and embankment walls are constructed of Siluro-Cambrian limestone quarried in the vicinity. The soldiers' monument is built of white marble, the base being of New England granite. The Peach Bottom slate is highly esteemed for roofing, and the Lehigh County slate is also extensively used for the same purpose.

LAWRENCE, MASSACHUSETTS.

The only important stone buildings in Lawrence are two large Catholic churches, one Congregational church, and a large prison. Stone has thus far been used to a very limited extent as material for construction in Lawrence, except as underpinning. The factories and tenement houses are almost all of brick, while the suburban residences are of wood. The same may be said of Lowell and Haverhill. The material for foundations and underpinnings is granite from New Hampshire and from cape Ann and Westford, Massachusetts. The streets are largely paved with Cape Ann and Westford granite. A few of the sidewalks are paved with Cape Ann granite, and curbs are of the same material.

LEAVENWORTH, KANSAS.

The limestone chiefly used in this city is from a 14-foot bed occurring about 20 feet above the ordinary water-mark in the river; it is of Upper Carboniferous age, and corresponds to No. 112 of section U. C. M. (See p. 94 of Part II, *Missouri Geological Report of* 1872.) Four feet above is another limestone (No. 115, Missouri section) which has been extensively used at Leavenworth city for sidewalks and foundations, but it often shows many sand tracts. Other rocks used largely at this city are from Junction City and Cottonwood Falls, Kansas. Cottonwood limestone was used in the construction of the court-house and the Missouri Valley Life Insurance building. The columns of the custom-house are of red granite from Red Beach, Maine. The riverside quarries at Leavenworth have been abandoned on account of the cost of stripping; at the present quarries there are from 4 to 8 feet stripping of earth and shales. Foundations are all rubble-stone from local quarries and from Fort Scott. The streets are largely macadamized with the limestone from local quarries; the sidewalks, however, are chiefly paved with brick, and to a limited extent with limestone from near Fort Scott. The only building constructed entirely of stone in the city is built of the local limestones.

LOCKPORT, NEW YORK.

Within the limits of this city there are extensive quarries of both sandstone and limestone, and they furnish all the material used for stone construction. The sandstone quarries are located on a ledge of Medina sandstone age, and by far the larger number of stone buildings are constructed of this material. It is used to some extent also for sidewalk paving and street-paving blocks. The greater part of the material for stone construction in Buffalo is also brought from these quarries. The limestone quarries are located on a ledge of Niagara age and on the same horizon as that over which the cataract of Niagara flows.

The foundations and underpinnings are usually constructed of limestone from the local quarries, but the Medina sandstone is also used for these purposes to a limited extent. The streets are but little paved with stone, there being only a quarter of a mile of the Medina block pavement. There is but little stone sidewalk pavement, the material used for sidewalks being planks; in such sidewalks as are paved with stone the Medina sandstone is the material used. Five double locks on the Erie canal are of limestone from local quarries and from the canal excavation.

LOGANSPORT, INDIANA.

The limestone that has been used so extensively in this city for entire buildings is taken from the quarries 3 miles below the city, on the Wabash river. The color of the stone is gray and quite uniform, and some of the finest structures in the city have been built of it. Oolitic limestone from southern Indiana is used extensively for trimmings; that from Stinesville is perhaps used most extensively at present for this purpose. The Amherst and Berea sandstones of northern Ohio were used to a limited extent for the same purposes. The Buena Vista stone of sub-Carboniferous age, quarried in southern Ohio, has been used for ashlar. The limestone quarried in the vicinity of the city furnishes material for foundations and underpinnings. The sidewalks are largely paved with limestone from southern Indiana and sandstone from Berea, Ohio; the curbs are of native limestone. The material used for bridge abutments and piers is sandstone from Williamsport and Attica, and limestone from Logansport, and the oolitic limestone from the southern part of the state.

LOUISVILLE, KENTUCKY.

The rock exposed in the immediate vicinity of Louisville is the sub-Carboniferous limestone, which is of the same age as the Indiana oolitic limestones; hence the city has a good local supply of building stone which answers well for all ordinary purposes of construction, and extensive use is made of this supply. For the finer purposes of construction the Indiana oolitic limestones are extensively used, and as the city is situated on the Ohio river it has ready access to the Buena Vista and other sandstone quarries near Portsmouth, Ohio, and much of this stone is used. The Bowling Green, Kentucky, limestone has also been very extensively employed. This limestone, like that of the local quarries, is of sub-Carboniferous age. The Louisville limestone, however, although taking good rank as far as durability is concerned, is hard and sometimes flinty, and is much more expensive to dress than the sub-Carboniferous limestones usually are where exposed in other places, and this fact confines its use to the ruder purposes. The streets of Louisville are largely paved with limestone from the local quarries, and a few of the sidewalks are paved with Bowling Green limestone, with curbs of the same material. The abutments of the railroad bridge over the Ohio were built of Utica, Indiana, stone. The wharf is constructed of cobble-stones; the locks and walls of the Louisville canal are built of the local limestone; it was also used in the construction of the custom-house and the city work-house. Limestone of sub-Carboniferous age, quarried near West Salem, Washington county, Indiana, was used in the construction of the Galt house and the city hall. Sandstone from the vicinity of Cannelton, Perry county, Indiana, was used in the construction of the water-works and locks.

LOWELL, MASSACHUSETTS.

There is quite a number of small factories, barns, and dwelling-houses in Lowell constructed of the blue mortar-stone taken from quarries in the immediate vicinity of the city. This material is considered more durable than the very micaceous granite; the disadvantage in using it for building purposes lies in the great difficulty of quarrying blocks of given dimensions. The Concord granite is preferred, owing to the small amount of iron in its composition. There is a very micaceous gneiss quarried in the immediate vicinity somewhat used for building purposes, but it is liable to rust on account of the quantity of iron in its composition, and it also has a tendency to crumble when subjected to the action of intense heat.

The following are the different building stones most used in the better class of stone construction in this city: Granite from Concord, New Hampshire; mortar-stone, quarried in the immediate vicinity; marble from Rutland, Vermont; granite from Westford, Massachusetts; granite quarried in the vicinity of the city; foundations and underpinnings are of granite from Concord, New Hampshire, Westford granite, and the various stones quarried in the vicinity of Lowell. A very large bridge is being constructed across the Lowell railroad of stone quarried in Westford, Massachusetts; the Episcopal church and Saint Patrick's church in Lowell are built of stone taken from Livingston quarry, within the city limits. The streets are largely paved with Westford and Concord granites. There is some stone sidewalk paving of Westford granite, with curbstones of the same material.

MANCHESTER, NEW HAMPSHIRE.

A very few stone buildings in Manchester are constructed of granite quarried in the immediate vicinity. The materials usually employed in construction here are brick and wood. In the construction of the Amoskeag dam 50,000 cubic yards of granite were used. The walls of a canal a mile in length and the piers of six bridges across the Merrimack river are built of granite from Bedford. These quarries are not now operated. The soldiers' monument was built of Concord granite. Foundations and underpinnings are of granite and gneiss quarried in the vicinity, from the lake gneiss formation, and the granite occurring in masses in the gneiss. There is a mile of street pavement of Hookset granite in blocks a foot square. There is very little stone sidewalk pavement of gneiss from the immediate vicinity. The sidewalk in front of the Merchants' exchange is paved with Potsdam sandstone. The curbs are of native granite and gneiss.

MIDDLETOWN, CONNECTICUT.

On account of the close proximity of the Portland quarries, which are on the opposite side of the river from Middletown, almost all the stone used in this city is obtained from them. There are very few stone buildings, however, by far the largest use of the stone being for foundations and underpinnings. The sidewalks for the most part are from 3 to 4 feet apart, and they as well as the curbstones are of a kind of gneiss from the Haddam and Maromas quarries; this material splits with rather a rough surface. In the principal business streets large flags of North River blue-stone are considerably used, and in many spots slabs of sandstone occur, which, however, do not stand well under foot-wear. In buildings the dressed sandstone scales off badly when set on edge; when laid as in the natural bed this defect is not apparent. A large railroad bridge across the Connecticut river, at Middletown, has its piers and abutments built of a granitic rock taken from the quarry, worked only for this purpose, a short distance up the river on the east side. The streets are not paved.

MEMPHIS, TENNESSEE.

There are but two buildings in Memphis constructed entirely of stone, the custom-house and the post-office. The first is built of marble from Knoxville, Tennessee; the second, of granite from near Iron Mountain, Iron county, Missouri. Eight buildings are enumerated as having stone fronts, one of which is built of sandstone from Alabama, six of limestone from Alabama and Kentucky, and one of freestone from near Portsmouth, Ohio. Foundations and underpinnings are chiefly of brick, but there are some of limestone from Alabama and Kentucky. Limestone is used in wharf paving and breakwater of riprap walls, of which there is now paved an area of 2,700 by 250 feet—equal to about 75,000 square yards. The arched culvert bridges and abutments are constructed chiefly of brick, and one arch culvert is built of limestone from Alabama.

The sewer system, built in 1880-'81, is constructed for the most part of vitrified clay pipe from 6 to 15 inches in diameter, the main outlet being of cast-iron and brick 20 inches in diameter. Granite and sandstone quarried in the vicinity of Little Rock, Arkansas, are used for building purposes. Sandstone and limestone from Arkansas and Missouri, and limestone from Illinois, Kentucky, Tennessee, and Alabama are all employed in construction here. Most of the quarries are accessible by water and by railroad, and their distance from Memphis ranges from 200 to 250 miles. The buildings within the fire limits are chiefly of brick, with some iron. The site of this city furnishes good foundations for buildings of every description. About 15 miles of streets and alleys are paved with stone; the material chiefly used for this purpose is limestone from Illinois, Kentucky, Alabama, and Tennessee, and granite and sandstone from the vicinity of Little Rock, Arkansas. Sidewalks are but little paved with stone, and the material chiefly used is limestone and sandstone from Alabama, with curbs of the same material.

MINNEAPOLIS, MINNESOTA.

The following list includes the Minneapolis buildings in which stone enters as an important constituent:

Brick buildings with limestone trimmings from the Trenton formation	179
With Berea, Ohio, sandstone trimmings	60
With Frontenac dolomite trimmings	13
With Joliet or Lemont, Illinois, limestone trimmings	3
With Fond du Lac limestone trimmings	48
With Kasota stone trimmings	11
With Minnesota granite	6
Buildings of stone or brick partly trimmed with granite	21
Buildings of brick with Vermont marble trimmings	1

There are perhaps 20 other brick buildings which have artificial-stone trimmings and 20 which are trimmed with brick of another color, or are painted so as to simulate trimmings of stone, of which no account has been made. This enumeration includes all stone structures; many of them are very large, such as the Washburn A, B, and C flouring-mills, the Pillsbury A flouring-mill, the university of Minnesota, and McAllister college. The list also embraces the Universalist church, the Irish and French Catholic churches, and the Plymouth Congregational church. The Trenton limestone supplied by the quarries of Minneapolis, formerly much used, is being abandoned as material for first-class structures, and in its place are put stones from towns in Minnesota, as well as stone from other states. The argillaceous character of the Trenton strata, and the thin but often lenticular banding of the sedimentary structure, cause the slabs and blocks of this limestone to disintegrate in sheets parallel with the bedding, and finally to wholly decay; when it can be kept from exposure to the weather it answers for walls better; hence it is still employed in foundations and in basements that rise a few feet above the ground. It is necessary even in such cases that it be well bedded in mortar and protected by a good water-table.

The use of stone as a material of construction at Minneapolis has been greatly influenced by an abundant supply of two other articles, as follows, viz: Cream-colored brick and pine lumber. It is becoming very fashionable to use red pressed brick from Saint Louis or Philadelphia or Baltimore for the fronts of first-class structures, trimming them with sandstone from Ohio, or limestone from Stone City, Iowa, or Joliet, Illinois. The piers of the suspension bridge over the Mississippi river and its anchorages are of the Trenton limestone, from Minneapolis, trimmed with Minnesota granite. The piers of the two other highway bridges and of the railroad bridge across the Mississippi are of the same material. The arched bridge across the east channel of the Mississippi is of the same, but has Red Wing rock in the angles. In several residences and business blocks artificial stone is used for window-caps or other trimmings, but with Trenton limestone sills, basements, and water-tables. Lemont, Illinois, limestone is seen in a few buildings which have other stones for trimmings. Steps and water-tables of Kasota stone are frequently put in buildings that have other stones for trimmings. In the Westminster Presbyterian church brown sandstone from Fond du Lac, Saint Louis county, Minnesota, is used.

The streets are but little paved, and the material used is a water-worn cobble-stone from the drift. Sidewalks are but very little paved with stone, owing to the abundance of pine lumber and its cheapness. In such sidewalks as are paved with stone, Niagara limestone, from Joliet, Illinois, Trenton limestone, from Minneapolis, and calciferous sand-rock, from Kasota, Minnesota, are used. The curbstones are of Minneapolis Trenton limestone.

MOBILE, ALABAMA.

The only stone building in Mobile—the custom-house—is built of Quincy, Massachusetts, granite. The streets in the business portion of the city are partially paved and macadamized with stone ballast from vessels and the Alabama sandstone. The sidewalks are paved with Alabama sandstone and brick; sandstone from Colbert county, Alabama, is used to a limited extent for this purpose; also the North River blue-stone and stone brought from Yorkshire, England.

NASHVILLE, TENNESSEE.

The stone chiefly used for fronts in the city of Nashville is oolitic limestone from Bowling Green, Kentucky. It is a good material, but contains petroleum which is drawn to the surface by the heat of the sun, and dust settling on it turns it a dark color. It is not uniform in color, but has yellow streaks. The United States custom-house is built of this material. The limestones of the Nashville formation are found in three principal layers; the quality and appearance vary in the same layer. The quarry from which the stone for the capitol is built was abandoned for the reason that the material is very fossiliferous and the fossils (*orthoceras*) weather out. Some of the courses are liable to decomposition when exposed to the weather. The stone is very distinctly laminated; it is not a pure limestone, but has considerable silica in its composition. It is most durable when laid in walls, as in the natural bed. The use of stone for construction is very general in Nashville, nearly every building of any prominence having considerable stone in its composition, and all new stores have fronts either entirely or partially of stone.

Stone basement stories, with the upper portions of brick with stone trimmings, is a very common form of construction. The usual custom is to use the Nashville limestone below ground, and above ground a Nashville limestone, carefully selected, with Bowling Green superstructure and trimmings. There is a desire at present to substitute some other stone for the Bowling Green for the purposes of construction in which that material is now used. The capitol building is constructed entirely of stone; the pillars of the halls of the legislature and ornamental work, railings, etc., are of Hawkins and Knox County marbles. The stone used in the walls of the building is from the next to the lowest course of the Nashville formation.

The Normal College buildings are of local stone. The basements of the Vanderbilt and the Fisk universities are of Nashville stone; the copings and trimmings are of Bowling Green limestone, and their foundations are of selected Nashville limestone. The new United States custom-house is constructed entirely of Bowling Green limestone.

The ruling taste here at present seems to favor white building stone; two churches built many years ago are of Nashville limestone, and stuccoed to represent brownstone; another church is built of rough Nashville limestone of a bluish color. No granite is used in this city for building purposes. The stone used in cemeteries is chiefly Italian marble; however, the Knoxville marble is rapidly coming into use as a material for cemetery work, as it seems but little affected by exposure. There are some monuments of Quincy granite. There is a growing sentiment in favor of paving streets with stone, as the limestone now used in macadamizing powders rapidly, making an offensive dust in summer and mud in winter. Limestone of the Nashville, Cincinnati, or Hudson River formation is used for every character of work except fronts; it is frequently quarried in getting out foundations in such large quantities that it is given away. The walls of yards around the city are constructed of it; some with rough and some with dressed surfaces. Walls of buildings on the river and piers of the bridges are built of it; occasionally in handsome fences around large inclosures of fine residences, the corner and gate posts are constructed of Bowling Green limestone, and the wall around the capitol grounds is constructed of this material.

NEW ALBANY, INDIANA.

The percentage of stone construction in New Albany is small, the material chiefly used being brick and wood, with brick foundations under the frame buildings; but so far as stone has been used here it has shown itself to be substantial and durable, the materials being of superior quality. There are no local circumstances unfavorable to stone construction, and the stones used are limestone from Salem, Indiana, and, to a limited extent, sandstone from the vicinity. The West Salem limestone was employed in the construction of the court-house. For foundations and underpinnings and for other ordinary purposes limestone from the vicinity is employed. The streets are largely paved with cobble-stone and limestone found in the neighborhood. But few of the sidewalks are paved; the stone used is limestone from New Albany and Vernon; curbs are of the same material.

NEWARK, NEW JERSEY.

Nearly all of the prominent stone structures in Newark are built of the Newark sandstone, but the elegant United States custom-house and post-office building and the large and massive county court-house are of Little Falls, New Jersey, sandstone. Nearly all of these buildings are large and costly structures, and the beauty and durability of the stone used are exhibited to good advantage in many of them. Some of the larger edifices are especially deserving of notice. The extensive use of stone in Newark is to be explained from the fact that there are five quarries of sandstone within the city limits; three of them are now worked, employing from 100 to 200 men, and their product is valued at $150,000 to $200,000 annually. There are many large and expensive private dwellings entirely of stone, and many with only stone fronts. Three bridges over Second river and 24 over the Morris canal are of Newark sandstone, and 2½ miles of the Morris canal is walled with the same material. Six railroad bridges beside wagon bridges over the Passaic river have piers and abutments of Newark sandstone. One large trunk sewer is built of the same material, as are also many walls about lawns and cemeteries. The total length of improved and graded streets is 176.8 miles; of streets paved with cobble-stones, 28.76 miles; paved with granite and trap blocks, 4.89 miles; Telford or macadamized streets, 12.21 miles; total of stone pavement, 45.86 miles. The total length of streets graded and improved but not paved is 130.94 miles. The narrow streets have sidewalks 4 feet in width; other streets or sidewalks 5 and 6 feet in width. The material used in paving these sidewalks is the North River blue-stone. No brick is allowed to be used for this purpose.

NEW BEDFORD, MASSACHUSETTS.

Of the 22 buildings in New Bedford constructed entirely of stone, 19 are of granite quarried in the vicinity, 2 of Rockport granite, and 1 of Quincy granite. At the entrance to New Bedford harbor is a large fort, while a smaller one guards the Fairhaven side opposite. They are both constructed of Cape Ann granite. Foundations and underpinnings are of granite from the vicinity of the city and from Rockport. The streets are largely paved with cobble-stone from the vicinity; North River flagging stone is exclusively used in the sidewalks; curbs are of granite from Rockport, in the vicinity.

NEW BRUNSWICK, NEW JERSEY.

The comparative cheapness of brick has interfered with the use of stone both for building purposes and for sidewalks. The red sandstone quarried in the city was formerly used to a limited extent in cellar walls and foundations, but the quarries are now discontinued. This stone has not proved to be durable, crumbling slowly when exposed to severe frost. It is adapted to use in inside filling of walls only, and the greater durability and cheapness of brick have enabled the builders to dispense with it entirely. North River blue-stone has a large use in building for steps, sills, caps, and other trimmings, especially in factories and storehouses. The college buildings afford examples of good and poor stones and of materials improperly laid; the old college building rear wall contains some soft argillaceous sandstone, which tends to split, although laid as in its bed in the quarry. In the west wall there are many stones which show clay-holes. The Geological Hall building has a few examples of stone from Connecticut quarries, which are laid with the lines of bedding in a vertical position, and they are beginning to chip or scale off, although the building has been constructed only ten years. The superiority of the Newark stone is apparent in comparing the general effect, and in the closer examination of the single blocks as they occur in these two structures—the Geological hall and the Kirkpatrick chapel. The Newark stone does not show the lines of bedding so plainly; it is more homogeneous in its composition, and its materials are not so much arranged on lines or in parallel planes as they are in the Connecticut stone which is ordinarily put on the market here. The durability of the Newark stone is displayed in the old college building, erected in 1809; the corners and edges are still sharp and well defined. The following are some of the principal structures of stone, with the materials from which they are constructed: Rutgers college (main building): Newark sandstone; Geological hall: Connecticut sandstone; Kirkpatrick chapel: New Jersey sandstone; First Reformed (Dutch) church: gneiss from New York; the Protestant Episcopal church and Saint Peter's Roman Catholic church: New Jersey sandstone; residence of John Carpenter, residence of Sisters of Charity, and Bartel's private residence: Connecticut sandstone; piers of the wagon bridge over the Raritan river at Albany street: Connecticut brownstone; Pennsylvania Railroad company's bridge (8 piers and abutments): from Stanton, Hunterdon county, New Jersey, and gneiss from Conshohocken, Pennsylvania; the locks of the Delaware and Raritan canal: Trenton freestone, Greensburg quarries. These locks are 200 feet long, or 250 feet including the wing walls; one is a double lock.

The following is a statement of the amount and kind of stone street pavement in New Brunswick:

	Miles.
Granite block, Westerly, Rhode Island, granite	$\frac{8}{10}$
Cobble-stone	$2\frac{7}{10}$
Telford macadamized road of trap-rock	$1\frac{2}{10}$
Total stone street pavement	$4\frac{7}{10}$
Nicholson wood pavement	1
The sidewalk of North River blue-stone laid by a street commission	8

Curbstones, mainly of North River blue-stone.

NEWBURGH, NEW YORK.

The nearest available source of building stone for Newburgh is the limestone quarries within 2 miles of the city. The material obtained there is used for foundations, underpinnings, and other work of that class; Connecticut brownstone and Haverstraw stone are also used for foundations. Of the stone buildings in the city the oldest is a story-and-a-half dwelling-house constructed of surface stones from the vicinity, and occupied by Washington as headquarters during the encampment at Newburgh. Saint George's Protestant Episcopal church is an old building of blue limestone obtained west of the city. Saint Patrick's Roman Catholic church is a new and large structure of blue limestone, a stone which is much disfigured by what seem to be argillaceous seams traversing irregularly the calcareous matrix. The darker shades of color in these clay seams give the whole a rather dingy appearance. The stone was obtained in part from the quarries west of the city and in part from Kingston, Ulster county; the latter stone has suffered more by exposure. It resembles in this respect the stone in the Second Reformed church in Kingston, and both show how much care is needed in the selection of limestone for fine work in prominent buildings. The First Presbyterian church, a very large, costly, and ornate edifice, constructed of graywacke and flagging stone quarried near Kingston, is trimmed with Ohio sandstone; the stone has retained its dark color, and does not show any signs of disintegration by weathering. The other buildings are small and private excepting the stuccoed Reformed Church edifice. Formerly brownstone from Haverstraw and Nyack was much used for door-steps and window-sills, but of late Connecticut brownstone and Ohio sandstone have been used almost exclusively, excepting the blue limestone from the neighboring quarries, which is used for rough work and cellar walls. Brick here takes the place of stone to a very great extent in both foundations and superstructures. The sidewalks are all laid with blue flagging stone; in the older streets they are from 10 to 12 feet wide, and the stones are of irregular size and generally small. The more recently laid walks are 6 feet wide and are a single line of stone. The cost of paving some of the fine foot-sidewalks has been $1 per linear foot. The length of sidewalks is unknown, but amounts to many miles. The cobble-stone pavements measure 10,000 feet; the average width may be 40 feet. In the front of a single block in Water street the pavement is Belgian block. The sidewalks are all paved with blue-stone from Ulster county, with curbstones of the same.

NEWBURYPORT, MASSACHUSETTS.

There are but two buildings in Newburyport constructed entirely of stone, and the material used is Cape Ann granite. Foundations and underpinnings are usually of the same material, but Maine granite is used for the same purpose to a limited extent. With the exception of a very few public buildings, stone is used only in the underpinnings and foundations. It is observed that the Cape Ann granite, the stone chiefly used here, is of a light color when quarried and grows dark with exposure, but does not decay. The Peabody granite becomes of a yellowish-brown color after long exposure to the weather. A ledge has been recently opened about 2 miles above Newburyport, on the Merrimack, for the purpose of extracting stone for the construction of a jetty across the sand-bar at the mouth of the river. The material quarried is called by the workmen common stone or trap. Sandstone from Springfield has been used to a very limited extent for trimmings. The little stone street pavement in this city is of Maine granite; the sidewalks are not paved at all, and the curbs are of Maine and Cape Ann granites.

NEW HAVEN, CONNECTICUT.

In New Haven, as in most of the other cities of Connecticut, the brown sandstone from the Connecticut valley furnishes the chief part of the material for stone construction. The other materials used are granite from Long Island shore, gneiss from Ansonia, trap from the East and West rocks, and sandstone from East Haven and Ohio. The breakwater in New Haven harbor has been built partly of coarse granite from the Branford quarries; considerable of East Haven sandstone has been used in bridge approaches, abutments, and piers; some 2 or 2½ miles in length of the side walls of the old canal, in which the railroads cross the city, are built entirely of East Haven sandstone and trap, about equal quantities of each being used, and requiring between 8,000 and 10,000 cubic yards of stone. Some of the Ohio sandstone used in New Haven, notably in one building, contains iron pyrites, which oxidizes on exposure to the weather, giving the stone a soiled appearance. The only defect noticeable in the Portland sandstone is that it scales off if laid otherwise than as in the quarry bed. The basement story of the old state-house is of limestone, which has crumbled very badly, and the material has not been used in any other structures. Brown sandstone from Newark, Essex county, New Jersey, was employed to some extent in some of the Yale College buildings. For foundations and underpinnings trap and East Haven sandstone are the materials used. Most of the streets are telfordized with trap from the East and West rocks. The sidewalks are but little paved with stone; the material used is North River blue-stone, with, in a few instances, mica-schist from Bolton, Connecticut. The curbstones are chiefly North River blue-stone, but granite has been used to a limited extent for the same purpose.

NEW LONDON, CONNECTICUT.

New London is built on granite rocks. Stone for cellars, foundations, and underpinnings is quarried almost anywhere within the city limits. The whole of the walls of the large Catholic church, and of another large granite church building, are built of stone quarried on the sites of buildings, the stone for trimmings coming from one of the quarries at Groton. The surface stone in New London, and also in neighboring quarries, is striped in appearance, not uniform, some pieces being more variegated than others. The color varies also considerably, but is always the same shade of gray.

Only 1 per cent. of the buildings is of stone, which is due simply to the question of first cost. Forts Trumbull and Griswold are built of granite from Groton or Millstone point.

The streets are but little paved with stone, and the material used for this purpose is the rectangular blocks of Groton granite. The sidewalks of the principal streets are paved with North River blue-stone and some Groton granite. The curbstones are Groton granite.

NEW ORLEANS, LOUISIANA.

The percentage of stone construction in New Orleans is very small. A large proportion of the houses are built of wood. The streets were all paved before the late war. There is one building, situated in the southern part of the city, entirely of rough-hewn stone from Sainte Genevieve. The custom-house is nearly all built of Quincy granite. Another building, on the corner of Royal and Canal streets, is built mostly of granite. A monument to General Robert E. Lee is now in course of construction; the base is of Georgia granite; the foundation on piles, and transverse timbers in concrete; the shaft is of Knoxville, Tennessee, gray marble; and this latter material is very highly esteemed here. The few stone fronts are of Westchester, New York, snowflake marble and Sainte Genevieve limestone; a good deal of the latter material was formerly used. The chief material now used for fronts is iron; the amount of stone used for purposes of construction in New Orleans since the war is very inconsiderable. The Westchester limestone was considerably employed before the war, and also the Sainte Genevieve limestone, for tombs and fronts; at present a great deal of brick is used and stuccoed. The use of artificial stone in buildings and pavements is increasing. The stone used for ornamental purposes is usually Italian marble, with some Vermont marble. Some Quincy granite was formerly brought to the city and used for curbstones, flagging, and purposes of that nature; as it was usually brought as ballast in ships, the expense attending its use was inconsiderable. The water is so near the surface in New Orleans that it is impossible to have stone foundations; the customary way is to lay thick planks transversely and to place the brick immediately on them; they are sometimes creosoted, but usually last well below water. This system of foundations is considered better and less expensive than driving piles. The sewers consist of stone-faced gutters, through which the water passes every night from the river to the lake; 221,760 feet, or 42 miles, of blue-flint banquettes; 42,240 feet, or 8 miles, slate-stone banquettes; 15,840 feet, or 3 miles, Schillinger artificial stone; in all, 279,840 feet, or 53 miles, of stone banquettes.

The following is a statement of the number of miles of stone street pavement: 113,520 feet, or 21½ miles, of Quincy granite square-block pavement; 15,840 feet, or 3 miles, of other square-block pavement; in all, 129,360 feet, or 24½ miles.

The greater part of the street pavement is of cobble-stone, brought as ballast; 42 miles of sidewalk pavement are of North River blue-stone; 7 miles of slate.

NEWPORT, RHODE ISLAND.

The materials most used in the better class of stone construction in Newport are Connecticut brownstone and Newport granite. Fort Adams is built of Westerly and Fall River granite, together with some of the local slate. The macadamized Telford road is much used in Newport and the stone employed is the local granite. The foundations and underpinnings are built of Newport granite; the streets are but little paved with stone, and the material used is cobble-stones from Block island and from Nova Scotia. Asphalt manufactured at Providence is much used for street paving. The sidewalks in the business portions of the city are paved with Hudson River flags and asphalt. The curbstones are Hudson River blue-stone and Fall River granite.

NEWTON, MASSACHUSETTS.

The city of Newton includes Newton, Newton Center, Newton Upper Falls, Newton Lower Falls, Newton Valley, West Newton, and Auburndale. Of the stone buildings enumerated three are churches, three private residences, and one mill; one church built of Ohio sandstone was rebuilt from the old Chauncey Street church, Boston. The material for foundations and underpinnings is granite obtained from the bowlders found in the vicinity, with some Westford granite. The streets are not paved with stone; a very few of the sidewalks are paved with Westford granite, with curbs of the same material.

NEW YORK CITY AND ENVIRONS.

By Dr. ALEXIS A. JULIEN.

City.	County.	State.	Population.
New York city	New York	New York	1,206,590
Brooklyn, including Williamsburg and Long Island City	Kings	do	583,806
Castleton, etc. (Staten island)	Richmond	do	40,000
Jersey City, including Hudson City, Bergen City, Bayonne, and Greenville	Hudson	New Jersey	120,728
Hoboken, including West Hoboken, town of Union, and Weehawken	Hudson	do	30,999

This district embraces the principal suburbs of the great metropolis, although the crowded trains and boats which constantly leave all the railroad stations and docks, especially in the morning and evening, point to the outer ring of suburban cities and villages, in the Hudson River counties, on Long island and in New Jersey, whose construction and enlargement chiefly depend for supply of material upon the stone- and brick-yards of New York island.

The statistics embodied have been obtained from many sources, partly by direct counting of houses from street to street, etc., partly by the issue of circulars, and partly by personal application to stone dealers, stone-yards, etc.

The courteous consideration with which, in general, my inquiries have been received calls for my special acknowledgment and thanks to a large number of persons, of whom I ought perhaps specially to name the following: James Wells, insurance agent, 167 Broadway; William E. Midgley, assistant secretary New York and Boston Insurance Company, Howard building, 176 Broadway; J. H. Langford & Co., insurance agents, 10 Pine street; the New York Board of Fire Underwriters; F. Collingwood, engineer in charge of New York approach, New York and Brooklyn bridge; David Acker, deputy commissioner of department of buildings, Brooklyn; James A. Baker, clerk of village of Edgewater, Staten island; J. R. Wardlaw, clerk, etc., Edgewater, Staten island; Miller & Simonson, West New Brighton, Staten island; John H. Cordes, real estate agent, 163 Harrison avenue, Brooklyn; Gill & Baird, John Vesey, Andrew Mills, New England Granite Works, Gillie & Walker, the Bay of Fundy Quarry Company, D. Hotaling, Brander, Boyd & Hutcheon, and Browne, McAllister & Co.

In compliance with my request for specimens of stone, trimmed in accordance with the directions of the building-stone department of the census, many such specimens have been sent to the National Museum at Washington, sometimes with a duplicate intended for the American Museum of Natural History in this city. For these we are specially indebted to the following firms, so far as I have been notified: New England Granite Works, James Morgan & Co., the Bay of Fundy Quarrying Company, and Browne, McAllister & Co.

My report is naturally divided into three parts:

I. The buildings of New York and adjacent cities, etc., their numbers, and common materials.

II. The building stones of these cities, described in some detail, their localities, and examples of edifices constructed of each variety. Public buildings and improvements, with description of materials employed; materials of pavements and roofs; market prices of building stones.

III. Durability of building stones in this district; agents of destruction; elements of strength and durability; methods of trial; means of protection and preservation. (This will form the subject of another chapter, and will be found on pages 364 to 393.

With a field so broad, and with imperfect sources of information, my report can hardly be free from errors and deficiencies; but every effort has been made to avoid them so far as time and opportunity have permitted.

I.—THE BUILDINGS OF NEW YORK AND ADJACENT CITIES; THEIR NUMBERS AND COMMON MATERIALS.

It may be as well to state here that the published maps used by the insurance companies, in which the position and approximately the material of each building are supposed to be laid down, are far from accurate. Not only have the additions and removals of buildings been in some cases imperfectly represented, but on many maps little attempt seems to have been made to exhibit the nature of the material (*i. e.*, of the faces) of the buildings, whether brick or stone. It has been necessary to correct these points, for the purpose of the census, by personal examination of many districts.

The building statistics have been arranged (Table I) to indicate the exact materials of construction in each city, and in an approximate way, the number of buildings erected for special purposes and the selection of materials employed for them. These figures are almost entirely derived from personal inspection and actual counting of the buildings in the several districts. The city of New York comprises an area of 24,893 acres, which may be divided into three great districts, viz:

1. District of wholesale business houses, comprising the entire area of the island south of the line of Canal and Rutgers streets, from the North (Hudson) river to the East river; also the buildings along the line of Broadway up to Fourteenth street.

2. District of small stores and tenements, comprising the area north of the line of Canal and Rutgers streets, and east of the Bowery and Third avenue, up to the Harlem river; also, the entire Twenty-third and Twenty-fourth wards, up to the northern boundary of the city at the Yonkers line.

3. District of large stores and residences, comprising the area north of the line of Canal street, and west of the Bowery and Third avenue, up to the Harlem river at Spuyten Duyvil.

In the city of Brooklyn the lines are much less sharply and easily drawn; however, three districts may be distinguished:

1. District of warehouses, tenements, etc., comprising wards Nos. 2, 4, 5, and 12, and portions of Nos. 1 and 6; *i. e.*, the area bounded by the following line: East river, Hudson avenue to Willoughby avenue; Willoughby avenue to Fulton street; Fulton street to Furman street; Furman street to Atlantic avenue; Atlantic avenue to Hicks street; Hicks street to Cole street; Cole street to Clinton street; Clinton street to Rush street; Rush street to Gowanus bay; along shore of Gowanus bay; Buttermilk channel to Fulton street, East river.

2. District of residences and small stores, comprising the rest of the city, including Williamsburg.

3. District of small residences, comprising the suburb called Long Island City (population 17,117).

The statistics of Jersey City, Hudson county, New Jersey, were gathered in two divisions:

1. Jersey City, including Hudson City and Bergen City, La Fayette, and Communipaw.
2. Bayonne and Greenville.

The statistics of Hoboken, Hudson county, New Jersey, have been gathered under three heads:

1. Hoboken proper.
2. West Hoboken and town of Union.
3. Weehawken.

It has been thought desirable to make this subdivision of the statistics, in reference to these small and, in many cases, at present unimportant places, in view of the enormous growth by which they are liable to be affected in the vicinity of the great metropolis.

Finally, as a matter of general interest, and for the purpose of proper comparison with the other great cities of the world, all the statistics above mentioned have been summed up under the head of New York city and its suburbs.

It may be here noted that a general improvement in the character of the building materials employed is constantly in progress in all these cities, so that the number and proportion of stone buildings have in many cities been sensibly increased since the year 1880; to which date all the statistics in this report, so far as possible, have been made to conform.

A consideration of this table presents the following chief points of interest:

NEW YORK.

Stone enters into the construction, chiefly as fronts, of 11.6 per cent. of all the buildings of the city. Of the entire number of stone buildings, 89.4 per cent. consist of sandstone, and the several varieties of stone occur in the following proportion:

	Per cent.
Brown sandstone	78.6
Nova Scotia and Ohio sandstones	10.6
Marble	7.9
Granite	1.8
Gneiss	0.9
Foreign sandstone	0.1
Blue-stone and limestone	0.1

The materials of general construction in the city occur in the following proportion to the total number of buildings:

	Per cent.
Brick, terra-cotta, stucco, etc.	63.2
Frame, *i. e.*, wooden in part, filled in with brick	24.3
Stone	11.6
Iron	0.9

In the business district brick predominates (77 per cent.), and most of the marble, and somewhat less than half of the iron buildings occur. The remaining iron buildings are mostly found on the large business streets in the other districts.

The tenement district still consists of frame buildings to the extent of 31.7 per cent., nearly half of the entire number in the city. Stone constitutes only 5.5 per cent. of the fronts, though largely employed in the trimmings; and iron and marble are rare. Brick somewhat predominates (62.6 per cent.).

In the residence district brick also predominates (60.9 per cent.), but stone is largely used (14.6 per cent.), including 70 per cent. of all the stone buildings of the city. However, the district comprises, in its unsettled and partially-built areas, the greater part (55 per cent.) of the wooden buildings of the city. Here most of the stucco buildings occur, but their number (166) is very small, particularly in comparison with their abundance in the metropolis of England.

BROOKLYN.

Stone is here employed in a proportion (9 per cent.) a little less than that of New York (11.6 per cent.), and in much less variety, the Connecticut brownstone predominating (95.7 per cent.) in the entire number of stone buildings. This stone is employed altogether for the residences throughout the city. Very few iron buildings occur, but there are over three times as many stucco fronts as there are in New York. The frame buildings constitute half of the entire number (50.9 per cent.), especially predominating in the outskirts, as in Long Island City (80.5 per cent).

STATEN ISLAND.

Stone enters in a very small proportion into the construction of fronts of buildings on this island (5 per cent.), though it is commonly employed for trimmings, walls of inclosures, and other masonry. Brick is largely employed, especially in the towns and villages (9.5 per cent.), but the common material is wood (90 per cent).

JERSEY CITY.

In the suburbs of this city the proportions of stone and brick employed are very similar to those on Staten island. But in Jersey City proper the predominance of frame houses is much less, the buildings amounting to 1.9 per cent., and the brick to 25.9 per cent. The selection of the dark trap-stone from the heights behind the main city for the construction of many fronts or of entire buildings is a peculiar local feature.

HOBOKEN.

The materials of construction in the suburbs of this city, upon the top of the trap ridge, etc., are similar in proportion to those on Staten island and in the suburbs of Jersey City. In Hoboken proper the proportion of stone buildings is large (3.9 per cent.), and the brick buildings constitute over half (52.7 per cent.) of the entire number.

THE METROPOLIS.

Finally, in regard to the whole district, it will be seen from the table that stone enters into the construction of the fronts of 9.1 per cent. of all the buildings of this city, though it is employed otherwise to an enormous extent for foundations, trimmings, walls, copings, stoops, etc. I have not been able to obtain sufficient data for the estimation of the entire import of stone into the city; but some idea of the vast expenditure involved in the construction of our buildings may be derived from the reports of the superintendents of the building departments of New York and Brooklyn, and have suggested the following by a writer in the *Am. Arch. and Building News*, 1878, Vol. III, page 71:

> It would seem from it that the average cost of a new building in New York city has been $13,741, and that with some additions of work, not formerly reported to the superintendent, the aggregate sum spent in adding to the plant and material on Manhattan island has reached the enormous sum of about $350,000,000.

From the annual reports of the committee on the fire patrol to the New York board of fire underwriters, of 1881 and 1882, the statistics given below have been extracted:

Number of buildings in New York city south of Fifty-ninth street:		
South of Canal street, west of Broadway	3,555	
South of Canal and Rutgers streets, east of Broadway	6,998	
		10,553
Lower district, south of Canal street:		
Between Canal and Fourteenth streets, west of Broadway	10,219	
Between Canal and Fourteenth streets, east of Broadway	16,481	
		26,700
Lower central district, between Canal and Fourteenth streets:		
Between Fourteenth and Fifty-ninth streets, west of Fifth avenue	20,559	
Between Fourteenth and Fifty-ninth streets, east of Fifth avenue	13,256	
		33,815
Upper central district, between Fourteenth and Fifty-ninth streets:		
North of Fifty-ninth street, west of Fifth avenue	6,372	
North of Fifty-ninth street, east of Fifth avenue	12,374	
Upper district, between Fifty-ninth street and Harlem river		18,746
New York city, Battery to Harlem river		89,814

The area comprised by the enumeration does not include that of the Twenty-third and Twenty-fourth wards north of the Harlem river, and the total, therefore, falls below that of the last column of the table given on page 329. The materials of construction are reported as follows:

Brick, with stone trimmings and in part with stone facings	64,783
Brick and frame	3,616
Frame	21,415
Total	89,814

Of this number the stores amount to over 5,300, whose value, at an average of but $100,000 each, might be estimated at $53,000,000.

Another enumeration of the number of buildings in New York city is now being carried on by committees of the fire department, but will not probably be completed for many months.

II.—THE BUILDING STONES.

A. VARIETIES, LOCALITIES, AND EDIFICES.

The series of buildings employed in New York and adjacent cities is rich and varied, comprising materials derived by water carriage from most of the sea-ports of New Brunswick and New England, and from many points along the Hudson river, and by railway from the interior of all the New England and middle states, even as far west as Indiana.

The only careful description of our American building stones yet made is found in the report of Dr. J. S. Newberry on the building stones displayed at the exposition at Philadelphia in 1876, and it will suffice for the object of this report to quote freely from the descriptions of varieties there given. It may be also remarked that from time to time various building stones have been brought to this market from numerous quarries of limited extent which have soon become exhausted; *e. g.*, the granite from Dix island. So large is the number of building stones, and so scattered are the sources of information concerning them, that some of subordinate importance may very likely not be included in the following list. In most cases prominent examples are given of the use of stone in the larger or public buildings of the city, both as ashlar for fronts and as the trimmings of buildings mainly constructed of brick.

The materials most commonly in favor for facings of the fronts of our buildings consist of red pressed brick, which is glaring and offensive to the eye; white marbles, which are at first too bright, but soon assume a dirty cream-colored tinge of discoloration; drab or olive-gray freestones, which rapidly become discolored by blackish-gray stains on fronts exposed to the north and east, and brown freestones or brownstones, very generally used for the ashlared fronts of residences. This latter stone presents rather a somber and cheerless aspect under a cloudy sky on a winter day, and imparts a great monotony to the appearance of our cross-streets; nevertheless, under the bright sky and brilliant atmosphere of many days of spring and winter, and above all of the summer in New York, it is not trying to the eye nor glaring like brick or marble or the light-colored granites and freestones.

The following details have been gathered partly from my own observation and that of my assistants, but for many particulars, especially in regard to examples of construction, I have been indebted to various persons, and I have not been able to verify them all:

FREESTONE (sandstone).—Shepody mountain, Hopewell, Albert, New Brunswick. Pale olive-green, and of medium fineness; uniform texture and tint, and of good strength; is a durable and serviceable stone, generally admired for its color (J. S. Newberry). Derived from the Millstone Grit formation. Examples of construction. (See Freestone of Dorchester, New Brunswick.)

FREESTONE (sandstone).—Mary's Point, Albert, New Brunswick. Colors, salmon, olive, and dark brown. Derived from the Lower Carboniferous formation. Examples of construction: The Reformed church, corner of Fifty-seventh street and Madison avenue; the fence surrounding Central park, the bridges, fountain, basin, and most of the freestone masonry in the park; also the similar masonry in Prospect park, in Brooklyn.

FREESTONE (sandstone).—Wood Point, Westmoreland county, New Brunswick. Color, dark brown. Examples of construction. (See below.)

FREESTONE (sandstone).—Sackville, New Brunswick. Derived from the Lower Carboniferous formation. Examples of construction. (See below.)

FREESTONE (sandstone).—Harvey, New Brunswick. Derived from the Lower Carboniferous formation. Examples of construction. (See below.)

FREESTONE (sandstone).—Dorchester, New Brunswick. Derived from the Lower Carboniferous formation. Examples of construction: Stoops and part of trimmings of Normal college, Sixty-eighth street and Lexington avenue; building of New York Historical Society, corner of Second avenue and Eleventh street; part of the wall and bridges in Central park. Trimmings of the Academy of Music, Montague street, Brooklyn.

FREESTONE (sandstone).—Weston, New Brunswick. Derived from the Lower Carboniferous formation. Examples of construction: Part of the wall and bridges in Central park.

FREESTONE (sandstone).—Kennetcook, Hants county, Nova Scotia. Colors, olive and blue. Derived from the Lower Carboniferous formation. It is also used for grindstones. Examples of construction. (See below.)

General examples of the construction in the "Nova Scotia" stone: Church in Twenty-fifth street, east of Fifth avenue; hotel Bristol, Forty-second street, near Fifth avenue; churches: Madison avenue, near Fifty-seventh street; Fourteenth street, west of First avenue; Fourteenth street, west of Sixth avenue; Fifteenth street, east of Third avenue; Sixth avenue, near Fifteenth street; Twenty-first street, east of Second avenue; Thirty-fourth street, east of Seventh avenue; Forty-second street, west of Seventh avenue; Lexington avenue, near Forty-sixth street; Lexington avenue, near Sixty-third street; Seventy-sixth street, east of Third avenue; Eighty-ninth street, east of Madison avenue; bank, Broadway, Brooklyn.

FREESTONE (sandstone).—East Longmeadow and Springfield, Massachusetts. Derived from the Triassic formation.

FREESTONE (brown sandstone or brownstone).—Portland, Connecticut. "Some varieties are laminated in structure and liable to exfoliate when used as ashlars and set on edge." This stone imparts a somber monotony of tone to the architecture of our cities. Color light to dark reddish-brown, inclining to chocolate; texture varying widely in fineness, but usually coarser than the similar freestone from Belleville, New Jersey. Examples of construction are abundant in the residences throughout our cities, *e. g.*, on the northwest corner of Fifty-seventh street and Fifth avenue: Academy of Design, in Brooklyn, Montague street, west of Fulton.

FREESTONE (sandstone).—Middletown, Connecticut. Derived from the Triassic formation. Examples of construction: Trinity church, corner of Clinton and Montague streets, and the Methodist Episcopal church, on northwest corner of Clinton and Pacific streets, in Brooklyn.

RED SANDSTONE.—Potsdam, New York. The oldest of all the sandstones, belonging to the Potsdam period of the Lower Silurian formation. Color, a warm reddish brown, slightly mottled and striped with white; structure, decidedly laminated, in thin parallel sheets, often crossed obliquely by obscure fissure lines of lighter color. It is quite refractory, and has been used for lining of iron furnaces. Examples of construction: Quoins, trimmings, and basement of residence in Fifth avenue, near Thirty-fifth street; dressings, string-courses, etc., of building of Columbia college, Forty-ninth street and Madison avenue.

BROWN SANDSTONE.—Oswego, New York. Example of construction: Part of first story of Masonic temple, Twenty-third street and Sixth avenue.

FREESTONE (brownstone).—Newark, New Jersey. Examples of construction: Churches on corner of Forty-eighth and Fifty-fifth streets and Fifth avenue; the synagogue, on Fifth avenue; church on corner of Madison avenue and Fifty-fifth street; Trinity Church school, on Church street; Trinity chapel, on Houston street; trimmings of buildings at Thirty-second street and Broadway, etc.

FREESTONE (sandstone or "brownstone").—Belleville, New Jersey. Derived from the Triassic formation. Colors, brownish-gray, light brown, light reddish-brown, and light orange-brown. Generally finer grained and more compact than the stone from Connecticut. Examples of construction: House on northeast corner of Fiftieth street and Madison avenue; Church of the Messiah, northwest corner of Thirty-fourth street and Park avenue; trimmings of many residences in Madison avenue, *e. g.*, on northwest corners of Sixty-seventh, Sixty-eighth, and Sixty-ninth streets, etc.; Baptist Church of the Epiphany, southeast corner Madison avenue and Sixty-fourth street; two shades of this stone presented in the church and chapel, Madison Avenue Methodist Episcopal church, northeast corner Madison avenue and Sixtieth street; Presbyterian church, corner Fifty-fifth street and Fifth avenue; Jewish temple, corner of Fifty-fifth street and Lexington avenue, with trimmings of Ohio stone; trimmings of Harney building, 16 Wall street; Seventh Ward bank; Mills building, corner Broad street and Exchange place, and many bridges in Central park; Fort La Fayette; houses on corner of Fifty-seventh and Ninety-third streets and Fifth avenue, and corner of Twenty-eighth street and Madison avenue.

FREESTONE (brown sandstone).—Little Falls, New Jersey. Derived from the Triassic formation. Example of construction: Trinity church, Broadway and Wall street.

FREESTONE (brownstone).—Base of Palisades, New Jersey. Derived from the Triassic formation. Example of construction: Part of the wall in Central park.

FREESTONE (brownstone).—Hummelstown, Pennsylvania. This has been largely used in Philadelphia, and is said to be an excellent variety. Example of construction: Building on Fifth avenue, above Forty-first street.

FREESTONE (sandstone).—Amherst, northern Ohio. Belonging to the Lower Carboniferous or Waverly series. Fine-grained, homogeneous sandstone, light drab in color, made up chiefly of grains of quartz; color, permanent. An excellent building stone. Example of construction: Building corner of Barclay street and Broadway, erected twenty years ago.

FREESTONE (sandstone).—East Cleveland, Ohio. Color, drab and dove-colored. Derived from the Waverly and Coal Measures.

FREESTONE (sandstone).—Independence, Ohio. Color, light drab, and coarser than the stone of Amherst. Derived from the Waverly and Coal Measures.

FREESTONE (sandstone).—Berea, Ohio. Derived from the Waverly and Coal Measures. Not quite so fine grained as the Amherst; a light bluish-gray, generally a strong and durable stone, sometimes liable to discoloration by decomposition of pyrites. Examples of construction: New York *Clipper* building; block on corner of Cliff and Fulton streets; Church of Transfiguration; west side of Sixth avenue, above Twenty-seventh street; Decker's building, in Union square; churches: One hundred and ninth street, near Madison avenue; One hundred and sixteenth street, near Third avenue; South Fifth street, near Canal; Bond building, on Broadway, next Trinity building; front of Rossmore hotel, Forty-first street and Broadway; trimmings of house, northwest corner of Forty-third street and Madison avenue; Williamsburg Savings bank, corner Broadway and Fifth street, Brooklyn, eastern district (with basement and pilasters of Quincy granite); Berea hall, Brooklyn, etc.

Buena Vista freestone (sandstone).—Portsmouth, Scioto county, Ohio. This belongs to the lower part of the Waverly series. It is finer grained and less siliceous than that from northern Ohio, "and has generally a more decided bluish tint when freshly quarried, but becomes lighter and more yellowish on exposure." It varies in color from brown, dove-colored, banded and mottled red and yellow to black.

Though some varieties of this stone are liable to stain and exfoliate, from the oxidation of the contained iron, as a general rule it is an excellent and very handsome stone, taking rank with the best and handsomest of the freestones of the country.—J. S. N.

Freestone (sandstone).—Waverly, southern Ohio. Derived from the lower part of the Waverly series.

Within a few years a considerable quantity of stone, which is known in New York by the name of "Carlisle" or "Scotch" stone, has been brought into New York as ballast. It is not the English stone known by the former name in England, but comprises three varieties of Scotch sandstone, here called merely by the name of the English port at which the stone is shipped, Carlisle. Each stone will be separately considered :

1. Corsehill freestone (sandstone).—Corsehill, near Annan, in Dumfries county, about 60 miles west of Glasgow, Scotland. Derived from the new red sandstone. Color, dark red to bright pink; close grained; weathers well, works easily, fit for ashlar, and well adapted for carving and for columns. Examples of construction: Trimmings of Murray Hill hotel, Park avenue and Forty-first street; stables on south side of Sixty-second street, between Park and Madison avenues; house corner of Fifty-seventh street and Fourth avenue; mantels in residence corner of Fifty-second street and Fifth avenue; trimmings of the Berkshire building, northwest corner of Madison avenue and Fifty-second street.

2. Ballochmile freestone (sandstone).—Ballochmile, Forfarshire, Scotland. A little darker in color than the Corsehill stone. Derived from the Carboniferous formation. Examples of construction: Two houses in west Seventy-eighth street; house in Fifty-seventh street and Seventh avenue.

3. Red freestone (sandstone).—Gatelaw bridge, 30 miles from Ballochmile, Dumfriesshire, Scotland. About equal in quality and perhaps superior in beauty to the Corsehill stone, but much superior to the Ballochmile stone. Example of construction: The only building constructed of this stone is the house on southeast corner of Forty-second street and Fifth avenue.

Red sandstone.—Frankfort-on-the-Main, Germany. Example of construction: Building in Sixty-eighth street, east of Third avenue.

Blue-stone (graywacke).—Albany, Delaware, and Greene counties, New York. The Greene County stone is obtained from some heavier beds in the Portage group, along the base of the Catskill mountains, and is shipped at Malden, on the Hudson river.

It is one of the very best flagging stones in the world. It may be quarried in slabs of almost any desired thickness or dimensions, the different layers varying much in this respect. The natural surfaces of these strata are comparatively smooth, and form a good walk without dressing. The stone comes from the Hamilton group of the Devonian system, and forms a belt of outcrop extending from Kingston on the Hudson to Port Jervis on the Erie railroad, and thence southward. It is a fine-grained sandstone, generally dark blue in color—whence its name—and is very strong and durable. When ground or sawed it forms a very smooth surface, and yet one that always has a tooth or grain which holds the foot well, whether wet or dry. In this respect sandstones are much superior to granites and limestones, which become slippery and dangerous when wet.—J. S. N.

Examples of construction: Part of the bridges and wall in Central park.

Montrose stone (blue-stone).—Kingston, Ulster county, New York. A variety more pinkish in color than ordinary blue-stone, but about the same in hardness and general characteristics. Examples of construction: Two stables in Fifty-first street, between Seventh and Eighth avenues; penitentiary on Blackwell's island; flooring of casemates in forts of the harbor; trimmings of National Academy of Design, Twenty-third street and Fourth avenue (with casing); porch of house, 15 East Thirty-sixth street; house in Fifty-seventh street, two doors west of Fourth avenue.

Wyoming blue-stone (graywacke and flag-stones).—Pond Eddy, Long Swamp, the Narrows, Lackawaxen, near and in Pike county, Pennsylvania, and across the Delaware river in New York. This stone is mostly shipped to Rondout by the Delaware and Hudson canal. Thickness of the flags and beds, from 2 to 18 inches. It is used for window- and door-sills, step-stones, water-tables, platforms, cellar, prison, and casemate floors, sidewalks, curbs, gutters, the bases of tombstones, candy tables, etc.

The blue-stone is the best; when it is struck with the hammer it has a metallic ring; and the finer the grain of the stone the better, because it is more apt to be smoother, tougher, harder, and truer over the face than a coarse-grained flag.—*The Manufacturer and Builder*, 1876, VIII, 138.

Examples of construction: The basement of residences, Thirty-fourth and Fifty-eighth streets; a building in Seventeenth street, on Stuyvesant square; trimmings of Produce Exchange building.

FREESTONE (limestone)—CAEN STONE (oolite) CAEN.—Normandy, France. This stone is of a pale cream-yellow color, of a loose, open grain, soils the fingers like chalk, and is very friable. It is very soft when first quarried, but hardens on exposure; is easily worked, sawed and carved, but weathers very badly; weighs from 116 to 142 pounds to the cubic foot. Examples of construction: The former Nassau bank, corner of Nassau and Beekman streets, built in 1828; the reredos in Trinity church; the Tontine building; six residences in West Ninth street, between Fifth and Sixth avenues, erected in 1857; the dormitory in Sixteenth street, adjoining the New York hospital on the Fifth Avenue side; house next to church, Fifth avenue and Twenty-ninth street; the plinths, bands, and cornices of church and parsonage on southeast corner of Nineteenth street and Fourth avenue; bands, mullions, etc., of oriels and general trimmings in Trinity chapel.

LIMESTONE.—Lockport, New York.

This comes from the encrinital layer of the Niagara group, and is a gray limestone thickly set with fossils, most of which are the joints of crinoids. Some of these are tinged with red, while others have a blue or opalescent shade, all of which give an agreeable variety to the color of the stone. It is less hard than the true marbles, and as a consequence takes a less brilliant polish and is more easily scratched. When properly wrought, however, it is quite handsome, and is considerably used for mantels and other purposes.—J. S. N.

Examples of construction: Lenox library, Fifth avenue and Seventieth street, and the dressings of apertures, bands, posts, etc., of the Presbyterian hospital, Madison avenue and Seventieth street.

OOLITIC LIMESTONE.—Ellettsville, Monroe county, Indiana. Example of construction: Office building in Cortland street, next to Coal and Iron Exchange building.

OOLITIC LIMESTONE ("Indiana limestone" or "Bedford stone").—Bedford, Lawrence county, Indiana. Examples of construction: Residences on northwest corners of Fifty-second and Fifty-seventh streets and Fifth avenue; Smith building, Cortland street; lowest story of Appleby Flat building, at Seventh avenue and Fifty-ninth street, and a similar building at Eleventh avenue and Eighty-fourth street; Bridge building, Fourteenth street; rectory, on Fifty-fifth street.

LIMESTONE.—Kingston and Rondout, New York. Examples of construction: Part of anchorages, approaches, and base of towers of New York and Brooklyn bridge.

LIMESTONE.—Isle La Motte, lake Champlain. Examples of construction: Part of the anchorages and towers of New York and Brooklyn bridge.

LIMESTONE.—Willsborough point, lake Champlain, New York. Examples of construction: Part of anchorages, approaches, and base of towers of New York and Brooklyn bridge.

LIMESTONE.—Greenwich and Mott Haven, Connecticut. Examples of construction: Part of wall in Central park.

GRANITE.—Bay of Fundy, Nova Scotia.

It contains almost no mica; is of moderately fine grain, the groundwork composed of a bright, light red orthoclase, mottled with perhaps one-fourth of the quantity of bluish quartz, and one-tenth or less of black hornblende. It is a very tough and compact rock, and takes as high and uniform a polish as any other variety of granite known.—J. S. N.

Examples of construction: The columns of the Stock Exchange building.

RED GRANITE.—Calais, Maine.

It is composed of pale red orthoclase, with a smaller quantity of a lighter feldspar, possibly albite, with quartz, hornblende, and a little mica. It takes a fine polish, is homogeneous in texture and color, and well deserves the good reputation it enjoys.—J. S. N.

GRANITE.—Bluehill, Maine. Light gray in color, and of good texture. Example of construction: The United States barge-office, Battery.

GRANITE.—Morgan's bay, East Bluehill, Maine.

A compact, homogeneous, light gray granite, composed of relatively large crystals of white orthoclase, with fine grains of glassy quartz and specks of black mica. In color it is one of the lightest of New England granites, and from the preponderance of feldspar, the absence of hornblende, and the granular condition of the quartz, it will work with unusual facility and will prove a handsome and durable stone.—J. S. N.

The stone is handsomely mottled and susceptible of a high polish. Examples of construction: Part of the towers and approaches of the New York and Brooklyn bridge.

GRANITE.—Spruce Head, near Rockland, Maine.

A clear, mottled, white and black syenite, which consists of nearly equal parts of snow-white orthoclase, glassy quartz, and black hornblende. The constituents are firmly united, making it a strong and durable stone, which takes a brilliant polish. The quantity of hornblende in it and the striking contrast in color between this and the feldspar give it a peculiar bright lively tint, which renders it one of the handsomest of the gray granites.—J. S. N.

Examples of construction: Part of towers of New York and Brooklyn bridge; bridges of Fourth Avenue improvement; Jersey City reservoir; hospital building for Sailors' Snug Harbor, Staten island.

RED GRANITE.—Red Beach, Maine.

This is a fine-grained granite, of which the general complexion is reddish, but less positively so than that of most so-called red granites. It is composed of pale red and creamy white feldspar, with smaller masses of smoky quartz, fine grains of black hornblende, and specks of black mica. It takes a good polish and is undoubtedly a strong and durable stone. In quality it will take equal rank with the Jonesboro, and Calais red granites, from which it differs chiefly in its greater fineness of mottling.—J. S. N.

GRANITE.—Hurricane island, Maine. A gray stone of good quality and susceptible of high polish. Examples of construction: Portions of the New York docks; part of the towers and approaches of the New York and Brooklyn bridge; part of the New York post-office.

GRANITE.—East Boston, Fox island, Maine.

A very fine grained stone, having the general complexion of the Westerly granite, but differing from that by showing a faint pinkish blush in its feldspar. In this respect it resembles the "harbor granite" of Fox island, of which it is indeed only a fine-grained variety.—J. S. N.

GRANITE.—Deer island, Maine. A light gray and biotitic granite. Example of construction: The grain elevator of the New York Central Railroad.

GRANITE.—Vinal Haven, Maine. Light gray and rather coarse. Examples of construction: Sailors' Snug Harbor, Staten island; the Butler monument at the mausoleum in Greenwood cemetery, etc.

GRANITE.—Saint George, Maine. Fine-grained and compact. Example of construction: The pedestal of the La Fayette monument at Union square.

GRANITE.—Augusta, Maine. A compact and fine-grained granite, containing both muscovite and biotite, and capable of receiving a good polish. Examples of construction: Mills' building, corner of Broad street and Exchange place; monument to Recorder Hackett; Roberts tomb in Woodlawn cemetery; Wood's tomb in Greenwood cemetery, etc.

GRANITE.—Biddeford, Maine. Examples of construction: A railroad elevator in Jersey City; docks along the North river, etc.

GRANITE.—Pownal Centre, Maine. Sometimes used for paving in New York city.

GRANITE.—Harbor, Fox island, near Rockland, Maine.

A coarse-grained, handsome mottled granite, composed of very pale pink and white feldspar, mingled with relatively fine grains of quartz and hornblende. Its general tone of color is reddish gray blotched with white, and quite pleasing to the eye. It takes a good polish.—J. S. N.

Examples of construction: Part of the towers of the New York and Brooklyn bridge; the basement of the Stock Exchange building.

GRANITE.—Hallowell, Maine.

A very light, fine-grained stone, consisting chiefly of white orthoclase feldspar, with relatively fine grains of glassy quartz, specks of black hornblende, and minute scales of silvery mica. This latter gives the stone a peculiar glitter and adds greatly to its beauty without seriously affecting its strength. Dressed surfaces are almost as white as white marble, and, where polished, the spangles of mica buried beneath the surface reflect the light and sparkle like diamonds. From the small quantity of quartz and the presence of mica, the Hallowell granite works with usual facility, both in the quarry and under the chisel; yet it takes a good polish and is as strong and will prove as durable as most of the esteemed varieties of this stone.—J. S. N.

Examples of construction: Finish of door-jambs, windows, etc., of Saint Patrick's cathedral, Jersey City heights; Ludlow street jail; the *Tribune* building; the "Halls of Justice" or "Tombs" prison, in Centre street.

GRANITE.—Round Pond, Maine. A dark gray and compact biotitic granite. Example of construction: The Seventh Regiment armory.

GRANITE.—Clark's island, Maine.

GRANITE.—Mount Waldo, Maine.

GRANITE.—Musquito mountain, Maine.

GRANITE.—Jonesboro', Maine. Examples of construction: Part of the panels at entrance of Williamsburg Savings bank, Brooklyn; the front of Welles building, on the corner of Broadway and Beaver streets, New York; the Hunnewell building, etc.

GRANITE.—Frankfort, Maine. A coarse, compact, and generally porphyritic gray biotitic granite. Example of construction: Part of towers and approaches of New York and Brooklyn bridge.

GRANITE.—Mount Desert island, Maine. A light gray biotitic granite. Examples of construction: Part of towers and of the Brooklyn approaches of the New York and Brooklyn bridge; Metropolitan Museum of Art; fort Schuyler, etc.

GRANITE.—Radcliffe's island, Maine. Examples of construction: Bridges in Central park.

GRANITE.—Dix island, Maine. A dark gray, compact granite. This quarry is now exhausted. Examples of construction: New York post-office; first base-course of Saint Patrick's cathedral; court-house in City Hall park; part of *Staats Zeitung* building; fortifications in the harbor; docks at Castle Garden, and the retaining-walls for the basin and barge-office.

GRANITE.—Concord, New Hampshire. Examples of construction: Booth's theater; German Savings bank, corner Fourteenth street and Fourth avenue (basement, Quincy granite); part of towers and approaches of New York and Brooklyn bridge.

GRANITE.—Saint Johnsbury, Vermont.

A gray stone of excellent quality and established reputation.—J. S. N.

GRANITE.—Bethel, Vermont.

A nearly white granite of a homogeneous texture, but not highly polished. It must be an admirable stone for special uses, but it is probably less durable than some of the more siliceous and compact varieties.—J. S. N.

GRANITE.—Barre, Vermont.

This stone has been proved by ample trial to be an excellent stone for architectural and monumental purposes. It is light gray in color, of medium fineness, very homogeneous, and firm.—J. S. N.

GRANITE.—Cape Ann, Massachusetts. Example of construction: The dark base stone and spandrel stones of the towers and approaches of New York and Brooklyn bridge.

GRANITE.—Quincy, Massachusetts.

A well-known stone consisting of quartz, feldspar, and hornblende without mica. The color varies considerably, and affords opportunity for the exercise of taste in combination and adaptation to different purposes. This variation of color is due to differences in the feldspar of the different beds. In one it is pale green, in another purplish-blue, and in the third pale pink. The black hornblende, which exists in considerable quantity, is the same in all, as is also the glassy quartz. The stone is susceptible of a high polish, and its strength and durability are amply attested by the trials to which it has been subjected. As a whole the Quincy granite is rather somber in tone, and on this account is for many purposes less desirable than the lighter varieties.—J. S. N.

Examples of construction: The Astor house; Reformed church, in La Fayette place, corner of Fourth street; custom-house, Wall street, corner of William; part of trimmings of Normal college, and Hahnemann hospital, Fourth avenue and Sixty-seventh street; part of *Staats Zeitung* building; Tryon row, between Center and Chatham streets.

GRANITE.—Westerly, Rhode Island.

This is a remarkably fine grained homogeneous stone, chiefly composed of pale-pinkish or brownish-white orthoclase and thickly set with minute grains of black hornblende and occasional specks of black mica. It takes a fine polish, and is justly esteemed as one of the best granites in the country.—J. S. N.

One variety is decidedly pinkish in color; the others gray, fine, and coarse-grained; all of good quality. Also red, white, and blue varieties. Example of construction: Part of Brooklyn anchorage of the New York and Brooklyn bridge.

GRANITE.—Thomaston, Connecticut.

It is lightest in color of all the granites exhibited at Philadelphia; is fine-grained, compact, and homogeneous, and is a remarkably beautiful and excellent stone, specially adapted to monumental work, for which it is largely used and highly esteemed.—J. S. N.

GRANITE.—Millstone point, Connecticut.

A dark gray granite of fine, homogeneous texture, showing strong contrast of color between polished and dressed surfaces.—J. S. N.

GRANITE.—Leetes island, Connecticut.

It is a reddish-gray, rather coarse-grained gneiss; a handsome building stone, but taking an imperfect polish, and is not well adapted to ornamental purposes.—J. S. N.

Example of construction: Bridge over Harlem river.

GRANITE.—Mystic Bridge, Connecticut.

A very fine grained, light to dark gray granite, homogeneous in texture, and handsome.—J. S. N.

GRANITE.—Stony Creek, Connecticut.

Pale red in color, of medium grain, and consists of flesh-colored orthoclase, greenish-white oligoclase, and glassy quartz, with specks of black hornblende and magnetic iron. Minute points of pyrites may also sometimes be seen in it. It is a strong, compact, and handsome stone, having an agreeable tint, taking a high polish, and has been proved by trial to be well adapted for both construction and ornament.—J. S. N.

Another variety is a gray, fine-grained stone of good quality. Example of construction: Part of New York anchorage of the New York and Brooklyn bridge.

GRANITE.—Umpewaug, Norwalk, Connecticut.

This is a rather fine grained, pinkish gray granite, homogeneous and compact; a good building stone.—J. S. N.

RED GRANITE.—Lyme, Connecticut.

Very coarse grained, composed mostly of pale red or flesh-colored feldspar mottled with a whiter variety and glassy quartz; it is also specked and streaked with hornblende. From the preponderance of coarsely crystallized pale red orthoclase in its composition, it has a more uniform tint than any other red granite shown in the exhibition, and on this account, should it prove sound and strong, it will be a valuable addition to the varieties now in use for architectural and ornamental purposes.—J. S. N.

GRANITE.—Niantic, Connecticut. Light gray and fine grained. Example of construction: Reservoir in Central park.

GRANITE.—Saint Lawrence county, New York. Derived from the Laurentian formation.

GRANITE.—Cornwall, New York (highlands of Hudson river). Derived from the Laurentian formation.

GRANITE.—Charlottesburg, New Jersey. Example of construction: Part of the New York anchorage of the New York and Brooklyn bridge.

GRAY GRANITE (Aberdeen granite).—Rubislaw, near Aberdeen, Aberdeenshire, Scotland. This occurs in large blocks, takes a fine polish, and is grayish in tint. It is of metamorphic origin, according to Haughton, and consists of quartz, orthoclase, and black mica. The city of Aberdeen is built from it.

GRAY GRANITE (Aberdeen granite).—Rubislaw, near Aberdeen, Aberdeenshire, Scotland. This stone is considered the best granite adapted as pavement for the traffic of London, as it is very durable and less slippery than most other granites. It was used in England in the London pavements, the Portsmouth and Sheerness docks, Bell Rock light-house, Waterloo bridge, and upper side of London bridge, and in many polished columns and stones of buildings throughout New York city, Brooklyn, etc. Its weight per cubic foot varies from 165 to 166 pounds.

RED GRANITE (Peterhead granite).—Sterling Hill, near Peterhead, 30 miles from Aberdeen, Scotland. This is the best and most beautiful of the granites of Scotland. Its weight per cubic foot is about 166 pounds. It is used in the columns and building stones of numerous edifices in all the cities of Great Britain, where it is justly esteemed for the beauty of its color, closeness of texture, and the large blocks it yields from the quarry. It contains red orthoclase, albite, black mica, and quartz, and has been considered eruptive by Dr. Haughton.

British examples of construction: Pillars of Carlton club-house; the Fishmongers' hall, London. Columns for interior of Saint George's hall, Liverpool. Columns in Provincial Bank of Ireland, Dublin.

The Scotch granites are justly esteemed for their beauty of color and closeness and uniformity of texture. * * * The popularity of the Scotch granites, excellent as they are, is not due however to any superiority over the granites of the United States, but rather to their early occupation and subsequent possession of the market. No stronger or more durable stone is likely to be found anywhere than the granites of Peterhead and Aberdeen, but they do not surpass in beauty or excellence the red granites of the Bay of Fundy and Gananoque, and the more esteemed varieties of red and gray granite from New England.—J. S. N.

Examples of construction in the United States: Many polished columns and stones in the fronts and entrances of many buildings throughout New York, Brooklyn, etc.

SYENITIC GRANITE.—The granite of Syene (syénite rose d'Egypte) occupies large tracts in Upper Egypt between the first cataract and the town of Assouan, the ancient Syene, including several islands both above and below the cataract. It was extensively quarried by the Egyptians as far back at least as the reign of Zestos, king of Thebes, one thousand three hundred years before the Christian era, and fashioned into columns, obelisks, sarcophagi, and colossal statues which have lasted with but little injury down to the present day, and adorn the cities and public galleries of modern Europe. These quarries may still be traced at intervals, and the marks of the pick and chisel are still fresh. * * * It consists of large crystals of red orthoclase, sometimes in twins, and porphyritically developed, a little yellowish oligoclase, quartz, and dark mica, with occasionally a little hornblende. Sometimes the orthoclase crystals are of very large size, and the whole rock extremely coarse grained. The general color of the rock is reddish, and it takes a fine polish.

The analyses of Egyptian granite (or "syenite"), from a fragment of an antique in the collection of the Louvre, Paris, by Professor Delesse, yielded the following results: Silica, 70.25 per cent.; alumina, 16.00; oxides of iron and manganese, 2.50; lime, 1.60; magnesia, potash, and soda, 9.00; water, 0.65. Examples of construction: The obelisk and pedestal in the Central park, New York city. The masonry at the base of the pedestal consists of nummulitic limestone from Egypt.

GNEISS.—New York island. This rock occurs in two common varieties: the one biotitic, fine-grained, often slaty, bluish-gray in color, and consisting of quartz, plagioclase, feldspar, biotite, with more or less garnet, magnetite, fibrolite, etc.; the other, hornblendic, black, glistening, slaty, and differing from the former chiefly in a large content or predominance of black hornblende. Examples of construction: The foundations of most of the buildings of the city; side walls of Saint Paul's church, corner of Broadway and Fulton street; church, Thompson street near Prince; Church of the Strangers, Mercer street, near Clinton place; All Saints church, Henry street, near Scannel street; Henry Street church, Henry street, near Market street; church, Henry street, near Rutgers street; church, Centre street, corner of Broome; basement of Irving hall, on southwest corner of Irving place and Fifteenth street; church, Twentieth street, west of Eighth avenue; church, Twenty-third street, east of Third avenue; Bellevue hospital, Twenty-seventh street, east of First avenue; church on southeast corner Thirty-eighth street and Madison avenue; asylum for the blind, Thirty-third street, near Ninth avenue; church, Thirty-fourth street, east of Seventh avenue; church, Madison avenue, near Thirty-eighth street; church, Forty-fourth street, east of Tenth avenue; church, northeast corner of Forty-seventh street and Madison avenue; church, Fifty-third street, east of Sixth avenue; church, Seventy-second street, near Third avenue; church, Seventy-fourth street and Fourth avenue; church, One hundred and seventeenth street, near Fourth avenue; church, One hundred and twenty-seventh street, near Lexington avenue; part of church of the Holy Spirit, corner Sixty-sixth street and Madison avenue; first story of Berkshire building, on northwest corner of Fifty-first street and Madison avenue; basement of New York foundling asylum, on southwest corner Third avenue and Sixty-ninth street; New York Juvenile Asylum, One hundred and seventy-eighth street (Kingsbridge road); Saint Ann's Avenue church, One hundred and fortieth street; church, Third avenue, near One hundred and forty-sixth street; Saint John's college, Fordham; cemetery office, Woodlawn; Methodist church, Washington place; church on northwest corner Washington place and Sixth avenue; Croton aqueduct, and the reservoirs at Fifth avenue and Forty-second street, and in Central park (quarried from site); Church of Saint Paul the Apostle, Ninth avenue and Fifty-ninth street (facings, red Connecticut granite); foundations of the Lenox hospital, Seventieth street and Madison avenue; basement of the Berkshire building, northwest corner of Madison avenue and Fifty-second street; the tower, bridges, and walls in Central park.

GNEISS.—Westchester county, New York. Examples of construction: Many bridges and walls in Central park.

GNEISS.—Willett's Point, Kings county, New York (Long island, on the shore of the sound). Examples of construction: Fort Schuyler, at Throgg's Neck, Long island. In Brooklyn: Church, State street, west of Bond street; church, Carroll street, south of Court street; church, Marcy avenue; naval hospital, near Harrison avenue; church, Fourth street, near Broadway; church, Kent street, east of Franklin avenue.

MARBLE.—Swanton, Vermont.

All the Swanton marbles have the excellencies and defects of those of Mallett's head—that is, they are hard and somewhat difficult to work, but take a proportionately fine polish, which they retain longer than softer stones. The mistake is frequently made of using these mottled, veined, and brecciated marbles for tiling, but this sort of wear speedily betrays the difference in hardness of the several parts and destroys their beauty; hence economy as well as good taste will be consulted by using for steps, thresholds, tiling, etc., the monochrome marbles only.—J. S. N.

Examples of construction. (See below.)

STATUARY MARBLE.—West Rutland, Vermont. Brilliant, white, somewhat tender and absorbent, and hence best fitted for use when it is not exposed to the weather. Similar marbles are also brought from Rutland Centre, Dorset, Danby, Pittsford, Brandon, Shelburne, and Middlebury, Vermont. Examples of construction. (See below.)

MARBLE.—Manchester, Vermont. A rather coarse, white stone, streaked or clouded with black or gray. Examples of construction: Building of Drexel & Morgan, corner of Wall street and Broadway, New York; Dutch Reformed church, corner of Twenty-ninth street and Fifth avenue.

MARBLE.—Sutherland Falls, Vermont.

General examples of construction in Vermont marbles: The Sutherland building, southeast corner of Sixty-third street and Madison avenue (beginning to be discolored by iron stains, chiefly derived from iron work); Savings Institution building on southeast corner of Clinton street and Atlantic avenue, Brooklyn. The latter building shows streaks of discoloration on moldings of cornices, etc.

WINOOSKI MARBLE.—Mallett's head, on Isle La Motte, in lake Champlain, near Burlington, Vermont.

It is mottled red, white, and brown, a hard stone, and somewhat difficult to work, but takes a high polish, and is very strong and durable. There is considerable variety in the tint of the Winooski marble, produced by the relative preponderance of the colors mentioned, and the size of the figure, some slabs being coarsely motled with white and brown, others chocolate and pale red, and others still light red, speckled, and mottled with white.—J. S. N.

Examples of construction: The reredos of Grace church, Broadway, between Tenth and Eleventh streets, New York.

MARBLE.—Isle La Motte, Vermont.

These marbles are dark gray and black; the latter is less deep in color than the Glens Falls and Lycoming black marbles, but is harder and stronger. It is largely used for tiling in combination with white marble or slate; for this purpose it has been in use for twenty-five years, proving itself to be an exceedingly durable and serviceable stone. The "fine gray" and "coarse gray" are valuable building stones.—J. S. N.

MARBLE.—Lee, Massachusetts.

The Lee marble is for the most part of a uniform though not brilliant white color, is coarser grained than the Vermont marbles, and yet finer than those of New York. It is a strong and durable stone, but contains a little iron, by the oxidization of which it becomes somewhat brown on exposure. It is doubtful whether its strength and durability are materially impaired by this, and the change of color which it produces is by some architects regarded as an excellence rather than a defect.—J. S. N.

It usually contains a little pyrites, but is a remarkably white marble. Example of construction: Saint Patrick's cathedral, Fifth avenue and Fiftieth street.

MARBLE.—West Stockbridge, Massachusetts.

It is similar in character to that from Lee, resembling coarse loaf-sugar.—J. S. N.

Examples of construction: The east, south, and west fronts of the old city hall, New York; the Treasury building in Wall street.

MARBLE.—Canaan, Connecticut.

It varies somewhat in color and texture, some of it being very white and of fine grain, and well adapted to monumental purposes; the greater part, however, is bluish-white or mottled. This is harder to work, more durable, and best suited for building.—J. S. N.

MARBLE.—Glens Falls, New York.

This is a very dark phase of the Trenton limestone. It has been little, if at all, metamorphosed, and is simply a hard limestone impregnated with carbonaceous matter, to which it owes its color. It is less hard and black than the most esteemed black marbles, but serves an excellent purpose for tiling, and is sometimes used for mantles and other interior decorations. Like all the black limestones, it will be found to lose its color and become gray by exposure to the weather.—J. S. N.

MARBLE.—Lockport, New York. (Already mentioned under Limestone.)

MARBLE.—Hastings, New York. Example of construction: The University building, University and Waverly places, often spoken of as "white granite".

MARBLE.—Tuckahoe, New York.

The quarries which furnish the Tuckahoe marble are located on one of the several belts of crystalline dolomite which traverse, with a north-northeast and south-southwest bearing, the country north of the city of New York. Of these, one reaches New York island, crossing the Harlem river at Kingsbridge; another outcrops on the sound, near New Rochelle; still others strike the Hudson above New York, at Hastings, Dobbs ferry, Sing Sing, etc. Several of these furnish good marble for building stone—gray, blue, or white—but none that is fine for decorative purposes. The best marbles yet obtained from these series of deposits are those of Tuckahoe and Pleasantville. The Tuckahoe marble is pure white in color, and much coarser in texture than any of those hitherto noticed. It is somewhat irregular in quality, but the better grades are highly esteemed for architectural purposes, and have been used in some of the finest buildings in the city of New York. * * * By exposure in the impure atmosphere of the city, its color changes to a light gray. This is apparently due to coarseness of texture, which gives a roughness to the surface and causes the smoke and dust to adhere to it more closely than they would to a finer stone.—J. S. N.

Examples of construction: The residence on the northwest corner of Thirty-fourth street and Fifth avenue; part of Saint Patrick's cathedral, Fiftieth street and Fifth avenue; the Stock Exchange building, and the New York Life Insurance building.

SNOWFLAKE MARBLE.—Pleasantville, Westchester county, New York.

The dolomite belt in which the Pleasantville marble quarries are situated is one of the broadest known, being more than half a mile in width. It consists chiefly of beds of impure dolomite, white or banded, which contain too much siliceous matter to be available for building or ornamental purposes, with some layers, often of considerable thickness, of pure white marble, in part similar to that of Tuckahoe, and partly still more coarsely crystallized. The beds are more or less interstratified with layers of granite and gneiss, the whole series standing nearly on edge among the marble layers in this locality; the most conspicuous and valuable is that which is worked by the Pleasantville Land Company, and which furnishes the "snowflake marble". This belt is about 400 feet wide, standing vertical, and consists throughout of pure white dolomite, almost without cloud or stain, and with no foreign matter.—J. S. N.

This stone weathers well in New York, but is apt to become stained, especially under window-sills. Examples of construction: The greater part of Saint Patrick's cathedral, New York; Union Dime Savings bank, Thirty-second street, between Sixth avenue and Broadway.

General examples of construction in Westchester marble: Block of houses on east side of Fifth avenue, between Fifty-seventh and Fifty-eighth street; the National Academy of Design, Fourth avenue and Twenty-third street; city hall, Brooklyn; court-house and municipal building; (?) Grand opera house, Eighth avenue and Twenty-third street; (?) church on northeast corner of Twenty-first street and Fourth avenue; Stewart's store buildings, Broadway, between Chambers and Reade streets, and between Ninth and Tenth streets; many store buildings in Chambers, Warren, Murray, and Barclay streets, Park place, etc.; the United States hotel, corner of Fulton and Pearl streets.

MARBLE.—Williamsport, Lycoming county, Pennsylvania. The "ebony marble" from this locality is one of the most beautiful of American black marbles.

It is a jet-black stone, not quite equal to the Belgian black in purity of color and hardness, but it is very black, and takes a brilliant polish. It contains a few specks of pyrites, and here and there a hair-line ring of white, marking the section of a fossil; but it works with great exactness, and seems to be an excellent, as it certainly is a handsome, stone.—J. S. N.

MARBLE.—Knoxville, Tennessee.

This is a highly-crystalline, compact, and hard marble, which varies in tint from brown to pink, but is not mottled, the color being distributed in sheets and belts, so that blocks of considerable size can be taken out, which are of nearly a uniform shade. Usually the color is pinkish-brown, traversed by lines of blue. It is free from cracks and flaws, and takes a very uniform and brilliant polish.—J. S. N.

Examples of construction: Ninth National Bank building; Park National Bank building; Grand Central hotel; Cisco building, etc.

MARBLE.—Doughertyville, Tennessee.

The prevailing tint of the Tennessee marble is chocolate, mottled with pure white, and is very pleasing to the eye. It is also commended by marble-workers as being sound and strong, and it takes, for a variegated marble, a high and uniform polish.—J. S. N.

MARBLE.—Carrara, Tuscany, Italy. Derived from the Jurassic, Trias, and Oolite.

The best quarries are opened along both sides of a deep valley, in which the village of Carrara is situated, and along which flows the Torano. In general the marble has a light bluish hue, or is white with bluish veins, such kinds being generally sawed into slabs at the numerous cutting and polishing mills situated along the course of the stream. The purer varieties, which are perfectly white, crystalline, and free from flaws, are quarried in blocks, sometimes 10, 12, or 14 feet in length, for statuary purposes, and drawn on strong wagons by teams of bullocks down to the railway station at Carrara.—Hull.

Its weight per cubic foot is 168.6 pounds. Examples of construction are abundant in mantels and interior decoration throughout our cities, and in the tombstones in Greenwood, Trinity, and Calvary cemeteries.

TRAP.—Palisades at Jersey City heights, Weehawken, etc., in Hudson county, New Jersey. Examples of construction: Stevens' institute, Hoboken, New Jersey, and the court-house and Saint Patrick's cathedral, Jersey City heights.

TRAP.—Graniteville, Staten island, New York. This is quarried almost entirely for pavements in the cities, and the refuse is crushed up to macadamize roads.

NORWOOD STONE.—Closter, New Jersey. Example of construction: Grace Episcopal church, One hundred and sixteenth street, near Third avenue.

SERPENTINE.—Hoboken, New Jersey. Examples of construction: Many private residences south of Stevens' hill; the wall facing part of the walk along the river; sewers and underpinnings, etc., throughout Hoboken.

SERPENTINE.—Chester, Pennsylvania. This stone is cheap and durable, and hardens by exposure.

This is a well-known coarse green building stone, quite largely used in Philadelphia and elsewhere. * * * It almost immediately assumes the appearance of age, which comports well with certain kinds of architectural design, and with the purposes of certain structures. It is also used in combination with other materials (brick and stone) with good effect, so that it adds an important element to the resources of our architects. The color is yellowish-green, it works with great facility, is fire-proof, and is probably durable.—J. S. N.

Examples of construction in serpentine and serpentine marble: Trimmings of synagogue on the southeast corner of Lexington avenue and Sixty-third street; arches in Saint Bartholomew's church, Madison avenue and Forty-fourth street.

B. PUBLIC BUILDINGS AND IMPROVEMENTS.

Many examples have been given of the common private edifices in whose construction the several varieties of building stone have been employed in this district, often, however, according to the caprice of owners and the hasty choice of architects. In the construction of many of the larger buildings, however, *e. g.*, asylums, hospitals, etc., the sunken portion of the Hudson railroad, as well as in the public edifices, more care and judgment seem to have been often exercised, and more interest is attached to the selection of materials in these cases.

1. PUBLIC BUILDINGS.—More or less reference has already been made to the materials used in the construction of the United States buildings, *e. g.*, the post-office, custom-house, barge-office, etc., and further details are given below of the character of construction in the fortifications of the bay and sound, in their approaches to the city.

It is sufficient to state in reference to other public buildings that their usual materials are given below, viz:

Prisons, bridges in parks and over the Harlem river—sandstone, limestone, granite, and gneiss.

The sewers—gneiss from the island and vicinity, and bowlders of a large variety of rocks derived from the excavations in glacial drift.

The Croton aqueduct, the high bridge over the Harlem river, and the reservoirs in the Central park and Prospect park, and at Forty-second street, New York city—granite from New England and gneiss from the island.

2. THE CENTRAL PARK.—In the report of the superintending engineer of the Central park for the year 1862 the following facts are given concerning the distribution of different building stones in the inclosing-walls, bridges, etc., within this park.

Freestone from Albert quarry, New Brunswick (also walls, etc., in Prospect park, Brooklyn); from Dorchester and Weston, New Brunswick, and from New Jersey—vertical wall and bridges.

Brown sandstones from base of Palisades, New Jersey—part of vertical wall.

Mountain graywacke and blue-stone from Hudson river, New York—part of vertical wall.

Limestone from Mott Haven and from Greenwich, Connecticut—part of vertical wall; granite from Radcliffe's island, Maine—bridges; gneiss, in park, bridges and retaining-wall, and lower portion of vertical wall; gneiss and white marble from Westchester county, New York—bridges.

3. FORTIFICATIONS.—Fort Richmond: granite from Dix island, Maine; fort Lafayette: brown sandstone (New Jersey); the fortifications at Willett's point: granite from Spruce Head, Maine; fort Schuyler (on Throgg's Neck): gneiss; fort Wadsworth, on Staten island, fort Hamilton, and fort Diamond are of Maine granite, as are also the defenses on Governor's, Bedloe's, and Ellis islands.

4. NEW YORK AND BROOKLYN BRIDGE.—I am indebted to Mr. F. Collingwood, the engineer in charge of the New York approach, for the following statistics, which have been compiled from his letters:

Materials used.—Granite, from the following localities: Frankfort, Maine; Concord, New Hampshire; Spruce Head, Maine; cape Ann, Massachusetts; Hurricane island, Maine; Westerly, Rhode Island; East Bluehill, Maine; Stony Creek, Connecticut; Mount Desert island, Maine, and Charlottesburg, New Jersey. Limestone, chiefly from Rondout and Kingston, New York: also, from Isle La Motte and Willsborough point, lake Champlain; and from near Catskill, New York.

Distribution.—In the anchorages the corner-stones, exterior of cornice and coping, and the stones resting on anchor-plates consist of granite from Charlottesburg and Stony Creek, in the New York anchorage, and from Westerly, in the Brooklyn anchorage. The rest of the material is entirely limestone, partly from Rondout, largely from lake Champlain. In the towers limestone was chiefly employed below the water-line, and, above it, granite from all the localities named, except Charlottesburg, Westerly, and Stony Creek. In the approaches the materials were arranged in about the same way as in the towers.

Total quantities.—The amounts of granite and limestone employed are estimated in round numbers as follows:

	Cubic yards.	Authority.
Anchorages..........	10,000	F. Collingwood.
Towers..............	85,159	E. E. Farrington.
Approaches..........	21,000	F. Collingwood.

In addition to the hewn stone considerable quantities of rubble were employed from various sources, but largely from Greenwich, Connecticut.

Selection.—The reasons for selection were the following: first, soundness, in regard to durability, and freedom from iron; second, color; third, price, with reference also to facilities for prompt delivery. As a rule all the cornices, parapets, and other cross-cut work and band-courses were required to be light in color. The granite for these was largely from East Bluehill; also from Westerly, Stony Creek, etc. On the contrary, base stones and spandrel stones were required to be dark. For these granite from cape Ann, etc., was used. The limestone was employed partly for cheapness and partly on account of greater specific gravity, as weight was desirable at the base of the towers and in the anchorages.

Strength.—Tests were made at the bridge works by Mr. Probasco on a number of samples of stones, in blocks 2 inches square, or with about 4 square inches of surface, with the following results:

Kind of stone.	Locality.	Position.	Crushing weight per square inch.
Granite	Frankfort, Maine	On bed	18, 026
Do	do	Not on bed	15, 700
Do	Spruce Head, Maine	On bed	14, 200 to 15, 875
Do	East Bluehill, Maine	do	12, 125 to 16, 250
Do	Long Cove, Maine	do	14, 040
Do	Concord, New Hampshire	do	17, 550
Syenite	Cape Ann, Massachusetts	do	12, 861 to 19, 280
Do	do	Not on bed	17, 875
Granite	Quincy, Massachusetts	On bed	18, 000 to 19, 600
Do	Millstone point, Connecticut	do	17, 425 to 17, 550
Sandstone	Medina	Not on bed	11, 880
Blue-stone	Hudson river	On bed	9, 000 to 13, 000
Do	do	Not on bed	11, 482
Limestone	Kingston, New York	On bed	13, 750 to 15, 550

[These figures have been incorporated in Table II.]

5. ROOFS, PAVEMENTS, AND SIDEWALKS.—*Roofs.*—Slate is very largely used for most roofs having a steep pitch. Many varieties are used, which are mainly derived from the following localities: Purple and green—Poultney, Castleton, and Fairhaven, Vermont; red—Middle Granville, New York, and Slatington, Lynnport, Bethlehem, etc., Pennsylvania.

Pavements.—The streets of these cities are mainly paved with stone, many experiments having been made, particularly in New York, in reference to the selection both of the best material and most satisfactory shape. It is a well-known fact that Broadway tests pavements more severely perhaps than any other street in the world.

For cobble-stone pavement bowlders and large pebbles from the till of the island are employed. It is found that the pointed ends of the cobble-stones, lying downward, have a tendency to sink unequally under heavy pressure, and that consequently hollows form in the pavement, rendering the roadway impassable.

The Russ pavement was first laid about the year 1853. It becomes smooth and slippery by uninterrupted travel. It consists of large square granite blocks, sometimes grooved, and answers temporarily, but the grooves are found to wear smooth at their edges. An attempt to groove the blocks already laid down led to the discovery that—

The surface of these stones had, by constant rubbing with iron horseshoes and wheel-tires, aided by atmospheric action, undergone such a physical (or chemical) change that the hardest steel tools could not cut the grooves, and the effort had to be abandoned. (*a*)

In order to increase the durability of the Russ pavement it was constructed in two layers in some portions of Broadway, the lower consisting of large, irregular, angular pieces of rock laid in the earth. Elsewhere large flag-stones were laid below, then a layer of earth, and then the large blocks of trap or granite. However, the result was unsatisfactory. The whole of the pavement has been broken up, and the blocks split into smaller cubical pieces for use in Belgian pavement elsewhere.

The stones for these [Belgian] pavements are obtained across the Hudson, where the range of basaltic rocks overlying the new red sandstone, and forming the eastern boundary of the state of New Jersey, contains many quarries. The Palisades, one of the natural wonders of the neighborhood, is a perpendicular range of basalt rocks from 300 to 600 feet high, forming the western bank of our beautiful river for a distance of some 20 miles. They are, in fact, a series exposed by nature, and the quarrying is going on so extensively there that some papers have expressed the fear that these picturesque walls will be destroyed; but a simple calculation shows the mass of basalt to be so immense that it would require several thousand years of constant labor at the present rate to make any great change in the outline. There is paving stone enough there for all the streets of New York, Brooklyn, Williamsburg, Jersey City, Hoboken, Hudson City, in short of the future great metropolis, covering several hundred square miles, and yet leave enough of the Palisades to be about as much of a natural curiosity as they are now. (*b*)

Still later, in place of basalt, a very hard kind of granite has been substituted, from the highlands of the Hudson, cut in flat blocks 10 by 12 inches square and 4½ inches thick, set edgewise, with longest dimension across the line of travel. "The pavement when laid looks much like a brick wall composed of very large gray bricks." This form appears more satisfactory in use than any previously employed. This has been also laid down in Atlantic and Myrtle avenues, Brooklyn.

Wood, concrete, and asphalt have been also used, in various combinations, on many of the streets, but in New York with little success, on account of the heavy wear to which they have been exposed; in Brooklyn the results have been more satisfactory. An enormous amount of trap, however, has been crushed and broken for use in macadamizing, and is still so employed in the upper avenues of New York island and in many of the streets in the

a *Manufacturer and Builder*, 1869, I, 194.

b The *Manufacturer and Builder*, 1869, I, 194; also 1874, VI, 157.

Twenty-third and Twenty-fourth wards; in many avenues and side-streets on the outskirts of Brooklyn, Jersey City, and Hoboken, and many of the streets and roads on Staten island. For this purpose the supply of material is inexhaustible.

Some idea of the quantity and cost of the stone and other materials that have been consumed in New York city for this object, may be deduced from the following estimate, made in 1874:

	Miles.	Cost per square yard
Macadam (Guidet improved)	22	$6 06
Granite (granite block on trap)	26	2 70
Trap-block	180	2 40
Wood	14	5 00
Cobble	83	58
Concrete, asphalt, etc	3	3 50
	328	

Sidewalks.—All the sidewalks of New York city are paved with stone, chiefly flag-stone, and this predominates in Brooklyn and the adjacent cities. The following materials are used for paving:

Bluestone or flagging, which is brought by water from the various points along the Hudson river, and by rail from the interior of the state, the Catskill mountains, and from Pennsylvania. The principal localities have been already mentioned among the building stones, under the heading of "Blue-stone". It is used both with its natural surfaces of cleavage, and, in the the larger blocks, with its surfaces planed by machinery.

Huge hewn slabs of several varieties of granite have been largely introduced into the pavements of large business streets, especially of Broadway, within a few years. Notwithstanding their roughly-dressed or picked surfaces, they are very objectionable on account of their slipperiness when wet or when covered with coatings of ice and slush.

Mica-slate, from Bolton, Connecticut, etc., was formerly used in considerable abundance, before the development of the quarries of blue flagging. It is a white, glistering, schistose rock, resisting well the weather and ordinary travel; but was mostly laid down in small blocks, whose edges and corners were first abraded or became broken by hard or long-continued wear, the material on the whole being too soft and slippery for this use. Examples of it may still be found in the following streets, though it is being fast taken up for replacement by blue flagging: Along West Nineteenth street, in La Fayette place, between Astor place and Great Jones street; along Clinton and Waverly places; in Liberty street, near Greenwich street, etc.

Gneiss, from Haddam, Connecticut, also, like the preceding, was considerably used in the early history of the city. It was laid down in small square stones, about 18 inches square, with a very rough surface, and was used both for pavement and for coping. Probably much of the gneiss from New York island and from Willett's point was once employed for this purpose.

Examples of these sidewalks may yet be found in several of the old and narrow streets below Pearl, *e. g.*, Pine street, etc.

The curbstones in New York and adjacent cities consist entirely of stone, chiefly flag-stone, but in part hewn blue-stone and granite, from the localities above mentioned.

An approximate idea of the prevailing market prices, chiefly in the year 1882, of the stones more commonly employed may be derived from the following table. The prices refer to the rough stone, per cubic foot, as delivered on the dock in New York city:

SANDSTONE.

Locality.	Color.	Price per ton.	Price per cubic foot.	Remarks.
Springfield, Massachusetts	Red and brown	$11 00		
Venice	Brown	25 00		
Portland, Middlesex county, Connecticut	do		$1 00 to $1 50	
Middletown, Connecticut	do		1 50	
Belleville, New Jersey	do	$1 00 to $1 75	1 00 to 1 50	
Newark, New Jersey	do		1 00 to 1 50	
Dorchester, New Brunswick	do	15 00	1 05 to 1 30	1874.
	Drab		1 00 to 1 10	
	Olive		1 00	
	Yellow		1 00 to 1 07	
Mary's Point, New Brunswick	Brown	15 00	90 to 1 10	
	Salmon	15 00		
	Olive	13 00		
Wood Point, New Brunswick	Brown	14 00	1 00 to 1 10	
	Red	12 00	1 05	
Wallace, Nova Scotia				
Kennetcook, New Brunswick	Brown		1 00	
	Olive	13 00		
	Blue	13 00		

SANDSTONE—Continued.

Locality.	Color.	Price per ton.	Price per cubic foot.	Remarks.
Berlin Heights, Ohio	Buff or yellow		$0 60 to $1 00	To $1 20, 1874.
	White		1 00	
New Amherst, Ohio	No. 1 buff		95 to 1 05	To $1 20, 1874.
	No. 1 blue and light drab.		80 to 95	
Cleveland, Ohio	White		90 to 1 00	
	Blue		1 00	
Independence, Ohio			1 10	
Buena Vista, Ohio			1 55	
Cincinnati, Ohio			1 00	
Berea, Ohio			1 00	Varied 85 cents to $1 15.
Carlisle, England	Red		1 00 to 1 10	
Corsehill, Scotland	do		1 00 to 1 05	

LIMESTONE.

Locality.	Color.	Price per ton.	Price per cubic foot.	Remarks.
Ellettsville, Indiana			$1 25	
Caen, France			1 50	
Bedford, Indiana			1 25	

MARBLE.

Locality.	Color.	Price per ton.	Price per cubic foot.	Remarks.
Westchester county, New York			$1 50	
Canaan, Connecticut			$1 55 to 1 70	1876.
Sutherland Falls, Vermont			1 25 to 1 75	

GRANITE.

Locality.	Color.	Price per ton.	Price per cubic foot.	Remarks.
Millstone point, Connecticut			$0 60	
Roxbury, Connecticut			$0 65 to 1 25	
Quincy, Massachusetts			2 00	
Westerly, Rhode Island			1 50	
Mount Waldo, Maine			60	
Clark's island, Maine			75	
Spruce Head, Maine			60	
Round Pond, Maine			1 50	For stones 20 feet and under.
Granite (hammered)		About $16 50	1 00 to 1 50	

GNEISS.

Locality.	Color.	Price per ton.	Price per cubic foot.	Remarks.
Foundation stone (rubble)			$0 08 to $0 10	
Building stone, per load			2 00 to 3 00	

BLUE-STONE AND FLAG-STONE.

Locality.	Color.	Price per ton.	Price per cubic foot.	Remarks.
Wilbur, Ulster county, New York	Bluestone		$0 70 to $1 50	For sills, lintels, etc.
	..do		07 to 1 00	For copings (per yard).
Kingston, Ulster county, New York	do		09 to 3 50	
Smithville, Chenango county, New York	do		1 25	
Skinner's Eddy, Wyoming valley, Wyoming county, Pennsylvania	do		1 00 to 1 50	
Wyoming valley, Mesboppen, Wyoming county, Pennsylvania	do		1 50	

FLAG-STONE.*

Length in feet.	Thickness, inches.	Per square foot, cents.
3	2	3
4	2	4
5	2	3½
6	2	6½
8	4	10 to 12

*Pond Eddy, Lackawaxen, etc., Pike County, Pennsylvania; retailed at 15 cents to $1 50 per square foot.

ROOFING SLATE.

	Per square foot.
Purple or green	$7 00 to $8 00
Red	15 00
Black (Pennsylvania)	4 75 to 5 25

STATISTICS OF BUILDINGS (NUMBERS AND MATERIALS) IN NEW YORK CITY AND BROOKLYN.

Material.	NEW YORK CITY.				BROOKLYN.			
	District of wholesale business houses.	District of small stores and tenements.	District of large stores and residences.	Entire city.	District of warehouses, tenements, etc.	District of residences and small stores.	District of small residences, Long Island city.	Entire city.
Freestone:								
Brown sandstone	566	1,598	6,979	9,143	225	6,377	4	6,606
Nova Scotia sandstone	237	88	725	1,050		167		167
Ohio sandstone		47	139	186				
Foreign sandstone			13	13				
Artificial							10	10
Limestone			3	3	1	1		2
Blue-stone			5	5				
Granite	149	9	46	204		3		3
Gneiss	3	40	61	104		18	5	23
Marble	636	10	272	918	7	87		94
Brick	8,515	20,457	34,157	63,129	5,691	23,581	211	29,483
Stucco	5	23	166	194	51	587		638
Iron	356	85	469	910	3	67		70
Frame	590	10,360	13,384	24,334	3,926	33,556	948	38,430
Total	11,057	32,717	56,419	100,193	9,904	64,444	1,178	75,526
Buildings with stone fronts				11,574				6,880
Buildings constructed almost entirely of stone				52				25
Total stone	1,591	1,792	8,243	11,626	233	6,653	19	6,905
Total brick and stucco	8,520	20,480	34,323	63,323	5,742	24,168	211	30,121

STATISTICS OF BUILDINGS (NUMBERS AND MATERIALS) IN THE SUBURBS AND IN THE ENTIRE METROPOLIS.

Material.	STATEN ISLAND.	JERSEY CITY.			HOBOKEN.				New York city and its suburbs.
	Castleton, etc. (Staten island).	Jersey City proper, including Hudson City and Bergen city.	Bayonne and Greenville.	Entire city.	Hoboken proper.	West Hoboken and town of Union.	Weehawken.	Entire city.	
Freestone:									
Brown sandstone	8	294	38	332	121	21		142	16,231
Nova Scotia sandstone	3	4		4	7			7	1,231
Ohio sandstone		15		15					201
Foreign									13
Artificial stone									10
Limestone									10
Blue-stone									215
Granite	4	4		4					153
Gneiss	15	3		3	7	1		8	1,027
Marble	12	3		3					63
Trap		8	50	58		5		5	
Brick	716	4,441	224	4,665	1,708	174	31	1,913	99,906
Stucco	16	96		96	136	5		141	1,085
Iron		8		8					988
Frame	6,951	12,656	3,036	15,692	1,518	2,452	98	4,068	89,475
Total	7,725	17,532	3,348	20,880	3,497	2,658	129	6,284	210,608
Buildings with stone fronts	40	331	88	419	135	27		162	19,075
Entirely of stone	2								79
Total stone	42	331	88	419	135	27		162	19,154
Total brick and stucco	732	4,537	224	4,761	1,844	179	31	2,054	100,991

STATISTICS CONCERNING THE PHYSICAL PROPERTIES OF THE BUILDING STONES USED IN NEW YORK CITY.

GRANITE.

Kind.	Locality.	Size of cube in inches.	Position.	Number of trials.	Compressive strength per square inch.	
					Range.	Average.
					Pounds.	*Pounds.*
Red	Bay of Fundy, Canada	2	Bed	2	11,812 to 12,020	11,916
Do	do	2	Bed	1		17,500
		2	Edge	1		18,750
Do	Fox island, Maine	2		2	11,700 to 14,875	13,287
Do	do	2	Bed	1		15,062
Do	do				11,892 to 14,185	
Do	Dix island, Maine	2		1		15,000
Do	do					24,000
Do	Spruce Head, Maine	2		2	13,500 to 17,500	15,500
Do	do	2	Bed		14,200 to 15,875	
Gray	Hurricane island, Maine	2	Bed	2	11,000 to 14,425	12,712
		2	Edge	1		14,937
Do	Palmer quarry, Maine					
Do	Jonesboro', Maine				11,233 to 15,952	
Light	Harbor quarry, Maine	2	Bed	2	16,218 to 16,837	16,527
Do	East Bluehill, Morgan's bay, Maine	2				17,200
Do	East Bluehill, Maine	2	Bed		12,125 to 16,250	
Light gray	East Boston, Maine	2	Bed	2	16,031 to 18,000	17,015
Do	City Point, Maine					
Do	Frankfort, Maine	2	Bed	1		18,026
		2	Edge	1		15,700
Do	Carver's quarry, Maine					
Do	Long Cove, Maine	2	Bed	1		14,040
Do	Wharf quarry, Maine					
Do	K., W. & Co.'s quarry, Maine					
Do	Concord, New Hampshire				8,812 to 9,838	
Do	do	2	Bed	1		17,550
Dark	Quincy, Massachusetts	2				17,750
Do	do	2	Bed		18,000 to 19,600	
Do	do					9,739
Do	do				11,730 to 15,622	
Light	do	2				14,750
Gray or mottled	do	2.2 to 2.9		2	12,390 to 15,929	
Do	Quincy, Massachusetts (Wigwam quarry)	1.5		3		29,330
Do	Cape Ann, Massachusetts	2	Bed	2	12,423 to 19,500	15,961
Syenite	do	2	Bed		12,861 to 19,280	
		2	Edge			17,875
Gray	Rockport, Massachusetts	2	Bed	1		16,300
		2	Edge	1		19,750
Do	do					15,296
Old quarry	Westerly, Rhode Island	2		2	17,250 to 17,750	17,500
Gray	do	2	Bed	1		14,687
		2	Edge	1		14,937
Do	do				15,591 to 18,778	
Do	Millstone point, Connecticut	2		2	16,187 to 18,750	17,468
Do	do	2	Bed		17,425 to 17,550	
Do	Greenwich, Connecticut	2		2	11,300 to 11,700	11,500
Do	Plymouth, Connecticut				8,620 to 10,412	
Niantic river	New London, Connecticut	2		1		12,500
		2	Edge	1		14,175
Porter's rock	Mystic River, Connecticut	2	Bed	1		18,125
		2	Edge	1		22,250
Gray	Stony Creek, Connecticut	2	Bed	2	15,000 to 15,750	15,375
		2	Edge	1		16,750
Do	Tarrytown, New York	2	Bed	1		18,250
Flagging	Hudson river, New York	2		1		13,425
Gray	Garrison's, Hudson river, New York	2	Bed	1		12,260
		2	Edge	1		13,370
Do	Peterhead, Scotland*	1.5			8,290 to 18,636	
Do	do*	1				6,273
Do	do*				9,666 to 10,102	

* Foreign stones for comparison.

STATISTICS CONCERNING THE PHYSICAL PROPERTIES OF THE BUILDING STONES USED IN NEW YORK CITY.

GRANITE.

Specific gravity.	Weight of one cubic foot.	Ratio of absorption.	Remarks.	Transverse strain.	Authority.
	Pounds.			*Pounds.*	
2.600	162.5	Not noticeable	Boldly marked, resembling fine breccia		Q. A. Gillmore.
		do	do Used in Central park		Do.
2.631 to 2.660	164.1 to 166.3	Very slow	Burst suddenly		Do.
2.660	166.3	do	do		Do.
					C. B. Richards.
2.635	166.5	Very slow	Burst suddenly		Q. A. Gillmore.
2.750	171.9	Very slow	Burst suddenly		Q. A. Gillmore.
					Probasco.
2.670	166.9		Burst suddenly		Q. A. Gillmore.
					C. B. Richards.
2.650	165.6	Not noticeable	Boldly marked, resembling fine breccia		Q. A. Gillmore.
	166.5	0.233 per cent			J. S. Newberry.
					Probasco.
2.630	164.4	Not noticeable	Finely marked; bluish		Q. A. Gillmore.
					Probasco.
					Do.
					Probasco.
					C. B. Richards.
					Probasco.
2.660	166.2	Very slow	Cracked before bursting		Q. A. Gillmore.
					Probasco.
2.67				235	T. Rodman.
					C. B. Richards.
2.695	168.7	Very slow	Cracked before bursting		Q. A. Gillmore.
					W. R. Johnson.
2.649 to 2.657	165.8	3.25 grains			Do.
		do	Broke suddenly		Do.
					Probasco.
2.610	163.2	1 to 152			Q. A. Gillmore.
2.65				274	T. Rodman.
2.646	165.6	Very slow	Broke suddenly		Q. A. Gillmore.
2.670	166.9	do	do		Do.
					C. B. Richards.
2.706	168.7	Very slow	Broke suddenly		Q. A. Gillmore.
					Probasco.
2.835	177.2	Very slow	Broke suddenly		Q. A. Gillmore.
					C. B. Richards.
2.660	166.25	Very slow	Broke suddenly		Q. A. Gillmore.
2.630	164.4	do	do		Do.
2.645	165.4	1 to 201	Burst suddenly		Do.
2.655	162.2	Very slow	Cracked before bursting		Do.
2.690	168.1	do	Broke suddenly		Do.
2.580	161.3	1 to 167			Do.
					G. Rennie.
		0.5 to 3.0 per cent	Wray		V.
					Bramah.

STATISTICS CONCERNING THE PHYSICAL PROPERTIES OF THE BUILDING STONES USED IN NEW YORK CITY—Continued.

Kind.	Locality.	Size of cube in inches.	Position.	Number of trials.	Compressive strength per square inch.	
					Range.	Average.
					Pounds.	*Pounds.*
	GNEISS.					
Harlem stone	Morrisania, New York	2		1		15, 800
Dark	Madison avenue, New York	2	Bed	1		11, 250
		2	Edge	1		12, 500
	TRAP.					
Blue	Staten island, New York	2	Bed	1		22, 250
Very dark	Jersey City heights, New Jersey	2	Bed	2	20, 750 to 22, 250	
Do	Palisades, New Jersey					19, 700
Whetstone	England*					8, 267
Do	do*					11, 970
	MARBLE.					
Eastchester	Tuckahoe, New York	2	Bed	2	12, 050 to 12, 950	12, 500
Do	do	2	Bed	2	13, 594 to 13, 711	13, 652
Do		4		1		4, 081
Do		1.5	Bed	1		23, 917
Do	Hastings, New York	1.5	Bed	9		18, 941
Do	Pleasantville, New York				18, 000 to 24, 000	
Vermont	Dorset, Vermont	2	Bed	1		7, 612
Do	do	2	Edge	1		8, 670
Do	Rutland, Vermont				1, 305 to 1, 375	
Do	West Rutland, Vermont				11, 000 to 12, 500	
Do	Pittsford, Vermont				11, 250 to 18, 750	
Do	Sutherland Falls, Vermont				10, 243 to 11, 250	
Do	do				12, 250 to 20, 000	
Do	West Stockbridge, Massachusetts	1.5	Bed	4		10, 382
Do	do	1.5	Bed	12		9, 071
Do	Stockbridge, Massachusetts	1.5	Bed	10		8, 812
Do	Lenox, Massachusetts	1.5	Bed	8		7, 153
Do	Stockbridge, Massachusetts	4		1		2, 410
Do	Lee, Massachusetts	1.5	Bed	3		22, 702
White	do				12, 917 to 13, 972	
Bluish	do				7, 705 to 17, 954	
Do	Canaan, Connecticut				4, 958 to 8, 794	
Carrara	Carrara, Italy*				9, 723 to 12, 600	
Common Italian	Italy*	2	Bed	2	11, 250 to 13, 062	12, 156
White Italian	do*	1.5				21, 778
	SANDSTONE.					
Freestone	Dorchester, New Brunswick	2	Bed	2	9, 150 to 9, 412	9, 281
Freestone (olive)	do	2	Bed	1		4, 250
		2	Edge	1		6, 050
Freestone (brown)	Mary's Point, New Brunswick					9, 250
Freestone (olive)	do					9, 250
Freestone (dark brown)	do				7, 586 to 7, 828	
Freestone	Wood Point, New Brunswick				3, 976 to 4, 932	
Do	Nova Scotia				6, 532 to 10, 322	
Brownstone	Middletown, Connecticut	2	Bed	1		6, 950
		2	Edge	1		5, 550
Do	Portland, Connecticut				5, 806 to 10, 928	
Do	San Diego, California*					20, 039
Carlisle stone	Corsehill, Scotland*	6				7, 909
Do	Craigleith, Scotland*	1				3, 137
Do	do*	1.5				5, 489
Do	do*	2				7, 842
Brown	Little Falls, New York	2	Bed	1		9, 850
		2	Edge	1		9, 150
Red	Haverstraw, New York	2	Bed	1		4, 350
		2	Edge	1		4, 025

* Foreign rocks for comparison.

STATISTICS CONCERNING THE PHYSICAL PROPERTIES OF THE BUILDING STONES USED IN NEW YORK CITY—Continued.

GNEISS.

Specific gravity.	Weight of one cubic foot.	Ratio of absorption.	Remarks.	Transverse strain.	Authority.
	Pounds.			*Pounds.*	
2.720	170.0	Very slight	Broke suddenly		Q. A. Gillmore.
} 2.920	182.5		Probably rich in iron		

TRAP.

Specific gravity.	Weight of one cubic foot.	Ratio of absorption.	Remarks.	Transverse strain.	Authority.
2.861	178.8	Very slight	Cracked before bursting		
3.030	189.5	Not noticeable			
			For pavements		
			Basalt (?)		Bramgh.
		Trace	do		Fairbairn.

MARBLE.

Specific gravity.	Weight of one cubic foot.	Ratio of absorption.	Remarks.	Transverse strain.	Authority.
2.875	179.7	Very small	Burst without cracking		Q. A. Gillmore.
2.800	175.0		Burst without cracking; whiter and better variety		Do.
					Page.
2.858	178.6	0.00393 oz			United States Commission, 1851.
2.861	178.8	0.0066 oz			Do.
					Q. A. Gillmore.
2.635	164.7	1 to 170	With slight explosion		Do.
2.683	167.8		do		Do.
2.635					H. A. Cutting.
2.666	167.0				United States Government.
2.661 to 2.672					H. A. Cutting.
					F. E. Kidder.
	166–178				United States Government.
2.714	169.6	0.0068 oz			United States Commission, 1851.
2.713	169.6	0.007025 oz			Do.
2.713	169.6	0.0087 oz			Do.
2.709	169.3	0.011966 oz			Do.
					Page.
2.862	178.9	0.0103 oz			United States Commission, 1851.
					Do.
					C. B. Richards.
					Do.
2.69	168.2	Very small	Without cracking		Q. A. Gillmore.
		Trace			Rennie.

SANDSTONE.

Specific gravity.	Weight of one cubic foot.	Ratio of absorption.	Remarks.	Transverse strain.	Authority.
			Without cracking		Q. A. Gillmore.
			do		Do.
			do		Do.
					J. Henry.
					Do.
					C. B. Richards.
} 2.360	148.5	1–40	Without cracking		Q. A. Gillmore.
					C. B. Richards.
2.640				425	T. Rodman.
					Kirkaldy.
					V.
					G. Rennie.
		8 per cent			Royal Commission.
} 2.250	140.6	1 to 34	Suddenly hardened by weathering		Q. A. Gillmore.
} 2.130	133.1	1 to 23	Without cracking		Do

STATISTICS CONCERNING THE PHYSICAL PROPERTIES OF THE BUILDING STONES USED IN NEW YORK CITY—Continued.

SANDSTONE—Continued.

Kind.	Locality.	Size of cube in inches.	Position.	Number of trials.	Compressive strength per square inch. Range.	Average.
					Pounds.	*Pounds.*
Gray	Belleville, New Jersey	2	Bed	1		11,700
		2	Edge	1		10,250
Pink	Medina, New York	2	Bed	1		17,250
		2	Edge	1		14,812
Drab	do	2	Bed	1		17,725
Do	do	2	Edge	1		11,880
Do	Berea, Ohio	2	Bed	5	29,000 to 41,000	
Brownish-gray	North Amherst, Ohio	2	Bed	2	5,775 to 6,650	6,212
		2	Edge	1		5,450
Light drab	do				7,000 to 8,000	
Do	Cleveland, Ohio				6,141 to 8,955	
Do	Berlin, Ohio	2	Bed			14,250
		2	Edge			12,000
Reddish brown	East Longmeadow, Massachusetts				9,121 to 13,506	
Brown	do				8,062 to 8,812	
Do	do				13,520 to 14,650	

SANDSTONE (BLUE-STONE).

Kind.	Locality.	Size of cube in inches.	Position.	Number of trials.	Range.	Average.
Blue-stone	Hudson river, New York	2	Bed		9,000 to 13,000	
		2	Edge			11,482
Do	Ulster county, New York				21,150 to 23,825	
Graywacke	Penmænmawr, Wales*	2				16,893

LIMESTONE.

Kind.	Locality.	Size of cube in inches.	Position.	Number of trials.	Range.	Average.
Glens Falls	Glens Falls, New York	2	Bed	1		11,475
		2	Edge	1		10,750
Lake	Lake Champlain	2	Bed	1		25,000
		2	Edge	1		21,500
North river	Kingston, New York	2	Bed	1		13,900
		2	Edge	1		11,050
Do	do	2	Bed		13,750 to 15,550	
Do	Garrison's station, New York	2	Bed	10		18,500
		2	Edge	1		18,275
Do	do	2	Bed	3	17,750 to 18,775	18,262
Caen	Caen, France*	2	Bed	2	3,450 to 3,650	3,550

*Foreign rocks for comparison.

STATISTICS CONCERNING THE PHYSICAL PROPERTIES OF THE BUILDING STONES USED IN NEW YORK CITY—Continued.

SANDSTONE—Continued.

Specific gravity.	Weight of one cubic foot.	Ratio of absorption.	Remarks.	Transverse strain.	Authority.
	Pounds.			*Pounds.*	
2.259	141.0	1 to 27	Suddenly		Q. A. Gillmore.
2.410	150.6	1 to 55	Lilac		Do.
2.390	149.3	1 to 51	More purple		Do.
2.420	151.1	1 to 70			Do.
					Probasco.
2.110 to 2.200	131.9 to 137.5	1.16 to 1.24	Without cracking; very friable		Q. A. Gillmore.
2.16 to 2.19	135.0 to 136.9	1 to 19	do		Do.
2.14	133.7		do		Do.
					J. S. Newberry.
					C. B. Richards.
					Q. A. Gillmore.
					Do.
					Saulsbury.
					McGregory.

SANDSTONE (BLUE-STONE).

Specific gravity.	Weight of one cubic foot.	Ratio of absorption.	Remarks.	Transverse strain.	Authority.
					Probasco.
					Do.
2.720				609	T. Rodman.
					Fairbairn.

LIMESTONE.

Specific gravity.	Weight of one cubic foot.	Ratio of absorption.	Remarks.	Transverse strain.	Authority.
2.700	168.8		Burst without cracking		Q. A. Gillmore.
2.750	171.9		do		Do.
2.69	168.2		do		Do.
					Probasco.
2.635	164.7		Burst without cracking		Q. A. Gillmore.
2.616	163.5		do		Do.
1.900	118.8	1 to 19 9.86	Burst without cracking; tensile strength, 150 (G. R. Bunnell); loss in dilute acid and boiling water, 6.17 per cent.		Do.

NORTH ADAMS, MASSACHUSETTS.

The materials used in the principal stone structures of this city are limestone from North Adams and quartzite from Clarksburg, Massachusetts. The foundations and underpinnings are of local limestone and Clarksburg quartzite, with some blue-stone. The Catholic church and two factories are built of limestone from the local quarries. Dr. Babbits' residence and Mr. Pendeman's office are two small edifices built of quartzite; as this contains a little pyrites some of the blocks are stained. The new Episcopal church in course of construction will be of blue-stone and pressed brick, with Longmeadow and Ohio sandstone trimmings over the windows and doors. The steps to the chancel will be of marble and the interior trimmings over the windows of terra-cotta. The railroad depot buildings and most of the churches are built of brick. The Hoosac tunnel is at this place, but the material used for archways is brick. The streets are paved with stone, the chief part of such pavement being on Eagle street, where cobble-stones are used for the purpose. The sidewalk on one block in front of the Wilson house is paved with North River blue-stone. Many of the sidewalks are paved with concrete; the curbs are of blue-stone, limestone, and quartzite.

NORTHAMPTON, MASSACHUSETTS.

There are but two buildings in Northampton entirely constructed of stone, and there are two others with stone fronts. The material used for the better class of stone construction is sandstone from Longmeadow, Massachusetts, and brownstone from Portland, Connecticut. One of the Congregational churches is built of the former material and the Smith Charities building of the latter. The materials used for foundations and underpinnings are sandstone and granite from quarries within the limits of the town, as both these formations are here exposed. One or two hundred feet of the pavement in front of the court-house is of thinly bedded sandstone from Smith's ferry; these blocks frequently exhibit rows of "bird tracks" upon them. They are now very much worn and the tracks are becoming obliterated. There is a quarry of coarse sandstone very near the Mount Tom station, 3 miles south of the main village, which furnishes stone for ordinary puposes of construction in the neighborhood. The streets are not paved with stone, with the exception of the space fronting the court-house already mentioned, and the sidewalk pavement is mostly of asphalt and brick; curbstones are of granite. The piers of the bridge across the Connecticut river are of sandstone from neighboring quarries.

OGDENSBURG, NEW YORK.

Limestone from the quarries near this city is of good quality, blue-black in color; and there are some examples of excellent stone work built of it, including range work and ashlar. Some of the structures of this limestone have Potsdam sandstone trimmings. These two materials when used together make a good harmony of colors, and the effect is pleasing. In some portions of these quarries it is necessary to use care in selecting the material, as parts of it contain iron. Some of the Ohio sandstones in the structures here have discolored, while others have retained their original appearance. There are several stone grist-mills in the city, two of the number being trimmed with sandstone from Potsdam and Hammond, Saint Lawrence county; the others are trimmed with native limestone. There are some heavy bridge abutments all constructed of limestone from the quarries within the city limits, and the breakwater is constructed of the same material. The streets and roadways are macadamized with limestone from the local quarries, and a few are paved with Potsdam sandstone; but few of the sidewalks are paved with stone, and the material used is the Potsdam sandstone. The curbstones are of Potsdam stone and limestone from Chaumont.

ORANGE, NEW JERSEY.

The cities of South and East Orange may be said to be noted for the size and elegance of their church edifices. They are all substantial buildings; several of them are brick with sandstone trimmings. Sandstone is largely used in cemetery walls, in walls surrounding lawns and other inclosures, in steps, house-trimmings, and in cellars and foundations. Nearly all of it has been obtained from the quarries in the faces of First mountain, 2 miles west of the town of Orange. The durability of the stone has been tested in the First Presbyterian church, erected in 1813, and also in some of the old walls in farm-houses of the surrounding country. The town is also noted for its Telford or macadamized roadways, in common with all of Essex county. Many miles of the best roads found in the United States are in this county; they are made of trap-rock from the large quarries in the eastern face of Orange or First mountain, a few miles west of Orange, which are all under the management of the Essex Road board. (*a*)

The following is a list of prominent stone structures in Orange, with materials from which they were constructed: Saint Mark's P. E. church, Grace P. E. church, First Presbyterian church, Central Presbyterian church, Munn Avenue church, South Orange Presbyterian church, all of Orange sandstone; South Orange P. E. church, trap-

a See Annual Report of the State Geologist of New Jersey, 1871.

rock with sandstone trimmings, both from local quarries; Orange Valley Congregational church, trap-rock with sandstone trimmings; South Orange Baptist church, Ohio sandstone; Saint Mark's P. E. church and school, Mr. J. G. Barker's residence, Mr. Davis Collamore's house, and Mr. Tome's private residence, all of trap-rock and sandstone, from local quarries.

There is no stone street pavement, excepting the road-bed of the First Street horse-car road, a road which is paved partly with rectangular blocks of trap-rock and partly with cobble-stones. The streets and roadways are pretty generally macadamized with trap-rock. The sidewalks are largely paved with stone, and the material used for this purpose is the North River blue-stone, from Ulster county, New York. Curbs are of the same material.

OSWEGO, NEW YORK.

The Oswego gray sandstone quarried in the vicinity is a good building material, except when set on edge in the exterior walls of buildings, in which case it flakes off by the action of dampness and frost. It is not suitable for sidewalk paving because its laminated structure causes it to separate into thin layers, when it easily breaks up under the action of foot-wear. Limestone from Chaumont, Jefferson county, New York, was used in the piers and abutments of the highway and railway bridges crossing the Oswego river in this city; it was also the principal stone used in the two dams across this river. A portion of the old breakwater now being destroyed consists of cut limestone from Chaumont. Fort Ontario—principally an earthwork—has some stone bastions of Oswego gray sandstone, and the largest and best quarry in this city is located in the fort grounds. The stone filling in the new breakwater cribs consists mostly of hardhead cobbles, with some quarried gray sandstone. Some red sandstone, found along the Oswego river about a mile south of its mouth, was used for crib-filling, but, owing to its rapid disintegration by wave action, it is no longer used for that purpose. For foundations and underpinnings the Oswego gray sandstone quarried in the immediate vicinity and some Chaumont limestone were used. There are but three streets paved with stone, and those chiefly with cobble. About half a mile of the 2 miles of paved street consists of block stone of materials from Potsdam, Jefferson county, North River blue-stone from Ulster county, and Oswego sandstone. The sidewalks are but little paved with stone, and the material used is Cayuga Lake stone, with some also from Chenango and Delaware counties. The curbstones are of Chenango County sandstone and Chaumont limestone.

PATERSON, NEW JERSEY.

There are sandstone quarries in the First mountain, near Paterson, which furnish a large part of the material for stone construction in the city. This sandstone is used largely in cellar walls and foundations; the quarries are in the eastern face of the mountain within the city limits and above the general level of the city, so that stone is afforded at a low rate. A quarry at Haledon, about 3 miles to the northwest, has furnished some material during the past season; this is a buff-colored Triassic sandstone resembling the Ohio sandstone. Within the city limits there are several old farm-houses, or structures originally built for farmers' houses, of red sandstone; the durability of the material as shown in these buildings is evidence of the value and adaptation to use in stone construction. Some of them were probably built of surface rock, that is, of loose blocks found on the surface in clearing up the country for farming purposes. In the adjacent parts of Passaic county there are very many old houses built of the native sandstone. These houses are usually low, being only a story and a half in height. The stone in the walls is sometimes dressed with square edges, and in some instances it is laid up rough-dressed only; and much of it is coarse-grained and soft.

The brown freestone of the Paterson and Little Falls quarries has been used extensively in the city, and there are many large structures of the material, among which may be mentioned the Passaic County court-house and jail, and the Roman Catholic church. This material has also been used in the construction of the aqueduct of the Water-Power Company, in the bridges over the canal, and in abutments and piers of bridges crossing the Passaic river; also largely in walls inclosing lawns and private grounds. The number of miles of graded streets in Paterson is 53½; of this length 2.76 miles are paved with cobble-stones; 0.16 mile with macadamized block pavement, the material being brought from New England; 9.44 miles with macadamized Telford pavement; the total number of miles of paved streets, 12.36. The sidewalks are largely paved with stone, there being about 25 miles of stone sidewalks, and the material used for this purpose is the North River blue-stone, with some stone from Carr's, Sussex county. The curbs are of North River blue-stone.

PAWTUCKET, RHODE ISLAND.

The five stone buildings in Pawtucket are constructed of what is known as the ledge stone, which is quarried in the vicinity. Foundations and underpinnings are of blue and red slate from ledges in the town, and bowlders gathered in the vicinity. Some of the underpinnings are of granite from Smithfield and Diamond Hill. All the mills, excepting two or three, are of brick or wood. There is one large mill made of ledge stone and bowlders in the vicinity. There are ledges of slate from which material is obtained for walls, underpinnings, etc., and bowlders are somewhat used for the same purposes. The two materials most used beside brick, for post trimmings and sills and underpinnings in the better houses, are granites from Smithfield and from Diamond Hill. The post-office front is partially of yellow sandstone, and the remainder is of brick with red sandstone trimmings, and several polished columns of red Aberdeen granite which resembles very much the material from Jonesboro', Maine. There are two stone bridges in the city; the upper one, built in 1858, has two arches of granite from a quarry in North Providence, near Smithfield. The Division Street bridge is a fine granite structure of 9 arches, and is built of granite quarried at Sterling, Connecticut. Only the streets in the central portion of the town are paved, and those chiefly with cobble-stones, though in recent years granite blocks of material from Diamond Hill have been employed. The sidewalk paving is chiefly of brick and concrete, though Hudson River flags and granite have been employed to a limited extent for this purpose. The curbstones are of granite from Diamond Hill and Smithfield, with some Hudson River blue-stone.

PETERSBURG, VIRGINIA.

There are three stone buildings in Petersburg—one, the custom-house, built of granite from the Namozine district, Dinwiddie county, in the immediate vicinity of the city. It is now more than twenty years since it was completed, and the stone is remarkably free from discoloration of every kind. That in the foundation, from the quarry of Dr. E. W. Lassiter, ranks with the best of building stones; and that in the superstructure is from a quarry now abandoned. The two fronts of Connecticut sandstone, on Sycamore street, show signs of decay; the material is destructible even in this latitude. The materials for foundations and all other ordinary purposes are obtained from the granite quarries in the immediate vicinity. A few of the streets are paved with cobble-stone; there is very little sidewalk paving of granite from the local quarries, and North River blue-stone, from Rondout, New York, has also been used for paving. Curbstones are of local granite.

PHILADELPHIA, PENNSYLVANIA.

That stone began to be an important element in construction in Philadelphia from its first settlement, and that it has always been preferred to other materials for use in the better class of buildings, we learn from old records that occasionally refer to the subject, and from the evidence of stone structures of various dates still standing. Many of the first brick houses with stone foundations are still standing in the older parts of the city, and may be known by their quaint style of architecture and by the peculiar checkered appearance of their walls, which are built of red and glazed bricks, arranged alternately—as the Penn mansion in Letitia court, built in 1682; the Swedes' church, in 1698, and Carpenter's hall, in 1770.

Government buildings, and college, school, church, hospital, prison, and most other public buildings are of stone, which has always held the first rank in the construction of the private residences of the wealthier classes. Stone is also used to a more than ordinary extent for caps, sills, base courses, corners, and other trimmings of brick buildings. One of the most noticeable features of the city, and one which adds much to its appearance of uniformity, is due to the custom which has long reigned here of trimming brick buildings with plain marble caps and sills. Of late years, however, the custom has not been so rigid, as Connecticut brownstone, Amherst (Ohio) stone, Hummelstown (Pennsylvania) brownstone, and North River blue-stone have been extensively used for trimmings.

A record in the office of revision of taxes in Philadelphia gives the following statistics: Total number of buildings in city in 1880, 168,176; number of stone buildings in city in 1880, 10,518; percentage of stone buildings, 6.

Of the 10,518 buildings classed as stone it is estimated that about 6,000 are constructed entirely of stone, and that the remaining 4,518 have stone fronts.

Until within the last fifty years the rock formations in and near the city had furnished very nearly all the stone used for building purposes; within that time Connecticut brownstone, North River blue-stone, New England granite, Vermont and Massachusetts marbles, Ohio sandstone, Chester county, Pennsylvania, serpentine or greenstone, Hummelstown brownstone, Richmond granite, and other stones have been introduced and extensively used for the better class of buildings.

The southern portion of Philadelphia is built on an alluvial deposit of gravel and clay which furnishes nothing for building purposes except the smooth, rounded pebbles gathered on the banks of the Delaware, and which have been extensively applied to street paving—two-thirds, perhaps, of the pavements in the city being of this material.

Near the central part of the city, the southern gneissic district, described by Professor Henry D. Rogers, (a) sets in. Of the area (129 square miles), including within the present limits of the city all not included in the alluvial deposit before described, excepting a few isolated exposures of steatite and serpentine, is made of this gneissic formation, and the ground where it prevails is gently rolling and sometimes hilly in its features. The process of grading and leveling has been going on to such an extent, especially in the more thickly settled parts of the city, that much of this rolling ground has been much modified in appearance. West Philadelphia, Fairmount park, Germantown, Manayunk, and other suburbs still retain something of their original features of surface.

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a Vol. I, *First Geological Survey of Pennsylvania.*

Near the Fairmount water-works cliffs of the gneiss are exposed to view, the large reservoir being in fact built on a natural elevation of this stone, and most of the masonry in connection with the water-works is of the same material.

Professor Rogers, in the report before mentioned, describes the gneiss substantially as follows: There are three principal varieties. The most common and typical variety is a gray-bluish rather finely laminated triple mixture of quartz, feldspar, and mica, the quartz for the most part white or transparent, the feldspar usually white and very generally somewhat chalky from incipient decomposition, and the mica black or dark brown and in small plates. The next most common variety is a dark bluish-gray, sometimes grayish-black, gneiss composed of hornblende and quartz with sometimes a little feldspar, the hornblende greatly predominating. A third variety is a micaceous quartzose rock generally of a light gray color. Some beds of this variety contain such a predominance of the crystalline quartz in minute granular division, and such a subordinate quantity of mica disseminated through it, as to give it the character of ordinary gray whetstone.

These three varieties of gneiss, thus described by Professor Rogers, are found in inexhaustible quantities within and near the limits of the city, and have been its principal resource for the ruder and plainer purposes of construction. It has been freely used in foundations, cellars, inclosure and terrace walls, bridge abutments, piers, wharves, rubble pavements, and work of that class, as well as in the construction of private residences and church, school, and other public buildings. Foundation and cellar work was all of this material until within the past fifteen years. Conshohocken limestone has been extensively used for the same purpose; an exception should perhaps be made also in favor of the Trenton brownstone, which has of late years been used to a limited extent for foundations.

Walls of this Schuylkill gneiss, as it is sometimes called, surround the Girard College grounds, the Eastern penitentiary, Laurel Hill, Woodlands, and numerous other cemeteries and public inclosures. Private residences were built of it in vicinities where it could be conveniently quarried, and in the early history of the city it was about the only source of supply for all purposes of stone construction, as may be seen by an examination of such of the structures of the last century and of the early part of the seventeenth century as are yet standing.

The following are among the buildings having foundations of the Schuylkill gneiss. The house in Letitia court, built by order of William Penn, about 1682, the oldest house in Pennsylvania, and said to be the first built within the limits of the city; Old Swedes' church, built in 1698, by settlers from Sweden, and presided over for one hundred and thirty years by pastors sent by the court of Stockholm; Carpenter's hall, built in 1770, and in which the first Continental Congress assembled in 1774; Independence hall, where the Declaration of Independence was signed July 4, 1776; Christ church on Second street, built in 1727, and numerous old fashioned and now dilapidated brick buildings on Second street and vicinity, which was in ante-Revolutionary days the business and fashionable part of the city.

Although in this locality brick seems to have been the favorite material for superstructures of the more pretentious buildings in early times, in the more northern portions, where the gneiss was at hand in inexhaustible quantities houses were built entirely of this material. Such parts of the original walls of the Belmont mansion, built in 1742 in Fairmount park, as are yet standing, are of the Schuylkill gneiss. The Mount Pleasant mansion, so rich in historic associations, situated on the opposite side of the Schuylkill from Belmont, is built of rectangular blocks of the gneiss. It is the variety which contains considerable feldspar in its composition, and the surface of the stone where exposed to the atmosphere seems inclined to roughen and crumble because of the decomposition of that ingredient. The walls are covered with a heavy coat of paint, which proves to be quite a valuable protection against the decomposing influence of the atmosphere. This house was built about the middle of the last century by Captain John McPherson, and it was purchased and occupied by Benedict Arnold while he was military governor of Philadelphia during the Revolution.

The house of John Penn, built in 1785, and still to be seen in the Zoological Gardens, is of this material, and is also protected by a coat of paint. The effectiveness of paint in protecting the variety of this gneiss, which contains considerable of the vulnerable feldspar in its composition, may also be seen in the portions of the foundations of Christ church which are above ground. In places where it has been abraded the roughening and crumbling process is going on, while the parts covered by paint remain intact.

In Germantown, now a suburb of Philadelphia, the Dutch settlers from the first constructed their houses of the gneiss which underlies the locality. Colonel Timothy Pickering, who was present at the battle of Germantown, writes that most of the houses standing there at that time were of stone. Chief Justice Benjamin Chew's stone house, Clivedon, which is at present occupied by his descendants, and is in a good state of preservation, was assaulted by the light artillery of the Americans during the battle for the purpose of dislodging several companies of British who had taken refuge there, but the masonry proved so solid that no impression was made except to break the windows and doors and destroy the statuary in the inclosed grounds.

The Woodlands, once a private residence occupied by the Hamilton family, built of rough blocks of the Schuylkill gneiss about the time of the Revolution, still stands in Woodlands cemetery. The high massive walls and imposing front of the Eastern penitentiary are built of the same material; also a number of churches in the central and northern portions of the city. This material is generally very distinctly stratified, the plates of mica showing quite plainly the parallel arrangement; but in the older buildings where the stone was used, it was laid up by the masons indiscriminately, apparently to suit their convenience, much of it being set on edge. This is particularly noticeable in the foundation walls of the Old Swedes' church. The stone seems to bear this treatment of setting on edge unusually well, showing but little disposition to scale off, and the practice still continues to some extent, as was noticed in buildings of recent date, particularly in the case of the buildings of the university of Pennsylvania, the foundations and basement stories of which are built of the gneiss. The treatment of setting on edge detracts something from the solidity and durability of a wall. Stratified rocks where used as building stone should invariably be laid the bed way.

An examination of many pretentious buildings of stone in this city shows that this important principle even now is often disregarded, sometimes in the case of stones least capable of withstanding such treatment. In one instance a huge rectangular block of brownstone serving as the base of a fine Corinthian column 6 feet in diameter was observed to be set on edge and already much defaced by the spalling off of the stone in thick slices. If the same block had been set the bed way, which it would seem could have been done quite as conveniently, no such injurious consequences would have resulted. Many of the stones used here for building purposes when set on edge will stand considerably less compression than where set bed way, as is demonstrated by crushing tests.

PENNSYLVANIA MARBLE.—The next source from which Philadelphia early began to draw building material was the marble in the limestone basin of Montgomery county. This is a narrow isolated strip of what is called by Rogers the Auroral limestone, the Siluro-Cambrian limestone of Professor Lesley in the *Reports of the Second Geological Survey of Pennsylvania*, and which is so important a feature farther to the northward in the Kittatinny or Cumberland valley. This material appears to have been first quarried by Daniel Hitner, about the time of the Revolution, or shortly afterward, (*a*) and from its close proximity to the city and its superiority in point of beauty to the Schuylkill gneiss, which had been the principal source of supply to builders up to this time, its use steadily increased from the first. Until 1825 it was transported to the city by teams, but about this time the completion of the Schuylkill canal afforded superior means of transportation and gave a great impulse to the use of this marble for building purposes in Philadelphia. In many parts of the city at the present time block after block may be seen having window caps and sills, and in many cases base courses and steps of this material. Of late years, however, New England marble is also largely used for these purposes.

The Montgomery County marble is distinguished from the other marbles in use here by its bluish color and coarser texture, the peculiarities of appearance being such as to make it easily recognizable after being once observed. It continued to be the only material used in the better class of stone construction from the time of its introduction to about 1840, when a new era was entered upon by the gradual introduction of brownstone, granites, and marbles from more distant points. During its reign of popularity many fine public buildings were constructed of it, among which are the Girard bank, built in 1798, the custom-house in 1819, United States mint in 1829, naval asylum in 1830, Merchants' exchange in 1832, and Girard college, begun in 1833. The sarcophagi in which rest the bodies of George and Martha Washington, at Mount Vernon, were wrought of this marble. A sarcophagus for Henry Clay, of Kentucky, is also said to have been made of it. Its reputation for durability is of the highest, but the superiority in point of beauty of the marbles from Vermont and Massachusetts and the Italian marble excludes it from the highest class of architecture, though it is now extensively used in that large class of stone-work wherein beauty is a secondary consideration, as for coping, inclosures, bases of monuments, and all the less ornamental class of work in cemeteries. Monuments are also frequently made of it, and in point of durability they often prove equal or superior to those made of the finer marbles.

Of the buildings constructed of Pennsylvania marble, the main Girard College building is by far the most considerable. This structure, well known as one of the finest specimens of Corinthian architecture in the world, is of Montgomery County marble, except the columns, bases of columns and architraves, which are of marble from Egremont, Massachusetts. There is much connected with this building calculated to offer a profitable subject for study to all who are interested in stone construction. The wide portico, extending entirely around the building, and supported by massive fluted columns, protects the outer walls entirely from wet, thus leaving scarcely any part of the building exposed to the destructive elements, excepting the marble roof and the outer steps, parts readily replaced when they have yielded to the effects of time. No combustible material enters into its construction nor into that of any of the accessory buildings designed for the accommodation of its pupils, and the ample grounds with which it is surrounded secure it from any injurious effects that might arise from the burning of adjacent buildings.

Since the transportation facilities by rail and water have enabled builders to choose their materials from a wide list, fashion seems to have dominated here to such an extent, as to private residences especially, that particular building stones have had their periods of popularity, some longer, and some shorter, when they were used for the better class of work to the partial exclusion of other stones.

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The following list of some of the most important buildings, with the dates or approximate dates of construction, will give a general idea of the time of introduction as well as of the periods of greatest popularity of each of the principal building stones that have been in use here from the first settlement of the city up to the present time:

Material.	Name of building.	Date of construction.
Schuylkill gneiss	Penn (Letitia) mansion (foundation)	1682
	Old Swedes' church (foundation)	1698
	Christ church (foundation)	1727
	Old state-house (foundation)	1732
	Belmont mansion	1742
	Mount Pleasant mansion	1760
	Church, Saint James of Kingsessing	1762
	Mennonite church	1770
	Chew house, or Clivedon	1770
	Carpenter's hall (foundation)	1770
	Woodlands mansion	1775
	Solitude	1785
	Eastern penitentiary	1823
	Seminary of Saint Vincent de Paul	1876
Pennsylvania (Montgomery county) marble	Girard bank	1798
	United States custom-house	1819
	United States mint	1829
	United States naval asylum	1830
	Merchant's exchange	1832
	Girard college	1833
Granite from—		
Quincy, Massachusetts	Moyamensing prison	1835
Cape Ann, Massachusetts	Woodlands Cemetery gateway	1850
Quincy, Massachusetts	Swaim's building, Chestnut street	1850–'60
	Elliot's building, Chestnut street	1850–'60
	Leland's building, Chestnut street	1850–'60
	Jayne's building, Chestnut street	1850–'60
	Dunbar's building, Chestnut street	1850–'60
	Mellor & Williamson's building, Chestnut street	1850–'60
	Jayne's building, Third street	1850–'60
	Leland's building, Third street	1850–'60
	Cope & Co.'s building, Market street	1850–'60
	Thurlow Hughes & Co., Fifth street	1850–'60
	Commercial bank	1850–'60
	Philadelphia National bank	1850–'60
	American Sunday-School Union	1850–'60
	First National bank	1865
Cape Ann, Massachusetts	Provident Life and Trust building	1865
Quincy, Massachusetts	Manufacturers' bank	1868
	French, Richards & Co.'s building	1869
	Pennsylvania Life and Trust Company building	1870
	Pennsylvania Railroad offices	1870
Cape Ann and Fox island, Maine	New Masonic temple (the porch is of Quincy granite)	1872
Concord, New Hampshire	Presbyterian Board of Publication	1873
Westerly, Rhode Island	New York Mutual Life Insurance building	1875
Concord and Richmond	Memorial hall	1876
Cape Ann and Quincy	Ridgeway library	1876
Dix island and Richmond	New post-office	Unfinished.
Connecticut brownstone	Moyamensing prison (east front)	1835
	SS. Peter and Paul's Catholic cathedral (front)	1846
	Saint Mark's P. E. church	1849
	Bank of Commerce	1850
	Bank of North America	1850
	Girard hotel	1850
	Old Masonic temple	1853
	Academy of Music (trimmings)	1855
	Holy Trinity Episcopal church	1857
	First Baptist church	1857
	Saint Clement's P. E. church	1859
	Fifth Baptist church	1863
	Union League house (trimmings)	1864
Picton sandstone from Nova Scotia and New Brunswick.	Harrison private residence	1851
	Sharpless Brothers' block	1858
	Strawbridge & Clothier block	1860
	Continental hotel	1860

Material.	Name of building.	Date of construction.
Marble from—		
Lee, Massachusetts	Farmers' and Mechanics' bank	1854
Vermont	Harrah private residence	1855
	Third National bank	1863
	Homer & Collady block	1866
Lee, Massachusetts	Dr. Jayne's private residence	1867
Vermont	Haffleigh's building	1868
	White's building, corner Twelfth and Chestnut streets	1869
Vermont and Lee, Massachusetts	Fidelity block	1869
Vermont	G. W. Childs' private residence	1871
Lee, Massachusetts	Philadelphia Trust and Safe Deposit	1874
Vermont	Saint George's hall (except front)	1876
	Baker building	1879
Lee, Massachusetts	New city buildings	Unfinished.
Serpentine, Chester county	Beth Eden church	1868
	University of Pennsylvania	1871
	Memorial Baptist church	1874
	Holy Communion church	1875
	Girls' normal school	1876
	Academy of Natural Sciences	1876
Ohio sandstone	Young Men's Christian Association	1868
	Academy of Fine Arts (trimmings)	1870
	Residence of Bloomfield Moore	1875
	Girls' normal school (trimmings)	1876
	Academy of Natural Sciences (trimmings)	1876
	Second Reformed Episcopal church	1878
	Horticultural hall (trimmings)	1881
	New city building (trimmings)	Unfinished.
	Saint Agatha's church, Roman Catholic (partly)	
	Saint Luke's Episcopal church (partly)	
Hummellstown, Pennsylvania, brownstone	Academy of Fine Arts (basement)	1870
	Holy Communion church (trimmings)	1875
	Academy of Natural Sciences (basement)	1876
	Philadelphia library (trimmings)	1877
	Building corner Fourth and Chestnut (trimmings)	1882
	Building corner Third and Walnut (trimmings)	1882
	Building corner Fifth and Walnut (trimmings)	1882
	Building corner Twenty-second and Walnut (trimmings)	1882
	Building corner Eighteenth and Spruce (trimmings)	1882

GRANITE.—The Moyamensing prison, built (1835) in gothic castle style, principally of Quincy granite, was probably the first building in Philadelphia in which granite was used. There is a streak of rust on the outside of the wall running down from each embrasure of the battlement, caused apparently by the streams of water directed through these openings in rainy weather. Parts of the wall protected from the streams of water retain their original color, a little dulled by time.

Among the most notable buildings of granite in Philadelphia are:

The new Masonic temple, Norman style of architecture, said to be the finest structure belonging to the order in the world. The porch is a very elaborate and ornate piece of work of Quincy granite.

The Ridgeway Library, Grecian architecture, situated in the center of ample grounds so as to be protected from injury by the burning of adjacent buildings—an advantage not possessed by some of the fine structures of granite here.

Memorial hall, erected to commemorate the one hundredth anniversary of the independence of the United States, is of the modern renaissance style of architecture, and cost $1,500,000; it has also extensive grounds surrounding it in Fairmount park.

The new post-office building on Chestnut street, a most beautiful structure of the French renaissance style, is approaching completion, and will cost when finished about $4,000,000.

The particular kinds of granite from which the buildings above mentioned are constructed are given in a list of the granite buildings. Cape Ann and Quincy are the kinds of granite most used in Philadelphia for general building purposes—the Quincy, which takes a superior polish, for the more ornamental work, and the Cape Ann for rougher work.

The polished red-granite columns in the fronts of many of the business and public buildings are mostly of Bay of Fundy granite; Maine, Quincy pink, and Aberdeen Scotch granite being also used to some extent for the same purpose. The bluish-gray polished columns are of Quincy granite. Concord, New Hampshire; Westerly, Rhode Island; Dix island, Maine; Richmond, Virginia, and other points have also furnished considerable of that material for general building purposes in Philadelphia.

CONNECTICUT BROWNSTONE.—That portion of the Philadelphia County prison formerly used for the debtors' department was built about 1835, of Connecticut brownstone, and is among the first, if not the very first, instance of its use as a building material in Philadelphia. The nature of the stone seems to have been but little understood by the builders, as the blocks are nearly all set on edge, evidently for the purpose of making the material "go" as far as possible, as well as to facilitate the dressing. The blocks are exfoliating and separating into layers. Occasional blocks set the bedway are still sound. Experienced builders here say that this stone should be quarried before the winter, so that it may receive a certain seasoning, in order that the frost acting on the natural dampness within a block on being first quarried may not disintegrate it. In the old Masonic temple, Chestnut street, built of Connecticut brownstone in 1853, the rather slender carved ornamentation of the cathedral style of architecture at the top of its front had to be removed on account of its falling off piece by piece. This disintegration was probably due to the exposed position at the top of a high building and to the slender character of the work.

The principal use of this stone here has been for fronts of private residences, three-fifths or more of the fine stone fronts of private residences on Walnut, Chestnut, Spruce, and other principal streets being of this material One of its most noticeable characteristics is the fresh, new appearance which it always retains, and in buildings here, where the material has been handled properly, it has shown itself to be substantial and durable. It is estimated that, including the Trenton, New Jersey, and the Yardleyville and Hummelstown, Pennsylvania, with the Connecticut brownstone, the geological formation to which they all belong (generally ascribed to the Triassic period), has furnished the material for about one-fourth of the whole number of stone buildings now standing in Philadelphia. The materials from this formation quarried at the different places above mentioned, and used in Philadelphia, though having some characteristics in common, are widely different in some respects. The Connecticut stone is of a lively and pleasing reddish-brown color; that from Trenton, New Jersey, and Yardleyville, Pennsylvania, known as the Trenton brownstone, is of a dull, grayish-brown color, and the Hummelstown stone a peculiar bluish-brown. The Trenton brownstone has been much used here for rubble work in the walls of school buildings and churches, and for foundations. The facility with which it is transported by water down the Delaware favors its use.

The Hummelstown brownstone, the hardest and most compact of all these brownstones, has been introduced here within the last fifteen years, and is used principally for trimmings in buildings of other stones and in brick buildings, giving a very pleasing effect. This stone as yet shows no evidence of disintegration in any of the buildings in which it has been used, and has the reputation here of being quite substantial and durable.

VERMONT AND MASSACHUSETTS MARBLE.—Though many of the more pretentious public edifices in this city were constructed before the introduction of the New England marbles, the most considerable of them all, the new city building now in course of construction, is of Lee, Massachusetts, marble, similar to that in the wings of the Capitol at Washington. Pennsylvania marble is used in some of its inner arched passage-ways, Ohio sandstone for some of its trimmings, Bay of Fundy red and Quincy granite for polished columns, and Richmond granite for foundation walls. It is estimated that the cost of this building when completed will be $10,000,000.

The Fidelity block, Baptist Publication Society's building, Third National bank, private residence of G. W. Childs, esq., that of Dr. Jayne, the Philadelphia Trust and Safe Deposit building, Guy's hotel, and many other equally fine buildings, have been constructed of the Vermont and the Lee, Massachusetts, marbles during the last twenty years. Quite a large proportion of the Vermont marble used here is for trimmings of houses and for monumental and other cemetery work.

OHIO STONE.—Ohio stone, as it is called here, quarried in the Berea grit of the sub-Carboniferous period, at Amherst, Berea, and other places in northern Ohio, has been much used in Philadelphia for fronts of private residences and for trimmings and ornamental work. The Young Men's Christian Association building, the Second Reformed Episcopal church, pyramid of the Gardel monument in Mount Vernon cemetery, and canopy over the soldiers' monument at Girard college are some of the structures of the Ohio stone in Philadelphia.

CHESTER COUNTY SERPENTINE.—The green serpentine of Chester county, Pennsylvania, was quite popular in Philadelphia a few years back, and was extensively used in the construction of churches, school buildings, and private residences, especially in West Philadelphia. It is proving here to be substantial and durable, but there is much difference of taste concerning its color and general appearance. It is customary to trim buildings of the serpentine with brownstone, Ohio, and other building-stones. The buildings of the university of Pennsylvania are the most extensive constructed of this stone.

FOREIGN BUILDING STONES.—Foreign building-stones have not been used in Philadelphia for outside work except in rare instances. There is a front on Walnut street of red sandstone from Carlisle, England, and colored Italian, Lisbon, German, and other foreign marbles have been used slightly for inside ornamental work; the principal part of this work, however, is of Tennessee marble, with some Lake Champlain marble. Occasionally a block of fine statuary marble is imported from Carrara, Italy, and for cemetery work the Serivezzia Italian marble is quite extensively used, though it has been rapidly giving place to the Vermont marbles.

The Pictou sandstone, quarried in Nova Scotia and New Brunswick, a stone resembling the Ohio very much in color, is not at present used in Philadelphia, though a number of business houses and private residences were built of it between 1850 and 1860.

USE OF VARIOUS STONES.—The following estimates received from the most reliable sources accessible show approximately the extent to which some of the principal building stones have been used in Philadelphia during 1881:

	Cubic feet.
Granite	250,000
Marble	135,000
Serpentine (Chester county)	50,000
Connecticut brownstone	25,000
Pennsylvania marble	25,000
Italian marble (cemetery work)	25,000
Hummelstown brownstone	21,000
Ohio sandstone	20,000

The following are estimates of the amounts of some of the principal stones used for paving, rubble work, foundations, inside ornamental work, etc., in Philadelphia during 1881:

North River blue-stone (Pennsylvania and New York), used for sidewalk paving	square feet	1,000,000
Conshohocken limestone, foundations and bridge abutments	cubic feet	200,000
Schuylkill gneiss, foundations and rubble work	do	150,000
Trenton brownstone, foundations and rubble work	do	75,000
Vermont colored marble, inside ornamental work, tiling, etc	do	4,000
Tennessee marble, inside ornamental work	do	2,500

Of the 10,518 stone buildings, including those with stone fronts, within the present limits of the city, it is estimated that about one-fifth of the number are constructed of Schuylkill gneiss; one-fifth of Pennsylvania and New England marble; one-sixth of Connecticut brownstone; one-twelfth of Trenton brownstone; one tenth of Chester County serpentine; one-tenth or less of granite; and the remainder of Ohio sandstone, Hummelstown brownstone, Pictou sandstone, and a few others. Owing, however, to the number of large public buildings, such as the Girard college, new city hall, custom-house, mint, naval asylum, etc., in which marble has been used, and to the custom of trimming brick buildings with marble, the quantity of that material used is probably much greater than that of any of the others mentioned.

Granite being the material used in many large structures, such as Memorial hall, new post-office, Masonic temple, and Ridgeway library, the quantity of it used here will also reach a high figure.

The estimates of the number of buildings of each kind of stone, though carefully made, cannot lay any claim to accuracy, but it is believed that with other data given they are sufficiently close to give a good general idea of the extent to which those materials have been used for purposes of construction in Philadelphia.

Cemeteries.—For the better class of monumental and other cemetery work Vermont marble, Italian marble, and granite from various places are all extensively used in Philadelphia.

The use of granite for the more expensive monuments is steadily gaining ground; Quincy, Cape Ann, Fox Island, Hallowell, Westerly, and Richmond granites are some of the stones used.

Montgomery County or Pennsylvania marble is extensively used for bases, curbing, coping, inclosures, etc., and occasionally for monuments.

Schuylkill gneiss is used to some extent for the rougher parts of the cemetery work. Ohio stone and Connecticut brownstone are used in a few instances for monumental work.

Among the most notable of the many elegant monuments and tombs in the different cemeteries are: The Kane tomb at Laurel Hill, in which lies the body of the celebrated Arctic explorer. It is excavated in a bed of the Schuylkill gneiss and faced with massive granite blocks in Egyptian style. The monument to T. Buchanan Read, at Laurel Hill, a polished granite monolith 30 feet in height; the Gardel monument, in Mount Vernon cemetery, consisting of a pyramid of Berea, Ohio, stone, with life-size statuary, executed at Bruxelles; the Drexel mausoleum, of marble, in Woodlands cemetery; granite shaft in Woodlands cemetery to Admiral Charles Stewart.

In the church-yard of the Old Swedes' church the first tombstones were of soap-stone quarried at Wissahickon, on the Schuylkill, a short distance above Philadelphia. Several of these stones yet remain, bearing dates from 1708 to 1773, and the inscriptions are yet quite legible in most instances, while many of the inscriptions on the marble stones of much later date are effaced. The process of decay in the case of the old marble head-stones appears to be by the dissolving of the carbonate of lime by exposure to the weather, leaving a rough surface, caused by the projection of the more siliceous particles, which finally fall off; the process is repeated, and in time the inscriptions are effaced. Some of the fine marble monumental work of late years in the new cemeteries is protected by canopies of stone.

The soap-stone was also used for tombstones in the yard of Christ church contemporaneously with its use in the Old Swedes' church, and it may be stated that the same material was used for steps, trimmings, etc., until the Pennsylvania marble was introduced for those purposes in the latter part of the last century. The soap-stone was used for trimmings in Christ church, the old state-house, and other buildings of an early date. It is soft and easily wrought, but is of unequal hardness on account of having lumps of imperfectly-crystallized serpentine in its composition, causing it to wear unequally, hence it was rejected as soon as the better-adapted Pennsylvania marble came into use.

The graves of Benjamin Franklin and his wife Deborah, in Christ Church yard, Arch street, have a plain horizontal slab, apparently of Hitner's white Pennsylvania marble, bearing simply the names of the deceased. The stone is undergoing the same process of decay as the other old marble tombstones before described.

Bridges.—The Delaware not being bridged at Philadelphia, on account of the interference it would offer to navigation, the bridge work is confined to the Schuylkill.

In Christian Street bridge Cape Ann granite is used; Girard Avenue bridge, Maine granite; Fairmount bridge, Fox Island granite; Pennsylvania Railroad bridge, Girard avenue, partly of Trenton brownstone—granite and Schuylkill gneiss being also used. Conshohocken limestone, Port Deposit stone, and Conewago granite (trap or diabase) from near Harrisburg have also been used in bridge abutments. The Schuylkill gneiss was the first material used here for the construction of bridge abutments.

Roofing.—Slate for roofing is quite extensively used in Philadelphia, there being abundant supplies of the material within easy reach. Lehigh slate from Lehigh and Northampton counties, and Peach Bottom slate from York county, near Mason and Dixon's line, are extensively used.

The Lehigh slate quarried from strata of Hudson River age resting on the Siluro-Cambrian formation of the great valley known in different parts of it as the Kittatinny, Cumberland, or Shenandoah, is the least expensive and most extensively used. The Peach Bottom slate of Archæan age, of excellent quality as roofing slate, is much used for roofing the better class of buildings.

Street paving.—On the 24th of November, 1718, the common council resolved that—

Whereas several of the inhabitants of the city have voluntarily gone into the paving of ye Kennel to the middle of the streets before their respective tenements with pebble-stone, and many are leveling to follow their example. But for as much as what is already done is very much damnified by the excessive weight of carriages, and will be every day more and more, unless some means are speedily taken to prevent the same, an ordinance is brought to prevent the cartmen and others their carrying such excessive loads.

We learn that the first regular paving of a street was due to an accident. A man on horseback being mired and thrown from his horse, breaking his leg, a subscription was raised and the street paved with pebbles from the river bank. In 1719 many sidewalks were being paved with brick, and the cartway with cobble-stone.

In 1750 the grand jury represented the great need of paved streets, "so as to remedy the extreme dirtiness and miry state of the streets"; but the first general effort worthy of mention to pave the streets was made in 1761–'62, and even then the only means applied to the purpose was that produced by lotteries.

The extreme inconvenience of unpaved thoroughfares was much felt from the beginning, and such old records as are now accessible show that frequent spasmodic attempts to remedy the defect were made, but for a long time little was done, and that little not of a substantial or permanent character.

Some of the streets had their channels or gutters in the middle. In cases where the streets were elevated and had a gutter at each side, they were defended by posts, curbstones not having yet come into use.

The first curbstones were set in Water street, from High street (now Market) to Arch street, about 1786–'88. They were of the Schuylkill gneiss, and some of them yet remain, though in a much worn and battered condition.

For the middle of the street, cobble- and rubble-stones continued to be about the only material used until 1848, when cubical blocks of granite having an edge of about a foot began to be introduced; Chestnut street in front of the custom-house and post-office was paved with the cubical blocks about this time. For some years these large cubical blocks were quite popular for paving purposes. In 1852 an ordinance was passed requiring owners of lots to set heavy granite curbstones between the sidewalk and street where paved with cubical blocks.

In 1854 the mayor was authorized to expend $50,000 in paving streets with the cubical blocks. The cubical-block pavements, though unsurpassed in regard to solidity and durability, soon came to be objectionable, since the surface of the large blocks wore smooth, and hence afforded but an uncertain foothold for horses. This difficulty was sought to be remedied by using small (Belgian) blocks 4 inches square, and a secure foothold for horses was thus obtained, but experience soon showed that with a width of about 4 inches the length of the block might be increased to a foot or more, thus securing a more solid pavement without sacrificing any other merit.

Some of the cubical-block pavement, so much of which was laid when in the zenith of its popularity, about thirty years ago, still remains in Chestnut and some other principal streets.

The following statistics were obtained at the office of the commissioner of highways and from other reliable sources:

Number of miles of paved streets in Philadelphia	900
Number of miles of unpaved streets in Philadelphia	1,100
Number of miles of granite-block pavement	50
Number of miles of cubical, Belgian, etc. (estimated)	2
Number of miles of cobble-stone pavement (estimated)	600
Number of miles of rubble-stone pavement (estimated)	248
Number of miles of pavement of Cape Ann granite (estimated)	44
Number of miles of pavement of Richmond granite (estimated)	3
Number of miles of pavement of Port Deposit gneiss, Schuylkill gneiss, Jersey City trap, North River blue-stone, etc. (estimated)	5

It will be seen by the above statistics that cape Ann, Massachusetts, is the main source of supply for granite blocks. The blocks are shaped at the quarry and shipped here by water.

Each of the principal street railways, by a late ordinance, is required to pave with granite blocks one mile of the street through which it runs; and this is the style of pavement now preferred.

The standard size of this block, 12 by 4 by 6 inches deep, is not rigidly adhered to with regard to the length, the blocks generally varying from 8 to 14 inches in length. Experience has shown that if the width be kept at about 4 inches and the block laid crosswise of the street, a sufficiently good foothold is secured for horses, even though the length should vary considerably. The practice here is to have the block about 4 inches wide, from 8 inches upward in length, and 6 or 7 inches in depth; blocks of these dimensions laid on a bed of gravel seem to give the most satisfactory results.

Sidewalk paving.—The sidewalk paving is left to private enterprise, each owner of a lot paving the sidewalks opposite to it according to circumstances. Brick is the main dependence for this purpose, though North River blue-stone is used almost exclusively for the better class of sidewalk paving. The North River blue-stone is now obtained, not only from Ulster county, New York, and neighboring districts on the Hudson, but from Pike county, Pennsylvania, where beds of flagging of the same formation, and equally well adapted to the purpose, have lately been developed.

The North River blue-stone has the reputation here of being perfectly adapted to the purpose of sidewalk paving. It is readily quarried in flags of the required thickness; the surface is even, the material so hard that there is no perceptible yielding to foot-wear, and there is a peculiar grit that prevents the surface from becoming slippery. It is estimated that there are 100 miles of stone sidewalk paving in the city, the greater part of which is of this stone, which was introduced here as early as 1835, or thereabout. During 1881 about 1,000,000 square feet of North River blue-stone was used in Philadelphia for sidewalk paving, and thicker layers of the material are used to some extent for trimmings of houses. The estimate given includes stone brought both from the New York quarries and from those near Pond Eddy and Shohola, in Pike county, Pennsylvania.

The sidewalks in front of some of the larger business houses on Chestnut street are paved with large flags of Cape Ann, Richmond, and other granites, which flags serve also as vault covers. It is found necessary to "ridge" the granite flags, as otherwise they become so slippery as to afford but an insecure foothold for pedestrians.

Slate from Lehigh county, Pennsylvania, has also been made use of to some extent for sidewalk paving. A good example of its conduct when used for flagging is seen in front of Independence hall, where the material is used. Such parts of the pavement as remain whole have a very even surface; but the slates, being laminated or in layers adhering together, are rapidly shelling or separating into thin plates by the action of water and frost.

The Wyoming blue-stone is also used for sidewalk paving to a limited extent, but the flags from the upper layers of these quarries are generally laminated, and, like the Lehigh slate, are disintegrated by water and frost, though the lower layers furnish material free from this objection, and which is in every way excellently adapted to the purpose of paving. The best curbstones in use here are of granite about 8 inches wide, 2 feet deep, and from 6 to 10 feet and upward in length.

Asphalt is but little used for paving in Philadelphia, and is mostly confined to some walks in Fairmount park, and a few small areas laid by private individuals.

PITTSBURGH, PENNSYLVANIA.

Several important buildings were constructed of the local stone (Morgantown sandstone of the *Second Geological Survey of Pennsylvania*), quarried within the limits of Pittsburgh, before its destructible nature was understood. The stone in all these buildings is being rapidly disintegrated by the action of the atmosphere. The native stone, however, in the construction of by far the greater part of the cellar and other underground work, is still used, and is thought to be durable when protected from the atmosphere.

Sandstone from Baden, Beaver county, Pennsylvania, a material easily dressed and durable, is largely employed for foundations, caps, sills, etc. The color of this stone is locally called "pepper and salt", owing to the presence of little brown specks of iron oxide throughout it. This characteristic renders it readily distinguishable from other Beaver County stones; its texture is rather coarse. Sandstone from Homewood, in the same county, is largely used for bridge abutments and for other rough building purposes. It is hard to dress, and hence is not a favorite where fine work is required. It is a durable stone, resisting the action of the atmosphere quite well. The Homewood sandstone is a well-known horizon of the Lower Coal Measures.

The quarries at Freeport, Pennsylvania, which formerly furnished considerable building stone at Pittsburgh, are not operated at present; however, near the last-named place, at Lucesco, Westmoreland county, there is a quarry which is beginning to furnish some stone for cellars and foundations at Pittsburgh. Some of the street paving stone and most of the sidewalk paving stone is brought from flag quarries on the Monongahela river, in Allegheny and Fayette counties. It is a very hard bluish-colored material, which comes out in convenient shape for flagging, and resists quite well the kind of wear to which it is subjected. One of the principal sources of paving blocks is Banning's quarry, near Connellsville, Fayette county. One or two churches and business blocks are built of Massillon sandstone, which is used to a considerable extent for finer grades of work.

The Smithfield Street German church, constructed of Massillon sandstone, shows signs of crumbling in one or two places. This church was constructed with two disconnected walls side by side; the outside one very thin and with many of the stones on edge, the inside one undressed and carelessly put up. This is but one of many instances in which a stone suffers by being improperly handled rather than through defects in the material itself.

The Ohio sandstone is employed to some extent for the more ornamental stone-work. The Allegheny court-house, built of the Morgantown sandstone quarried in the vicinity, the stone in the walls of which was rapidly disintegrating, was lately burned. The atmosphere of Pittsburgh is severe on building stones. In the large number of iron and other manufacturing establishments an immense amount of bituminous coal is consumed, and a cloud of sulphurous smoke continually envelops the city. At times the fog is so dense that gas must be lighted during the day.

There are two or three buildings constructed of Niagara limestone from Lemont, Illinois, and there is one building—the Dollar Savings bank—with a front of Connecticut brownstone. The streets are largely paved with stone, and besides the paving blocks already mentioned, which are used for the better class of street paving, cobble-stones from the Allegheny river are more extensively used for that purpose than any other material. There is considerable stone sidewalk paving, though brick is generally used for this purpose. For the portions which are of stone, flag-stone from points in Allegheny and Fayette counties is chiefly used. Flagging from Warren, Ohio, is also used to some extent; also sandstone from Baden and Homewood, in Beaver county. The wharves are constructed of cobble-stones taken from the bed of the Allegheny river. The abutments of several of the older bridges across the Allegheny and the Monogahela rivers are built of the native stone quarried within the limits of the city of Pittsburgh. Bridge abutments are now built of the massive sandstones from Beaver and Homewood. Sawmill Run wall, which holds up the embankment of the Pittsburgh, Cincinnati, and Saint Louis railroad, along the south bank of the Monongahela river, is built of a sandstone similar to the local stone from the railroad company's quarry near Walker station, Allegheny county. For all first-class cemetery work granite is preferred, owing to the peculiar severity of the atmosphere.

PITTSFIELD, MASSACHUSETTS.

The following is a list of stone buildings in Pittsfield, with the materials of which they are constructed: The Berkshire County court-house, of white marble from Sheffield; the public library, of Longmeadow granite; the house and barn of Mr. Thomas Allen, of Quincy granite; one house built of limestone from New York; farm-house of Mr. A. A. Rice, of cobble-stone found in the vicinity.

There are no important quarries here, and surface stone, stated by Professor C. H. Hitchcock to be of Cambro-Silurian limestone of the Berkshire valley—called the Stockbridge limestone by Professor Emmons—is found in the vicinity and is used for foundations and underpinnings. There are also some small limestone quarries from which the material is obtained for these purposes. The soil everywhere is full of rough limestone blocks of quartzite—cobble-stone of Potsdam sandstone age, according to Professor Hitchcock—and where cellars are dug much of the stone taken from the excavations is broken and used for the walls. In many places in the vicinity the limestone ledge crops out, but has never been quarried to any great depth. The streets are not paved with stone, excepting the gutters, which are usually paved with cobble-stones. The sidewalks of about half a mile of the business streets are paved with North River blue-stone, and the remainder of the sidewalks with concrete. The curbtsones are a blue flagging, said to have come from Catskill, with some limestone from a local quarry.

PORTLAND, MAINE.

The material chiefly used for the better class of work is granite from Hallowell, Biddeford, Spruce Head, and Yarmouth. Next in importance is the Nova Scotia sandstone, used for fronts. There are four churches built of material obtained from rough granite bowlders found in the vicinity of Portland; one building is of Vermont marble. Stone for foundations, cellar walls, and work of that class, is rough granite bowlders obtained in the immediate vicinity of the city; underpinnings are of granite from Biddeford, Yarmouth, and Spruce Head; in the steps, posts, and basements of better houses, the following granites appear to have been used: Spruce Head and Biddeford, quite extensively; also Portsmouth, and Hallowell granites; Yarmouth and Hallowell granites are used in fronts, sills, and trimmings. The Spruce Head granite is especially conspicuous by its patches and its freshness even after a long exposure. One old building is fronted with Quincy granite. The granite from the Maine Central quarry at North Jay has been used only in the trimmings of the Maine Central Railroad office. Iron railings in the elaborately-wrought granite supports invariably discolor the blocks; even the smallest piece of iron at a considerable height discolors everything below it. Part of the breakwater in the harbor is built of granite from mount Waldo and Bluehill. Forts Preble, Gorges, and Scammel are of granite from Mount Waldo, Biddeford, Spruce Head and perhaps other places. The post-office is a large and beautiful building of Vermont marble, with fluted columns, and considerable carved work, the best being of Hallowell granite. The custom-house is a very beautiful granite building of Hallowell and Concord granite, the main building being of Concord, while the towers are of Hallowell granite.

The city hall, quite a large structure, has a front of fine yellow sandstone from Nova Scotia and a basement of granite. Several churches and the Emory block are built of granite, chiefly from Hallowell; also, some are built of irregular pieces of sappy slate and mica-schist picked up in the vicinity of Portland, with granite trimmings; one or two of these have square blocks of quarried granite interposed, which give them a peculiar appearance. The Centennial block has a front of red and yellow Nova Scotia sandstone, and two beautiful polished granite columns of material from Red Beach, Maine. The county jail is built of Biddeford granite. Stone is now used exclusively in paving such streets as are paved, and the material formerly used for this purpose was cobble-stones from Cranberry islands and East Maine; the material now used is granite blocks from Yarmouth, Hallowell, and Fox island. There is a small amount of stone in sidewalk pavements, of Hudson River flags, but brick is the material chiefly used for paving. The curbstones are of granite from Falmouth and the vicinity of Portland usually, but granites from Yarmouth and Hallowell, and some from Spruce Head, were so used.

POTTSVILLE, PENNSYLVANIA.

Pottsville is very picturesquely situated close to the foot of the mountains and partially on their sides, all of the ground on which the city is situated being uneven, thus making considerable stone-work necessary for bringing the bases of buildings to a level, and also for terrace walls and other purposes necessary in cities built on very uneven ground. Montgomery County marble has been used to some extent for steps, base courses, sills, and other trimmings; also some Vermont marble for the same purposes. Ohio sandstone was used for trimmings in the *Miners' Journal* building, a fine structure of brick. New England granite has been used in a few important business buildings for steps. Goldsboro' brownstone is used in two or three buildings for trimmings; it approaches Connecticut brownstone in color more nearly than does the Hummelstown of the same formation.

In several buildings the bad effects of placing the stone edgewise instead of the bed way are manifested by the disintegration of the material. Edging proves to be particularly injurious to the brownstone—less so in the case of marble, still less so with the Pottsville conglomerates and laminated granites; but it is desirable to avoid the practice in all cases, as experience proves. The Henry Clay monument, on the side of the hill above the *Miners' Journal* building, is of iron with base of Pottsville conglomerate, a material abundantly exposed near Pottsville. The largest stone structure in the city is the Schuylkill County prison; the front of this building is of Trenton brownstone of Triassic age; the architecture is of the castellated style, and the side and rear walls are constructed of Pottsville conglomerate.

For cemetery work New England and Italian marble, brownstone occasionally, and some granite, have been used. Besides the stone buildings enumerated there are about 200 buildings with considerable stone in their structure in the way of base courses, caps, sills, lintels, and steps. Hummelstown brownstone has been the stone chiefly used for trimmings, it being easier of access than any other stone good for that purpose; it proves here to be substantial, durable, and in every way satisfactory for trimmings. A large rectangular block of this stone was observed serving as steps in front of a business house; although it has been in place twelve years and subjected to continued foot-wear, but little impression has yet been made on it.

None of the streets are paved with stone. The city is so situated that there is perfect drainage in almost all parts, and the gravelly nature of the soil is such that the streets are naturally firm and the need of paving them with stone is not urgent. There is, however, considerable stone sidewalk pavement, chiefly of the sandstone quarried in the vicinity. The North River blue-stone is used to a limited extent for the same purpose. The curbstones are of the native Pottsville conglomerate. The abutments of the small bridges needed are of Pottsville conglomerate. The slate roofs are principally of Lehigh County slate.

POUGHKEEPSIE, NEW YORK.

Stone found in the vicinity of Poughkeepsie, either in small quarries or in excavations of various kinds, is a hard blue limestone suitable for rough work only. As to durability, however, it is indestructible by the ordinary action of the elements. The only stone used here that has shown signs of disintegration is the brownstone, much of which comes from Connecticut. Sills and lintels of this material show signs of disintegration after the lapse of years. Besides the materials already mentioned as used in stone construction, limestone from Westchester county, Ohio sandstone, and gneiss from the vicinity are employed. For foundations and underpinnings hard, blue limestone and other rocks from the small local quarries and from various excavations are used; for underpinnings dressed sandstone and blue-stone are used to a limited extent. Two and a half miles of the principal streets are paved with large cobble-stones, and there are 300 feet of Belgian block pavement. Sidewalks are largely paved with stone, and the material used for this purpose as well as for curbing is the North River blue-stone. Blue-stone and bowlders are used in the construction of buildings, docks, wharves, and bridge abutments.

PROVIDENCE, RHODE ISLAND.

The foundations in the city of Providence are generally from the so-called ledge stone from the great quarry in Cranston and smaller ones in North and East Providence, a slate of great strength in resisting strains. It is very hard to break across the grain. In digging for foundations in this city miry ground is occasionally struck, and quicksand is often encountered. The great length of blocks attainable and the strength of the slate make it very serviceable for filling up such ground, because the slate does not break into smaller pieces by the strain upon it. In the case of the Providence gas-house the reason given for making the dome of great size is said to be the desirability of relieving the pressure on the lower parts of the building on account of the unfavorable condition of the ground. In the older buildings the Quincy granite and Connecticut sandstone are chiefly used for underpinnings, especially the latter; and the Nipmuck stone and Smithfield granite are also used to a considerable extent for this purpose. The other granites were brought into use lately, and have been extensively employed also. In one or two houses a blue-stone, probably of Hudson River age, has been used. As regards the sidewalks, Providence uses much concrete. The Bolton, Connecticut, flags were once employed very extensively and are still found, but none are sold now in the city. Very often there exists in them tongues of harder rock in the soft blue schist, and by the wearing of frost and water the stone becomes grooved in a very peculiar manner, with the tongues standing out as ridges. This softness and want of homogeneousness must be serious defects. In old times large amounts of crossings, flags, and even curbs were hauled into the city from Nipmuck ledge, from near Coventry; they are distinguished from others by their yellow look. The same stone has been used in some old dwelling-houses; it has quite a large proportion of muscovite, with much less biotite in layers, and hence splits quite smoothly, so that it is designated by Providence architects as "natural face" stone. Trimmings of white and blue Vermont marble are used in one or two buildings, and artificial stone has also been used. Tuckahoe dolomite is used in one front and for trimmings in one or two buildings, and two old posts before a house are capped with this same material. There is a great tendency in the newer buildings to use fine red brick with yellow sandstone trimmings. The finest stone structure in the city is the new city hall. It is built of Hurricane Island, Westerly, and Concord granites. The basement up to the pencil mark is of Hurricane Island granite; above this the front and right sides are all Westerly except the columns, which are Concord granite; the back and left sides above the basement are Concord granite. The granite slabs on the sidewalk of the new city hall, obtained from the Cape Ann Quarry Company, are claimed to be the largest granite flags quarried in this country. The dimensions are from 22 to 23 feet long, 5½ to 8 feet wide, and 1 foot deep; some are from 10 to 12 feet wide, but the width is usually less. These different granites harmonize perfectly. The building is said to have cost $1,400,000. Polished columns of Westerly granite support the lamps. The stone in the soldiers' and sailors' monument in front of the city hall is of Westerly granite; the United States post-office and custom-house of Quincy granite; the Providence athenæum has front and columns of Quincy granite and sides of Smithfield granite. In front of it is a very beautiful drinking fountain, said to be of light Concord granite, and two handsome polished columns of Quincy pink granite. The new court-house just opposite is a magnificent brick building extensively trimmed with red sandstone, partly carved, and in the entrance stand six polished columns, two of red Westerly, two of blue Westerly, and two of Diamond Hill granite. The arcade runs from street to street, and was erected in 1828. The twelve large columns are made of Smithfield granite, and must have been a large undertaking at that time.

The high school is of brick with yellow sandstone trimmings; it has a high basement built of Westerly granite and polished columns of red Westerly and Quincy pink granites; the Roger Williams monument is of Westerly granite; the new Catholic cathedral, the most imposing stone building, is entirely of brown sandstone from Portland, Connecticut; Grace church is built of Little Falls, New Jersey, sandstone; the First Congregational church is of granite from Smithfield; All Saints' Memorial church and Saint Stephen's church are of Connecticut brownstone; Saint Mary's church is of granite from Westerly, Diamond Hill, and Northbridge; the Central Congregational church is of Connecticut brown sandstone; Sayles Memorial church at Brown's university is of red Westerly granite trimmed with Connecticut brown sandstone; Saint Xavier's academy is an old stone building made of material from Nipmuck ledge, Coventry, Rhode Island; the Providence Savings institution was built twenty-seven years ago of Quincy granite; there is a handsome private residence near the Friends' school-house built entirely of cut red and white Westerly granite; Saint Patrick's church is built of rough stone from the vicinity; the gateway of the North burial-ground is built of Diamond Hill granite; in Grace Church cemetery the posts, coping, etc., are made of West Greenwich granite; the Dexter asylum has an immense stone wall of natural-faced stone from Nipmuck, in the vicinity of Providence; the old state prison is built chiefly of Quincy granite; the Burgess building is fronted with Tuckahoe dolomite; the Richmond building is of brick trimmed with olive sandstone, and has red and gray polished granite columns; the Wilcox building has some carved and polished work of Westerly granite in its composition; the Aldrich house has a front of white limestone which came from the city of Montreal, Canada; each block was sent on dressed into the proper shape and numbered. This quarry is said to be within the limits of Montreal. Saint John's church is built of bowlders and natural-faced stone from the vicinity of Providence; the building is trimmed with red sandstone. The College Library building of Brown university has a basement of Sterling-granite; it is built of brick trimmed with yellow and blue sandstone. There are also red and gray polished granite columns, probably from Red Beach, Maine, and Diamond Hill. The granite in the pumping-station is from Westerly; there are two wharves in which granite was used extensively; in one the material is from Diamond Hill and the other from Pascoag, Rhode Island.

There are 135 miles of recorded streets; 16 miles of this length are paved with granite blocks and cobble-stones; the material is from Diamond Hill and Westerly, Rhode Island, from Connecticut, and some from Maine granite quarries.

The sidewalks are but little paved with stone, concrete being usually the material employed for this purpose. In such sidewalks as are paved with stone the Hudson River flags are used, with occasionally granite from Diamond Hill and Smithfield, gneissoid granite from Nipmuck, Rhode Island, and flags from Bolton, Connecticut. The curbstones are of granite from Diamond Hill, Smithfield, Westerly, and Nipmuck; and Hudson River blue-stone is used to a limited extent for this purpose.

QUINCY, MASSACHUSETTS.

The seven stone buildings in this place are constructed of Quincy granite. All the stone used for building is obtained from the quarries within the city limits. The streets and sidewalks are not paved with stone, but there are some curbs of the material from the local quarries. Among the important stone buildings are the town hall, the Unitarian church, and the school building.

READING, PENNSYLVANIA.

Quarries of the Siluro-Cambrian formation are operated within the limits of Reading for local building purposes. The material at this point, however, is used only for the rougher building purposes, such as foundations, underpinnings, etc. Stone is not used to any great extent; there is an abundance of brown sandstone south of the town, the northern edge of the formation which furnishes the brown sandstone passing within a short distance of it. No extensive quarries of this material are being operated in the neighborhood; what stone is needed for local use in Reading and vicinity is obtained from the surface bowlders. Much of the material in this locality is a conglomerate, and only the surface bowlders have as yet been made use of; consequently the stone, well seasoned and tested by the weather before being used, proves to be durable. The buildings of this sandstone are usually in a good state of preservation. For the better class of stone construction Hummelstown brownstone is the material most used. The stone used for bridge abutments and arches is the brown sandstone already mentioned; none of the streets are paved with stone; some of the sidewalks are paved with Hudson River blue-stone, but the amount is small. The curbstones are made of local limestone and Hudson River blue-stone. Bricks of good quality are manufactured in the vicinity, and the Philadelphia pressed brick is also being largely used.

RICHMOND, INDIANA.

Stone is but little used in the construction of buildings in Richmond, and is chiefly confined to foundations; the material employed for this purpose is the Cincinnati blue limestone, outcrops of which are found along a creek in the vicinity. The stone from this formation at nearly every point where it is exposed or quarried shows itself to be lacking in the important quality of durability, and its use here has demonstrated that after a comparatively short exposure to the atmosphere it begins to weather. The ground on which the city is built furnishes secure foundations, and there are no conditions of topography or of climate that are especially unfavorable to the extensive use of stone as a building material, although the stone from the Cincinnati formation quarried in the vicinity is used for foundations and for the ruder purposes generally; the twenty stone buildings are constructed of Berea, Ohio, sandstone of sub-Carboniferous age. The streets are not paved with stone, and the sidewalks but very little; the material used in such streets and curbings as are paved is limestone from New Paris, Ohio.

RICHMOND, VIRGINIA.

There are but five buildings in Richmond constructed of stone, four entirely of stone and one front. In two of the buildings granite quarried in the vicinity is used; and in the walls of two buildings stone from surface bowlders found in the vicinity is used, while one building is of Quincy, Massachusetts, granite. There is a one-story building on Main street, between Nineteenth and Twentieth streets, which has stood for more than a century; it is constructed of bowlders of granite rock, and has no significance in an inquiry concerning stones used in construction, except to show the durability of these bowlders. The stone used in a church on Grace street was obtained from a quarry below the city, but it has been practically abandoned. The stone used in the custom-house came chiefly from the Old Dominion Granite Company, and there is scarcely any change perceptible in the material since it was laid in the walls of the building. The pedestal of the Washington monument is constructed of granite from the Tuckahoe district, Henrico county. The piers of the five bridges across the James river at Richmond were constructed of stone quarried for the most part on the island in the river and along the right bank of the river not far from the ends of the bridge. There are several docks where this material is also largely used. The granite quarried near Richmond ranks with the best granites, and it has been used in the construction of many important public buildings throughout the country, notably the superstructure of the new State, War, and Navy Department building in Washington, District of Columbia. In the business portions of the city the streets are paved with cobble- and rubble-stones from the vicinity. The sidewalks are but little paved with stone, and the materials used are the mica-schist from Lynchburg, and North River blue-stone shipped from Rondout, New York. The curbstones are of the local granite.

ROCHESTER, NEW YORK.

The materials used in stone construction in Rochester are, for foundations and underpinnings, limestone from the local quarries, and to a limited extent sandstone from Ohio and from Albion, New York. For the better class of stone construction, Ohio sandstone, Medina sandstone from Albion, and granite and limestone from the vicinity, are all used. By far the larger number of stone buildings are constructed of limestone from the vicinity. For piers and work of that class done by contract Waterloo limestone is used. The streets are largely paved with Medina sandstone rock from Albion, New York; and there is considerable stone sidewalk, the material used being Medina sandstone and Hudson River blue-stone. Curbstones are principally of the latter.

ROME, NEW YORK.

Most of the buildings in Rome are of brick or wood—largely of brick. The foundations and underpinnings are built of limestone and sandstone quarried at Higginsville and Verona, Oneida county. For the better class of stone construction sandstones from Verona and Potsdam, New York, and limestone from Onondaga and Oneida counties are used. There is little stone street pavement; the material used is cobble-stone. There are about 12 miles of stone sidewalk pavements of sandstone from Cayuga county, New York, and Hudson River blue-stone. There is but little curbing.

RUTLAND, VERMONT.

As there are quite celebrated marbles quarried in the immediate vicinity of Rutland, that is the chief material used in stone construction. Considering the convenient source of supply for building stone the number of the stone buildings in the city is not large, there being only twelve constructed entirely of this material and one front of marble. The following are some of the principal stone buildings in the vicinity: Two mills at Sutherland Falls are built of marble quarried at that place; the Episcopal church is constructed of gray limestone; the Catholic church is of limestone taken from the lot upon which it is built; the old jail, now used as a dwelling, is also of limestone; the Chatterton dwelling-houses near Sutherland Falls are of limestone; Sheldon & Slason's 2 mills, store, and office are of West Rutland marble; the Catholic church, H. H. Brown's store and office, the mill of Gilson & Woodfin, and that of the Manhattan Company are of the same material.

The population of Rutland is scattered over a wide area, the principal village being comparatively small. The unusual number of stone buildings is due to the proximity of the marble quarries. This material is used not only for the better class of construction, but also for foundations and underpinnings, and for all ordinary purposes. The location of the quarries is north and west of the town. Slate from Fair Haven and Chester, Vermont, is also employed to a limited extent for foundations and underpinnings. The streets are not paved with stone, and about a mile of sidewalk pavement is of marble and slate, and a little of granite from Chester, Vermont. The curbstones are of marble, slate, and granite.

SAINT PAUL, MINNESOTA.

In the enumeration of stone buildings in Saint Paul every business front having separate numbers, though included in the same block with others, was counted as one building, and the number of stone buildings given in the tabulation includes every stone structure whether large or small. The use of stone in Saint Paul has exceeded that in Minneapolis on account of the ease of quarrying and its accessibility, and the comparatively greater cost of wood. The great lumber mills are at Minneapolis, and their products would have to be hauled by wagon or by steam a distance of ten miles to make them available at Saint Paul. The following is a list of Saint Paul buildings with materials of which they are constructed:

Structures with brick walls and Berea sandstone fronts	4
Structures with brick walls and Saint Paul limestone trimmings	208
Structures with brick walls and Kasota calciferous sand-rock trimmings	107
Structures with brick walls and Frontenac dolomite trimmings	49
Structures with brick walls and Fond du Lac limestone trimmings	7
Structures with brick walls and Berea, Ohio, sandstone trimmings	30
Structures with brick walls and Vermont marble trimmings	1
Structures with brick walls partly trimmed with Minnesota granite	27

The state capitol now in process of construction is to consist essentially of Red Wing pressed brick, with trimmings of the dolomite from Frontenac. At the base of the building one course of brown sandstone from Fond du Lac, Minnesota, will show about 10 inches; the unexposed part of the foundation is of the blue dolomite from the upper part of the Trenton formation, at Saint Paul, which is a much better stone than the beds of this formation that are usually quarried for building purposes. Some of the principal buildings of the city that deserve enumeration are the following: The market building, built of brick, trimmed with Kasota stone; Baptist church, built wholly of Kasota stone; the cathedral is wholly of Saint Paul limestone; the McMullen block and the Fire and Marine Insurance building are of Saint Paul limestone; the Drake business block is of brick, trimmed with Kasota stone and granite; the business block of Auerbach, Finch & Van Slyke, of brick, trimmed with Frontenac stone; the Manheimer business block and the German-American bank are of brick, with Ohio sandstone fronts; the Saint Paul Episcopal church is built of Saint Paul limestone; the United States custom-house is of Saint Paul limestone, with Saint Cloud, Sherburne county, granite trimmings; the Saint Paul rolling-mill is of Saint Paul rock, with Kasota trimmings; the Presbyterian House of Hope church and the piers that support the bridge over the Mississippi river are of Saint Paul limestone; the trimmings of Lindeke's, Warner & Sherman's, Barney's, Gilfillan's, and Odd Fellows' blocks are of the magnesian limestone from Frontenac, Goodhue county, Minnesota; the front of the Nichols & Dean block is of granite from Sauk Rapids, Minnesota.

The streets are but little paved with stone, wooden blocks having been chiefly used for this purpose. The sidewalks in the business parts of the city are very generally paved with Saint Paul limestone and granite from Minnesota, sandstone from Ohio, and the calciferous sandstone of Kasota. Curbstones are of the Saint Paul limestones.

SALEM, MASSACHUSETTS.

In the few buildings in Salem in which stone enters as an important ingredient, Cape Ann granite, Peabody granite, and Springfield sandstone are the materials used. Foundations and underpinnings are of Cape Ann and Peabody granites. There is considerable stone street pavement of Cape Ann and Maine granites. Sidewalks are not paved with stone, but the curbs are of Cape Ann and Peabody granites.

SALT LAKE CITY, UTAH.

The assembly house is built of Cottonwood granite, and the old tabernacle has piers of Red Bud sandstone. The new Mormon temple is to be constructed of the Cottonwood granite. On account of the greater cost, stone is used to only a limited extent; brick, adobe, and wood being well adapted to the climate and much less expensive than stone. Of the forty stone buildings in the city the Red Bud sandstone was used in the construction of over thirty, and three or four were built of granite quarried in Little Cottonwood cañon; and in such foundations as are built of stone these materials are employed, though bricks are chiefly used for foundations. The streets and sidewalks are not paved with stone.

SANDUSKY, OHIO.

The city of Sandusky has a much larger percentage of stone buildings than any other city in Ohio. Of buildings entirely constructed of stone it has absolutely by far the largest number of any Ohio city, owing to the cheap and abundant supply of good building stone within the limits of the city, which constitutes a great limestone quarry covered with but a very shallow layer of soil or earth. The stripping rarely amounts to 2 feet, and below there lie from 8 to 10 feet of easily-quarried, strong, and durable limestone of good color, and in every way adapted to all building purposes. In early days it was the cheapest building material accessible, and so came to be used in many of the houses first built in the city.

The white limestone that lies immediately below the blue is reached but in a single city quarry; this is a massive stone fit for dimension work and well adapted to cutting, but the great supply of it comes from Kelley's island and point Marblehead. The blue limestone from the city quarries is largely used in the construction of piers and docks in the vicinity, and also for flagging, but it is not very well adapted to this use; it is laid in blocks or slabs from 4 to 8 feet square, not very smooth until polished by wear, and then becoming dangerously smooth. The stone of the city all proves very durable and the best of foundations are secured at small expense. The Sandusky court-house is of the Massillon sandstone. The streets and roadways are chiefly macadamized with broken blue limestone.

SAN FRANCISCO, CALIFORNIA.

The first stone structures in San Francisco were two buildings erected in 1854, of granite brought from China, quarried and dressed in that country. In the years 1856-'57 the granite quarries of Folsom were opened, and the fronts of several buildings on Montgomery and Battery streets were constructed of it. In 1865 the Bank of California building was erected of a beautiful blue sandstone quarried at Angel island, in the bay of San Francisco; it holds its color and surface well. The earthquake of 1868 made some cracks in the walls and gave rise to the belief that the stone was weak, and that stone in general was not fitted for use in this region. The United States mint has a basement of granite and walls of sandstone, from New Castle island, in the gulf of Georgia, British Columbia. There are six fluted columns, 27 feet high by 5 feet 6 inches at the base and 4 feet 6 inches at the top, of New Castle sandstone. The new city hall is the most extensive building in San Francisco. The walls are of brick, but the foundation is of rubble from Angel island. Considerable granite is used in the basement and steps from the quarries at Rocklin and Penryn, near the American river, in Placer county. The window-sills, key-stones, and balustrade are of sandstone from San José, in Santa Barbara county; the corridor floors are marble from Vermont and Massachusetts, and black marble from Glens Falls, New York. The Penryn granite, from the quarry of Griffith & Griffith, was employed in the construction of the basement of the United States mint, water-table of new city hall, dry-dock at Mare island, the new Stock Exchange and the Real Estate Associates' buildings. The people are afraid of stone buildings on account of their being cracked by earthquakes, and most of the large business buildings are of iron. The foundations and underpinnings are of granite, rubble from the vicinity of the city and from Folsom and Penryn and Napa, and sandstone from San José. There are about 46 miles of streets paved with cobble-stones, basalt, and granite from Sonora and Penryn. A few of the sidewalks are paved with granite from Folsom, and Vermont slate. Curbs are of granite from the various quarries which supply the city with this material. There are 11,000 feet of sea-wall constructed of rubble from Telegraph hill. The San Francisco dry-dock is constructed of granite from Folsom. The terrace walls and basements of the buildings of Messrs. Stanford, Hopkins, and Cooks are built of basalt from Sonora. Penryn granite is largely used in brick and iron structures as steps, sills, stairways, and window-caps.

SARATOGA, NEW YORK.

The stones used in Saratoga are mostly blue limestone from rocks of Trenton age quarried near the town. Foundations are built of this stone. Ohio sandstone and Connecticut brownstone are used for trimmings in some of the large buildings. Brick has been employed in the construction of the large hotels and other public buildings. Most of the streets are macadamized with cobble-stone and broken limestone. Broadway has about three-quarters of a mile of cobble-stone pavement. The sidewalks are mainly laid with brick, excepting in the business part of the town, where the North River blue-stone and a little Vermont marble are laid on the curbs of the cross sidewalks with blue limestones from the vicinity.

SAVANNAH, GEORGIA.

The nearest stone quarry to the city of Savannah is located near Milledgeville, in this state, distant about 175 miles. The granite at that point is excellent, but being difficult to work on account of its hardness, no systematic effort to introduce it here has been made. Most of the granite is in use for steps and window- and door-sills, brought from Stone mountain, near Atlanta. The Presbyterian church is a large granite building, with a wooden steeple The custom-house is built entirely of granite. These are known as stone buildings, and the materials in both case came from Quincy, Massachusetts. Cobble-stone for paving material comes as ballast from northern ports. Only the business streets are paved, and the materials used are the cobble-stone and Hudson River blue-stone from New York. A few of the sidewalks are paved with the Hudson River flags.

SCHENECTADY, NEW YORK.

Stone is rarely used in this county except for foundations, and there are not many opportunities of judging of the character of the material used in stone construction. In one or two instances, Saint George's church, for example, the stone from the local quarries when properly laid has proved to be of most excellent quality. It makes, when carefully laid in foundations, very regular faces, and preserves its rich color for an indefinite period; however, when improperly handled by the masons, as when set on edge, it is liable to exfoliate to such an extent that it becomes necessary to substitute new blocks of stone. It may be so handled as to form substantial and durable walls in stone structures. All the streets are paved with cobble-stones, from 4 to 6 inches in diameter, found on the surface of the ground in the vicinity. The sidewalks are paved with stone 5 feet wide and 2 inches thick, from the Helderberg formation.

SCRANTON, PENNSYLVANIA.

The Coal Measures are eroded from the mountain ridges on either side, leaving the Seral-Conglomerate Pocono sandstone and Catskill sandstone exposed on their sides and crests. These sandstones furnish most of the stone for ordinary purposes of construction in the city.

The amount of stone construction is but trifling; the most important building—the new court-house—is now in course of construction, and is located in what was once a deep swamp; the foundations are 30 feet in depth and constructed of the Seral-Conglomerate quarried at Shanty hill, in the vicinity of Scranton. The superstructure is to be of Catskill sandstone quarried in the mountain ridge just west of Scranton, and the heavy trimmings of Devonian limestone from near Syracuse, New York.

For bridge abutments the Catskill sandstone quarried in the mountains near Scranton is used; it is extremely hard, withstanding exposure, and is easily quarried in regular blocks suitable for the purpose. Only two streets are paved with stone, and the material used in these instances is cobble-stone from the stream. There is considerable stone sidewalk paving, and the material for the purpose is brought from Nicholson, Wyoming county, Pennsylvania; also some from Brandt, Susquehanna county; Lehigh slate is used to a limited extent for the same purpose. The curbstones are Catskill sandstone quarried in the vicinity.

SPRINGFIELD, MASSACHUSETTS.

Brick is largely used for the purposes of construction in Springfield, to the exclusion of stone. In addition to the number of stone buildings enumerated which are built of Longmeadow sandstone and Monson granite, those two materials are frequently employed for sills, cornices, and other trimmings. A few buildings have trimmings of Ohio sandstone; none of these materials show signs of decay, as the stone structures are all of recent date. The upper part of the city is built on terraces of stratified sand; the lower part has some foundations in clay, and in places piles are driven before laying foundations; these are thought to be in the old channel of the river on the lower terrace; some settling has been noticed under the spires of two churches, but this is attributed to faulty construction and not to the ground. The foundations and underpinnings are chiefly of Longmeadow sandstone. The streets are macadamized with trap from Westfield, and a few of the sidewalks are paved with Hudson River flags and granite flags from Monson. Curbstones are of Monson gneiss and Longmeadow sandstone.

SPRINGFIELD, OHIO.

Stone from the upper or Springfield division of the Niagara formation is quarried in the vicinity of this city, and is used for the less ornamental classes of construction. The stone from the quarries here is chiefly used in rough work, such as cellar walls, bridges, sewers, and the like. The Episcopal church edifice, on High street, Springfield, is built of this stone in the rough, and displays fine architectural effect. The Central high school was built of limestone from the local quarries. As very few buildings of this kind have been put up in this city, scarcely any judgment can be made of the Springfield stone; for other and rougher work it has stood the test of time for half a century or more. The site of the city is well adapted to buildings of weight; indeed but few feet in depth would place buildings upon solid strata of the Niagara limestone. The Portsmouth and the Berea sandstones have both been used to a limited extent for trimmings. But few of the streets are paved, and those are paved with cobble-stones and macadamized with the local limestone. Sidewalks are but little paved with stone, and the material used is the Springfield and Dayton limestones; also to a very limited extent the Berea and Portsmouth sandstones. For bridge abutments, sewers, and work of that class the limestone from the home quarries is employed. Whether it is set on edge or as in the natural bed seems to make less difference with this material than with most building stones.

STEUBENVILLE, OHIO.

Material for all stone construction in this place is quarried in the vicinity from the beds of sandstone in the Upper Coal Measures. The material is durable and comparatively pleasing in appearance, and is used for caps, sills, corners, and other trimmings. The Jefferson County court-house is the only building of importance in which stone from a distance is used; this structure is built of Amherst, Ohio, sandstone. Of the buildings enumerated as having stone fronts, none have fronts entirely of stone. The principal church and McGowan's block are built of sandstone from local quarries. Considerable of the cemetery work, such as monuments, bases, and inclosures, is made of sandstone from a local quarry. This material is susceptible of fine carving, though it is of rather coarse texture. The wharves in Steubenville are constructed of cobble-stones taken from the Ohio river at low water. The abutments of the Pan Handle Railroad bridge across the Ohio river at this point, and the water-works, are also constructed of the local sandstone. In such streets as are paved cobble-stones from the Ohio river are the material used. There is but little stone sidewalk pavement, and the material for this purpose is obtained from local quarries.

TAUNTON, MASSACHUSETTS.

In the vicinity of Taunton there are several small ledges which are worked occasionally for a short time when wall stones are needed for some particular building. The irregularity with which these openings are worked does not admit of their being enumerated with important quarries. Their product is a bluish "wall" or "mortar" stone, similar to a material quarried near Lowell, Massachusetts. Of the eight stone buildings in Taunton three are built of granite from Acushnet, and five of the "mortar" stone from the vicinity. The foundations and underpinnings are of the local mortar stone and Acushnet granite. The streets are but little paved with stone, the material used being cobble from the fields in the vicinity. A few of the sidewalks are paved with Acushnet granite, and curbs are of the same material.

TERRE HAUTE, INDIANA.

Stone is but little used in this city, but that employed comes from quarries that furnish the best building stone in the state—those of Bedford, Ellettsville, and Stinesville. There is no building constructed entirely of stone, and the number of stone fronts, chiefly of the materials above mentioned, is about 100. Brick is used for foundations because of its cheapness, the impression here being that a stone foundation costs as much as an entire building constructed of wood. Sandstone that may be found near is not suitable for use in construction.

TOLEDO, OHIO.

Toledo is so situated as to have ready access by water to noted quarry regions, such as Amherst and Berea, Kelley's island, point Marblehead, and other places in the vicinity of Sandusky. The stone for the rougher building purposes is the limestone from Sandusky, point Marblehead, and vicinity; that for the better class of construction is chiefly sandstone from Amherst and Berea. In one building constructed of the Sandusky limestone the wall has been broken by frost, to which it is said to have been subjected before the material was out of the quarry long enough to be thoroughly seasoned. Out of 140 miles of sidewalk there are 3.6 miles paved with stone; the total length of the streets is 271 miles; total length of pavements 44½ miles, of which 7¼ miles are paved with Medina sandstone; 4 miles with small bowlders picked up from the surrounding country; 3 miles macadamized with sandstone; 3¼ miles paved with cedar blocks; and 27 miles are paved with plank. Some of the sandstone used in the outside walls of buildings has been set on edge, consequently the color resulting from weathering is not uniform.

TOPEKA, KANSAS.

The stone found in the vicinity of Topeka is an impure limestone suitable for foundations, underpinnings, and work of that class. The other materials used here to a limited extent are sandstone from Warrensburg, Missouri, and limestone from Cottonwood, Chase county, and from Junction City. This latter can be sawed with an ordinary tooth-saw, is full of chert concretions, and is subject to discoloration when exposed; it is not now used. The Cottonwood limestone is a good, strong, substantial material; it can be obtained in masses of from one to five cubic yards, and is now being used for the foundation of the main building of the state capitol.

Safford limestone is a very fine material, composed almost wholly of shells in an unbroken state, takes a good polish, and is quite durable; it is used for steps, trimmings, and curbing.

The Warrensburg sandstone is gray in color and is used for fronts, but in other places to a greater extent than here, and has given satisfaction. A red sandstone found in Colorado, near Pueblo, is used for trimmings; it forms a fine contrast with native limestone. The streets are not paved with stone; the sidewalks are paved with a flagging of a slate formation found in Osage county and sandstone flagging from near Fort Scott, Kansas. The college building, female seminary, and the state insane asylum are built of native stone (magnesian limestone of Permian age) found in the vicinity of Topeka. This material is not suitable for fine trimmings. The west wing of the state capitol was built of limestone from Cottonwood quarry; the United States post-office buildings, now in course of erection, are of the soft limestone found in Crowley county. The east wing of the state-house was built of limestone from Junction City, Davis county.

TRENTON, NEW JERSEY.

Among the stone buildings of Trenton the most prominent are: Of Ohio sandstone: The United States government building. Of Trenton sandstone: The state capitol, the state prison, Saint Mary's Roman Catholic cathedral, Warren Street Presbyterian church, State Street Presbyterian church, Prospect Street Presbyterian church, State Street Methodist Episcopal church, Clinton Avenue Baptist church, Bishop Scarborough's residence, James Moses' residence, John Moses' residence, Richie's private residence, the Pennsylvania Railroad depot. Of Connecticut brownstone: The front of Taylor hall.

Of the buildings enumerated, the United States government building is a new structure and presents a fine appearance. The brown sandstone or freestone of the Greensburg quarries, sometimes known as Trenton freestone, is very largely used for house trimmings, as sills, lintels, caps, and steps; also for table-tops, etc. Montgomery county, Pennsylvania, marble is also used to some extent for trimmings with Philadelphia and Trenton pressed brick, but the use of the freestone is increasing while that of the marble is diminishing. North River blue-stone is also used to some extent for the same purposes. Trenton is very largely built of brick, as Philadelphia and Trenton pressed or front brick are conveniently had, and at comparatively low rates, being less expensive than stone.

The Pennsylvania Railroad Company's bridge crossing the Delaware river has abutments and piers of Greensburg brownstone; the abutments and piers of the wagon bridge over the Delaware are also constructed of the same material, as are the locks, walls, and feeder of the Delaware and Raritan canal.

The majority of the streets are paved; and in such streets as are paved, stone from Lambertville, New Jersey, and some granite are used.

The following is a statement showing the extent of stone pavement in Trenton:

	Feet.
Belgian block	14,170
Cobble-stones	2,880
Telford macadamized	3,000

There is considerable sidewalk pavement on the principal streets, and the material used is blue-stone from the North River quarries, and stone from the quarries at Medford, Hunterdon county, New Jersey. North River blue-stone is used for curbs.

TROY, NEW YORK.

The materials used for stone construction in Troy, for foundations and underpinnings, are shale, quarried in the vicinity, and similar material quarried near Schenectady. For the better class of stone construction Connecticut brownstone from Portland, limestone from the Upper Aqueduct quarry and from near Niskayuna, are the principal materials. The bridge abutments are of shale and Upper Aqueduct limestone; some limestone is also brought from the Lower Aqueduct quarry, but it is not as durable as the Upper Aqueduct limestone. The streets are largely paved with granite blocks from Clarke's island, Maine, and from Weehawken, New Jersey. The sidewalks are largely paved with blue-stone, brought chiefly from Malden, New York; and mica-schist from western Massachusetts is used to some extent for the same purpose. Curbs are of blue-stone from Malden, New York.

UTICA, NEW YORK.

There is an abundance of good building stone within a short distance of Utica, and until recently the rates of transportation have made brick a cheaper building material. The sandstone of the immediate vicinity has been used most largely for foundations, but at present, for heavy buildings the limestone of the Trenton formation is used. The sandstone is not durable enough for heavy foundations; it was largely used in former years as stone for cross-walks and the like, but was found to flake under heavy traffic. There are no peculiarities of the ground that render it difficult to use stone for building purposes, but, owing to the comparative cheapness of brick and lumber, it has been considered expensive. There are within the limits of the city sixteen iron bridges over the Erie canal, the abutments of which are built of limestone from Little Falls, New York; also three bridges over the Chenango canal, the abutments of which are built of Cayuga sandstone. There is one block in the city faced with marble. The weigh-lock and house of the Erie canal is of Little Falls limestone. For foundations and underpinnings for the rougher purposes of stone construction sandstone from the local quarries is used; also, to a very limited extent, limestone from Canajoharie, New York. The streets are largely paved with stone, and the material used is cobble-stone; also Medina sandstone, and stone from Hammond, New York. The sidewalks are largely paved with Cayuga sandstone and Hudson River blue-stone.

WATERBURY, CONNECTICUT.

The stone quarried in and about Waterbury is a coarse, hard, granitic rock, and is irregular in many respects as to color, hardness, and general appearance, though most of it is very hard, and there are places in some of the quarries where blocks, regular as to shape and uniform in texture, may be extracted. It is an excellent stone for foundations and for cellar walls, but, unless selected with great care, it is of little use for other purposes. The streets are not paved; about half a mile of the sidewalks is paved with North River blue-stone, with curbs of the same material.

WATERTOWN, NEW YORK.

Watertown lies on both sides of Black river, whose rapid currents have worn a channel through the limestone rock, composed of blue limestone, Birdseye and Trenton. Some of the fine churches and grist-mills and factories were built of limestone, but at present brick is used in the construction of such buildings, it being less expensive, although the limestone is easily worked and very durable.

The limestone rock is very much grooved and striated in places by the passage of glaciers, especially where they cross the Black river. The Lorain shale, so-called by geologists, is native in the town of Lorain; the rocks of the county present an interesting field for geologists. There are exposures here of the Upper and the Lower Silurian rocks. The limestone rock of the Black River valley is studded with fossils of animal life that existed only in the sea; cephalopods are bedded in the blue limestone, which is comparatively pure carbonate of lime, but is very brittle; otherwise it is durable and susceptible of a fine polish. There is in this vicinity what is called Scotch granite, and also a marble known as Carrara marble. They are probably so called from their resemblance to the Aberdeen Scotch granite, and to the rare Carrara Italian marble, respectively. These were lately discovered in large quantities, which lay in perpendicular strata. Talc is found in large quantities and is being manufactured; it lies generally between Archæan rocks, and often unconformable to those which are in regular strata, and make beautiful flagging stones for sidewalks.

WASHINGTON, DISTRICT OF COLUMBIA.

The formations in the vicinity of Washington are made up chiefly of sand, gravel, and clay, with some isolated bowlders detached from the primitive rocks lying to the north and west. North of Rock creek the rocks of Archæan age are exposed, and ledges of mica-schist of this age have been quarried in and about Georgetown since the first settlements were made. It has been employed chiefly for the ruder purposes of construction, such as foundations, terrace walls, rubble pavements, and work of that class. The most important structure built of it is the new Georgetown College building. It was employed in the foundations of the Executive mansion, the Treasury building, and in those of most of the other public buildings in which the Acquia Creek sandstone was used for superstructure. A chapel in Oak Hill cemetery, built after the style of the time of Henry VIII, is of this material, trimmed with Seneca sandstone.

Mr. George P. Merrill, of the Smithsonian Institution, made careful field observations and examined specimens and microscopic sections of the different varieties of this rock, and reported as follows:

> The rock quarried in the vicinity of Washington, and of which the walls of Georgetown college and various other public buildings are composed, is a compact mica-schist of a structure and texture varying from coarsely schistose, splitting easily into thin sheets, and a fine-grained massive rock in which the individual ingredients are so evenly commingled that all traces of stratification are lost. The essential constituents are quartz and mica, the latter being biotite of a deep green color.
>
> Under the microscope numerous accessories are found to be present, among which are epidote, apatite, garnet, magnetite, and rutile, the first-named being the most abundant, while the rutile occurs only as small occular crystals penetrating the quartz granules. A plagioclastic feldspar is occasionally met with, and in this case the rock approaches gneiss in constitution. The chief objection to the use of this rock for architectural purposes lies in the fact that it frequently contains a large amount of pyrite or iron bisulphide. On being exposed to the air this pyrite becomes oxidized, and the rock disintegrates, or at best is badly stained or discolored. It is this same ingredient that renders many of our sand and lime stones unfit for use, they becoming streaked and spotted with unsightly spots of a rusty red color after being exposed a short time to atmospheric agencies.
>
> In conclusion, I would say that there seems no reason why this rock should not be utilized for building purposes, provided sufficient care be exercised in selecting only such portions as are entirely free from this deleterious substance.

On the Potomac river, 40 miles below the city, at Acquia creek, there is a ledge of light gray and rather coarse sandstone, and quarries of the material were purchased by the United States government in 1791 for the purpose of using it in the construction of the public buildings; the Executive mansion and other older buildings are of Acquia Creek sandstone.

The Executive mansion, or "White House", was commenced in 1792. On September 19, 1793, the corner-stone of the Capitol building was laid by Washington himself, and the central or older portion is constructed entirely of Acquia Creek sandstone from the government quarries. This material was used in the construction of all the important public buildings that were commenced up to 1837. The list includes the Executive mansion, the central or old part of the Capitol building, the old portion of the Treasury building, the old portion of the Patent Office building, and the foundation of the city hall. The Van Ness residence, at the foot of Seventeenth street, was also built of it in 1802.

About 20 miles north of the district, on the Potomac river, the southern edge of the Triassic, or new red sandstone, formation crosses the river, and at this point furnishes the material called "Seneca sandstone", the equivalent of the Connecticut brownstone.

The stone at the mouth of Seneca creek was used in the construction of the Smithsonian Institution building; the *National Republican* building, now used as the Pension Office; the District jail; the front of the Freedman's Bank building, now occupied by the Department of Justice; Lincoln hall; portions of the terraces about the Capitol, Treasury, and other public buildings; the United States prison; the Memorial Lutheran church; and in the trimmings of the chapel in Oak Hill cemetery. When the Chesapeake and Ohio canal was built, in the early part of this century, the Seneca sandstone was much used for locks and dams, especially in that portion of the canal lying near these quarries. In these various situations it has shown remarkable wear and endurance of exposure. This canal constitutes a convenient and inexpensive method of transportation from the Seneca quarries to Washington.

The three materials described, the Potomac mica-schist, the Acquia Creek sandstone, and the Seneca sandstone, from their close proximity to Washington and accessibility by water, may be said to constitute the local supply of building stone.

Washington has access by water to all the important quarry regions of the Atlantic coast, and of late years building stones from the localities named below have been used more or less extensively: Granite from the coast of Maine; from cape Ann, Massachusetts; Westerly, Rhode Island; Woodstock, Maryland; and from near Richmond, Virginia. Marbles from Rutland and Sutherland Falls, Vermont; Montgomery county, Pennsylvania; Tuckahoe, Westchester county, New York; Lee, Massachusetts. Hudson River blue-stone from Ulster county and vicinity, in New York. Brownstone from Portland and other places in the Connecticut valley; from Belleville and New Brunswick, New Jersey; Hummelstown, Pennsylvania, and Manassas, Virginia. Slate from Vermont, New York, Pennsylvania, and Buckingham county, Virginia. Gneiss from Port Deposit, Maryland, and sandstone from Nova Scotia.

The materials from distant points began to be introduced about 1840, as at that time the stone from the government quarries at Acquia creek which had been used in the construction of so many important public and private buildings was found to be so inferior in point of durability and general appearance that the quarries were abandoned and other sources were looked to. An examination of the buildings constructed of the Acquia Creek sandstone shows that numerous clay-holes have appeared, caused by the disintegration of portions of the rock from exposure to the atmosphere. Experience with this stone has proved that within a few years, unless constant attention is given to it by filling the clay-holes and covering with a coat of paint, the stone becomes flimsy and unpresentable. All the public buildings in which it was used are painted, both for the sake of preservation and to make them harmonize with the white marbles and light-colored granites that have been used in the construction of additions and extensions, as the exigencies of the public service required the buildings to be enlarged. The two wings of the Capitol are built of Lee (Massachusetts) marble, excepting the columns, which are of Cockeysville (Maryland) marble. The style of architecture is Corinthian.

There is quite a variety of stones used in the interior decoration of the Capitol. The eastern stairway leading to the galleries of the Senate Chamber, the eastern and western stairways leading to the galleries of the Hall of Representatives, and the walls of the Senate reception-room (Marble room) are of polished Tennessee marble. There are Ionic columns of breccia or variegated Potomac marble in the apartment of the Supreme Court of the United States; the National Statuary hall, formerly used as the Hall of Representatives, has a circular colonnade of shafts of this material surmounted by capitals of Carrara marble executed in Italy. This stone, when highly polished, presents to the eye an apparently rough and broken surface, which delusion is only dispelled by touching it.

The western stairway to the gallery of the Senate Chamber is of Italian marble, and the statuary in and about the Capitol is chiefly of Carrara and Serivezzia Italian marbles.

Greenough's colossal statue of Washington, in the east park, weighs 12 tons, and was executed in Florence, Italy. The stones used in the terraces, walks, and inclosure-walls about the Capitol are of Seneca sandstone, Lake Champlain marble, North River blue-stone, Rock Creek mica-schist, granite from Maine, Massachusetts, Richmond, Virginia, and other places, and the sub-Carboniferous sandstone from northern Ohio.

The old portion of the Treasury building, commenced in 1836, was constructed of the Acquia Creek sandstone, with foundations of Potomac mica-schist. The extensions made to the northeast and west sides of the building were begun in 1855. The material used in the extension is Dix Island, Maine, biotite granite, with foundations of Port Deposit gneiss. The style of the building is Grecian-Ionic. The granite shafts of the colonnades are monoliths. Opposite the north front is an ornate fountain of circular shape, 12 feet in diameter, cut from a solid block of granite. The following materials were used in the walls of the lower story: Stylobate; base, Isle La Motte, Vermont, marble (magnesian limestone); moldings, Bardiglio veined marble from Serivezzia, Italy; styles, dove-colored marble (magnesian limestone) from Pittsford, Vermont; panels, yellow sienna Italian marble; dies, Hawkins County, Tennessee, marble (limestone); above stylobate, pilasters and panels, white-veined Italian marble; styles, yellow sienna Italian marble; panels, Bardiglio veined marble from Serivezzia; cornice, white-veined Italian marble; upper story, stylobate, same as lower; above stylobate, as in lower story, except the panels, which are Pyrennean breccia.

The State, War, and Navy building.—The stone used in the superstructure is a light gray biotite granite, quarried near Richmond, Virginia; the basement being of Vinal Haven, Maine, granite. The interior walls of the basement of the southeast wing are built of Seneca sandstone. The tiling of the corridors and passages is of white and black Vermont marble and Lehigh, Pennsylvania, slate. The tiling in nearly all the public buildings in Washington is of the same materials.

There is an example of marble interior decoration in the library of that portion of the building assigned to the Navy Department; the walls of the library are of the following materials: Alps green or verde-antique, a kind of serpentine, yellow sienna Italian marble, French griotte marble, and Lake Champlain red mottled marble.

The General Post-office.—The post-office is of Corinthian style of architecture. The E-street portion, constructed in 1839, of West Chester, New York, snowflake marble (dolomite), was the first important structure in Washington built of marble. In 1855 an extension to the north of the building was commenced, and the material used was marble from Cockeysville, Maryland, with portions of the foundations and facing of the court of granite. The columns of the extension are marble monoliths.

The Patent Office building.—This is considered quite a good specimen of Grecian-Doric style of architecture, and covers 2¾ acres of ground. The original building, commenced in 1837, is of Acquia Creek sandstone. In 1849 the extension, built of Cockeysville, Maryland, marble, was begun. This extension was added to the northeast and west sides in such a way as to inclose a quadrangle, the walls of which, and the sub-basement of the whole edifice, are built of Maine, Quincy, Massachusetts, and Woodstock, Maryland, granite.

The Smithsonian Institution.—The Smithsonian building is constructed of the Seneca sandstone. An examination of the building at the present writing shows it to be firm and substantial, and practically unaffected by any agencies, whether atmospheric or otherwise, except that Mr. Owen described the color of the stone when first quarried as a lilac gray, whereas it is now of a deeper and darker red color, due to its nature. In occasional nooks and corners in shaded portions of the building moss has appeared on the surface. It should be stated, however, that stone which is to be used for building purposes should be carefully selected. The top courses and others manifestly inferior should be rejected. A little observation reveals that many building stones, especially sandstones, acquire an unfavorable reputation by lack of care in not rejecting the unfit portions, as in nearly all quarries there are layers close to the surface, and sometimes in deeper portions, which are defective and unfit for use.

The building is in style of architecture Norman, dating about the end of the twelfth century, and ranks as one of the best specimens of this style now in existence. The different portions of the edifice, examined separately, are unlike in appearance, yet the general effect is pleasing and harmonious.

THE WASHINGTON MONUMENT.—According to the original design of the Washington monument, an obelisk 600 feet in height and 55 feet square at the base was contemplated. The original foundation was 80 feet square and 16 feet 8 inches in height, 7 feet 8 inches extending below the surface. The wall of the obelisk is 15 feet in thickness at the base, gradually tapering at the rate of a quarter of an inch to the foot on the outside, the inside being perpendicular. The work is now rapidly progressing according to the original design, except that it is proposed to limit the height to 525 feet. The old foundation was pronounced defective by a board of engineers, and was enlarged to 126 feet 6 inches square, a work which was completed in 1880, and was done by excavating 70 per cent. of the earth from beneath the monument and introducing a mass of concrete 13 feet 8 inches in thickness. The great height of this structure, together with the marshy nature of the ground in its vicinity, made it necessary to use more than ordinary precautions in constructing a foundation that could be considered secure. The exterior walls of the shaft are of marble from Cockeysville and Texas, Baltimore county, Maryland, though in the beginning some Lee, Massachusetts, marble was used. The interior walls are chiefly of granite from different places on the coast of Maine. In a report made by Colonel Thomas L. Casey, corps of engineers, United States army, engineer in charge of the construction of the monument, to W. W. Corcoran, esq., chairman of the joint commission for the completion of this structure, dated July 27, 1878, is found the following table. So extraordinary a test of stability is given to the stone by the great weight of the superstructure, that it will be watched closely by builders and engineers as time determines its endurance:

Distance of joint from top in feet.	Contents in cubic feet.	Average weight per cubic foot of masonry in several divisions.	Weight in pounds.	Pressure in tons (2,240 pounds) per square foot.			Distance of "line of resistance" from axis in feet.	Stability under action of the wind.
				Least.	Mean.	Greatest.		
25	....	First division.................169.5 pounds.	....	....	....	....	0.603	29.454
50	13,555		2,297,630	2.67	2.96	3.26	1.052	17.378
100	34,719		5,884,973	4.41	5.23	6.04	1.676	11.529
150	63,957		10,840,728	5.85	7.24	8.64	2.087	9.758
171.66	79,239		13,431,081	6.44	8.08	9.72	2.224	9.360
200	101,674	Second division..............167.8 pounds.	17,195,713	7.14	9.12	11.09	2.383	8.983
250	148,298		25,019,140	8.35	10.90	13.44	2.607	8.610
300	204,273		34,411,997	9.54	12.63	15.73	2.779	8.452
343.66	261,191		43,963,655	10.56	14.11	17.66	2.899	8.417
350	272,369	Third division................165.8 pounds.	45,816,912	8.28	11.51	14.73	2.892	8.481
400	366,268		61,385,397	10.09	13.84	17.60	2.869	8.902
450	470,495		78,666,278	11.76	16.03	20.30	2.889	9.190
500	585,476		97,264,244	13.38	18.02	22.658	2.928	9.413

The mean pressure per square foot upon the lower joint is 18.02 tons, and the maximum pressure brought upon any square foot of the lowest joint under the action of the wind is 22.658 tons. The crushing weight of the marble, as determined by the board above mentioned, is 517 tons per square foot.

Nearly 200 memorial blocks were sent by the different states of the Union, by corporations, lodges, societies, individuals, and foreign countries, to decorate the interior walls of the monument. Blocks of granite came from the various regions of New England, Virginia, Maryland, California, Minnesota; marble and limestone from Vermont, Massachusetts, New York, Pennsylvania, Maryland, Virginia, North Carolina, Ohio, Kansas, Missouri, Iowa, Illinois, Mississippi, and Canada; and sandstone from the Triassic brownstone quarries of Connecticut and New Jersey. The following are some of the stones received from foreign countries: A block from the tomb of Napoleon, island of St. Helena; block of Grecian marble from the temple of Esculapius, presented by the officers of the United States steam frigate Saranac; block from Foo-chow, China; lava from Mount Vesuvius; sandstone said to be from the original chapel built to William Tell in 1358, on lake Luzerne, Switzerland; red syenite (granite) from the Alexandrian library in Egypt; porphyritic biotite granite from the Swiss Confederation; gray biotite gneiss from the empire of Brazil; Grecian marble from the governor and commune of the islands of Paros and Naxos, Grecian archipelago; marble from the Ottoman empire; a block of peculiar and characteristic greenish stone from China; a highly-polished block of red granite from Bremen; Grecian marble from the kingdom of Greece; a head carved between two and three thousand years ago by ancient Egyptians for a temple erected in honor of Augustus, on the banks of the Nile, and set in a block of Italian marble.

Some of the contributions from corporations, societies, and individuals in this country are of Italian marble.

In the following list will be found some of the principal stone structures in Washington and vicinity, with kinds of stone used in their construction:

1. Acquia Creek sandstone.

Executive Mansion.
Capitol building (old portion).
Van Ness residence.
City Hall foundation.
Treasury building (old portion).
Patent Office building (old portion).
Van Ness mausoleum.

2. Potomac mica-schist.

Foundation of Executive Mansion.
Foundation of Treasury building.
Foundation of Washington Monument.
Chapel in Oak Hill cemetery.
Georgetown College (new building).

3. Seneca sandstone.

Smithsonian Institution.
Chapel at Soldiers' Home.
Chapel in Oak Hill cemetery (trimmings, front).
Department of Justice, formerly Freedman's Bank.
District jail.
National Republican office, now Pension Office.
School-house, Second and Potomac streets.
Lincoln Hall.
Cabin John's bridge, parapets and coping.
Memorial Lutheran church.
Sub-basement south wing State, War, and Navy Department building.
Center Market (foundations).

4. Westchester County, New York, marble.

E-street portion of the General Post-Office building.

5. Cockeysville, Maryland, marble.

Exterior walls of Washington Monument.
Columns of the Capitol extension.
Extension of Patent Office building.
General Post-Office building (extension).
Ascension church.
Dormitory at Soldiers' Home.

6. Lee, Massachusetts, marble.

Portion of the exterior walls of the Washington Monument.
Capitol extension.

7. Maine granite.

Interior of Washington Monument.
Extension of Treasury building.
Basement of new State Department building.
Quadrangle of Patent Office building.

8. Quincy, Massachusetts, granite.

Patent Office interior walls, foundations, and basement (partly).

9. Woodstock granite.

Foundation of the Patent Office building (partly).
National Museum (foundation).
Masonic Temple (foundation).

10. Port Deposit gneiss.

Foundation of Treasury building (extension).
Saint Dominick's church.

11. Belleville, New Jersey, brownstone.

Corcoran Art Gallery.

12. Manassas, Virginia, brownstone.

District jail (trimmings).

13. Montgomery County, Pennsylvania, marble.

Stone-work at Botanical Garden.
Sarcophagi containing bodies of George and Martha Washington, at Mount Vernon.

14. Cape Ann granite.

Residence of Benjamin F. Butler.

15. Connecticut brownstone.

Foundation and trimmings of E-street Baptist church.
Saint Marc hotel.
Arlington hotel (front).
Columbia Institution for the Deaf and Dumb (trimmings).
Masonic Temple (partly).
Residence of Senator William Windom.
Residence of Lieutenant Broadhead (trimmings).
Metropolitan church.
Agricultural building (trimmings).
First Presbyterian church.

16. Nova Scotia sandstone.

Masonic Temple (trimmings).
Colonization building (front).
Riggs house.

17. Richmond, Virginia, granite.

State, War, and Navy building (superstructure).
Bureau of Engraving and Printing (foundation).

18. Ohio sandstone.

National Republican building, now Pension Office (trimmings).
Baltimore and Ohio depot (trimmings).
Lewis Johnson & Co.'s bank.
British Legation building.
National Museum building.
Ex-Governor A. R. Shepherd's block, opposite Farragut statue (Buena Vista stone).
Portland flats.
Capitol grounds, inclosure-walls (partly).
Columbia Institution for the Deaf and Dumb (trimmings, partly).

19. Hummelstown brownstone.

Residence of Hon. James G. Blaine (trimmings).
Residence of Senator John Sherman (trimmings).
Residence of Senator J. D. Cameron (trimmings).
Residence of Jerome Bonaparte (trimmings).
Bureau of Engraving and Printing (trimmings).

20. Chester County serpentine.

Residence on Fourteenth street.
Residence on Iowa circle.

21. Vermont marble.

Floors of National Museum building (Swanton Lyonnaise marble).
Walls of library of Navy Department (partly).
Walls of cash-room in Treasury Department (partly).
Corcoran mausoleum, Oak Hill cemetery.

22. Cheat River, West Virginia, sandstone.

Catholic institution between Twelfth and Thirteenth streets.

STONE PAVEMENTS.—In the report for the year ending June 30, 1880, Lieutenant F. V. Green, United States engineer corps, assistant to the engineer commissioner of the District of Columbia, gives the following interesting facts concerning the condition of the streets of Washington on the 1st of July, 1880:

	Square yards.	Miles.
Asphalt and concrete (coal tar)	981, 348	40. 66
Stone block	411, 774	14. 87
Rough stone	559, 051	18. 04
Macadam	215, 330	7. 45
Gravel	644, 993	31. 31
Wood	509, 481	22. 10
Unimproved	1, 799, 541	95. 62
Total	5, 121, 518	230. 05

It is stated that there were in all 1,188,597.47 square yards of wooden pavements, aggregating a length of nearly 50 miles, and costing $4,003.744; that in 1878 there were, exclusive of paving between railway tracks, 790,000 square yards, or 34 miles, of wooden pavements; and that on June 30, 1882, these pavements had been partially replaced to the following extent:

Years.	WITH ASPHALT.		WITH GRANITE.		WITH ASPHALT BLOCK.		TOTAL.	
	Square yards.	Cost.	Square yards.	Cost.	Square yards.	Cost.	Square yards.	Cost.
1878–1879	104, 022. 52	$200, 900 18	56, 993. 24	$129, 657 32	1, 093. 35	$2, 661 61	162, 109. 11	$333, 219 11
1879–1880	67, 962. 91	104, 143 17	45, 084. 28	87, 390 42	3, 214. 08	6, 349 51	116, 261. 27	197, 883 10
Total	171, 985. 43	305, 043 35	102, 077. 52	217, 047 74	4, 307. 43	9, 011 12	278, 370. 38	531, 102 21

The proportion of stone to asphalt laid in two years, from July, 1878, to July, 1880, is as 10 to 17.

The granite-block pavement here is laid on a foundation of gravel and sand, and the joints are filled with cement of coal tar and gravel, as before stated. Of the 18 miles of stone-block pavements 7 miles are composed of North River blue-stone and the balance of granite. The granite comes from various quarries in Maine and cape Ann, Massachusetts, from Westerly, Rhode Island, and from Richmond, Virginia. The texture of the different varieties is quite dissimilar; the finer-grained stones make a smoother surface for a pavement and the coarser ones a more durable surface. Of the 17.50 miles of rough stone pavements 8 miles are composed of cobble (quartz or sandstone drift) and the remainder of rubble, mostly the so-called blue-rock or mica-schist, of Rock creek. A small amount of rubble is of the Seneca stone, which, owing to its more ready attrition, does not prove to be well adapted to paving purposes, excepting for sidewalks.

The macadam pavement is mainly of the mica-schist from Rock creek, but part of it is broken cobble-stone and a part of it flint-stone—that is, quartz found in seamy ledges in the mica-schist formation.

WHEELING, WEST VIRGINIA.

The site of Wheeling is very narrow, on account of the abrupt hills, situated a short distance back from the river, which oblige the city to extend itself to a great length along the stream, as the hills are too abrupt to furnish sites for buildings. The material used in stone construction is the Coal-Measure sandstone quarried in the immediate vicinity, and on the opposite side of the river, in Belmont county, Ohio. This is of sufficiently good quality to answer for all ordinary purposes of construction. For the soldiers' monument in course of construction the material used is granite obtained from the New England Granite Works at Hartford, Connecticut. Strictly speaking, there are no stone fronts in the city, but there is considerable stone in basement stories, corners, and other trimmings. The abutments of the suspension bridge across the Ohio river at Wheeling are constructed of sandstone from the local quarries. The wharves are constructed of cobble-stones gathered from the river at low water, and the streets are nearly all paved with this material. There is a small amount of stone sidewalk paving, and the material used is sandstone from the local quarries and from Buena Vista, Ohio; the Buena Vista stone comes already sawed to the proper dimensions for paving purposes; it stands foot-wear well. The local stone, from its coarser and more granular and friable structure, wears away more rapidly under foot-wear.

WILKESBARRE, PENNSYLVANIA.

Wilkesbarre is located in the celebrated Wyoming valley, which lies between two ranges of the Allegheny mountains, the sandstone of Catskill age being abundantly exposed on their sides and much used in Wilkesbarre for purposes of construction. This material is very durable, but hard and expensive to dress for fine work. One of the principal quarries of this stone is situated in the mountains 7 or 8 miles east of Wilkesbarre; for the better class of trimmings Wyoming blue-stone from Meshoppen is now used almost exclusively, though considerable Catskill red sandstone is also employed for caps, sills, and trimmings generally. The Luzerne prison in Wilkesbarre is the most important stone structure of the place. It is built of Campbell's ledge stone, a siliceous conglomerate of a rich buff color, very substantial and durable. Several fine private residences in Wilkesbarre are constructed of it. There are some buildings trimmed with limestone from near Syracuse, New York. The material chiefly used for foundations and underpinnings is the Catskill red sandstone from the mountains in the vicinity. The Seral-Conglomerate, also quarried near, is used to a less extent for the same purpose. Only two or three streets are paved with stone, and the material used is cobble-stone from the Susquehanna river. The sidewalks are largely paved with stone, the material being the Catskill red sandstone before mentioned, and considerable Wyoming blue-stone from Meshoppen. Lehigh slate is also used to a limited extent for the same purpose. The curbstones are of Catskill red sandstone and Wyoming blue-stone. The bridge abutments in the bridges crossing the Susquehanna river are of Catskill red sandstone.

WILLIAMSPORT, PENNSYLVANIA.

There is no good stone for the better class of construction quarried near Williamsport, and where stone caps, sills, etc., are wanted they are brought from Hummelstown, Pennsylvania, almost exclusively, although some Berea and Amherst stone have been used for trimmings in one building. The Lycoming County court-house is trimmed with Nova Scotia sandstone, which nearly resembles the Ohio sandstone in color and texture. A few buildings have steps of the Montgomery County marble; the steps of the court-house are of New England granite, and are becoming slippery from foot-wear. In the cases of the North River blue-stone, Wyoming blue-stone, Ohio stone, and others having a sandy grit, there is no tendency to become slippery. The siliceous conglomerate, probably of Seral or Pottsville Conglomerate age, quarried at Ralston, Lycoming county, is the stone most used for steps and base courses; it is quite durable, does not become slippery, and seems to give entire satisfaction. It resembles the conglomerate at Pottsville quite closely. The stone most used for curbing is an even-bedded, slaty stone, easily quarried in suitable shapes for curbing; one piece being observed which was 30 feet long and one foot square at the end, resembling a hewn log. For bridge abutments rough stone from the mountains in the vicinity is used. Stone has heretofore been comparatively little employed at this place. Only one street is paved with stone and the material is rubble from the vicinity. There is but a limited amount of stone sidewalk pavement; the material most used is Wyoming blue-stone from near Meshoppen. Red and light-colored flags quarried in the vicinity are also used for this purpose, and there are a few flags of Ohio sandstone.

WILMINGTON, DELAWARE.

The building stones used in Wilmington are the Connecticut, Ohio, and New Jersey sandstones; marble from Cockeysville and Texas, Maryland; serpentine from Chester county, Pennsylvania; and granites from Brandywine creek, near the city. This last is the most convenient source of supply for the city for ordinary purposes, such as foundations and underpinnings, and for stone street pavements. The sidewalks are not paved with stone; the curbs are granite from Brandywine creek. The Cockeysville marble and the serpentine from Chester county are, however, in easy distance from the city, and have been used extensively. The court-house and a large church are constructed of the serpentine before mentioned, and also a building of Connecticut sandstone. The material in the walls of this building was set on edge, and it exfoliated badly. The following buildings are constructed of the Brandywine stone: Saint John's Protestant Episcopal church, Market street, and the houses of William Brinckly, Kennet street; Edward McIngalls, Eleventh and Jefferson streets; Joab Jackson, Eleventh and Washington streets; William Bush, Browne street; and Edward Tatnall, Market street.

WINONA, MINNESOTA.

Taking into consideration the location and readiness of access to the quarries and the quality of the material, there is no possibility of obtaining a better supply of building stone for use here than material found at Winona, Red Wing, and Stillwater. The stone when freshly quarried is easily wrought, but becomes hard by weathering. The railroad bridge, the jail, the sheriff's residence, and the piers and abutments of Winona bridge across the Mississippi river, are built of Winona limestone. Most of the business blocks are of red brick made near Winona. Some Ohio sandstone has been lately imported for trimmings. Among the other stones used for trimmings are the sandstone from Fond du Lac, Wisconsin, and the lime-rock from Frontenac and Kasota. The streets are not paved with stone, and there is but very little stone sidewalk pavement; the material used for this purpose is lime-rock from Winona.

WOONSOCKET, RHODE ISLAND.

In this place stone is very little employed as a material of construction. The quartzite and mica-schist, especially from the local quarries, have been largely used in building the mills, many of which are stuccoed. Northbridge, Massachusetts, granite and Diamond Hill granite are considerably used for underpinnings in the better houses. Curbs and crossings are usually of the Northbridge granite; walls are built largely of the local quartzite, which forms the poor man's stone of Woonsocket. The cobble-stones used in some of the buildings are found in the vicinity; in one or two structures Connecticut brown sandstone is employed.

WORCESTER, MASSACHUSETTS.

The houses here are mostly brick and frame structures. The main street contains most of the stone buildings. The local quarry known as Millstone ledge was some time ago given by its owner to the citizens for their free use; it is, however, mostly quarried by one man. The stone is good for common uses, but is not quite uniform in texture, and is too much stained for finer buildings or trimmings. The Arnold row of stores, built of this stone, exhibits its durability, and at the same time its rather unattractive appearance. The firm, sandy clay which forms the site of the city furnishes good foundations. The proportion of houses to inhabitants is large on account of the many small frame structures designed for the accommodation of factory employés. The foundations and underpinnings are of local gneissoid granites from the Millstone ledge. The principal business streets are paved with granite from Fitzwilliam, New Hampshire, and Westford, and the streets and sidewalks are usually paved with local and Fitzwilliam granites. The curbs are of the gneiss from the Millstone ledge. There are nearly 2 miles of stone arch sewers and bridge abutments built of the material from the local quarry. The Fitzwilliam granite is largely brought here by the proprietor of a local quarry. The Messrs. Norcross have constructed fine residences of the Longmeadow sandstone.

YONKERS, NEW YORK.

The stones in the vicinity of Yonkers available for building purposes are the trap bowlders and a very rough gneiss-rock, good only for foundations. For the better class of stone construction brownstone from Portland, Connecticut, and Ohio sandstone are used. There is an aqueduct some 300 feet long and 40 feet high faced with partly rough and partly dressed stone, the rough material of which is broken bowlders of trap, and the cut stone is gneiss from a local quarry. There is also about the town a great deal of retaining-wall made almost entirely of broken bowlders of trap. All these bowlders, of which there seems to be an unlimited supply, are found on or near the surface of the ground, enough being usually found in digging the cellar to build the foundation walls, and often underpinning also. The streets are to some extent macadamized with limestone from Tomkins Cove and with trap-rock and crushed bowlders. This style of paving is known as the Telford paving; in some localities the sidewalks are largely paved with North River blue-stone, as are all the cities which are within easy reach of the blue-stone region. Curbstones are also of this material.

YORK, PENNSYLVANIA.

The Siluro-Cambrian limestone, quarried in the vicinity of York, furnishes all the material that is used for the construction of cellars, foundations, street paving, and road macadamizing. The Goldsboro' brownstone from the Triassic formation in York county is used to a considerable extent. Of the marbles used for caps, sills, curbing, etc., considerable comes from Cockeysville and the town of Texas, near Baltimore, Maryland, some from Montgomery county, Pennsylvania, and some from Vermont and Massachusetts. The Gettysburg granite, a trap-rock precisely similar to the Conewago granite, is much used in York for steps, bases, caps, and sills. It is quarried on the battle-field at Gettysburg. The limestone quarried in the vicinity is the only stone used near York in the construction of bridges. There is a canal wall constructed of it. For steps and curbing, beside the Goldsboro' brownstone, which is principally used, considerable Gettysburg granite is used; also some Richmond, Virginia, granite; marble from Cockeysville, near Baltimore; some Montgomery County marble, and, occasionally, Connecticut brownstone. For base courses Gettysburg granite is used to some extent; for caps, sills, etc., Cockeysville marble, Montgomery County marble, New England marble, and some Gettysburg granite. For hall-ways and office floors, black and white marble tiling prepared in Philadelphia is used. One building is trimmed with the Amherst, Ohio, stone. The streets are nearly all macadamized with the native limestone. Sidewalks are but little paved with stone, and the material chiefly used is the native limestone. Peach Bottom slate, however, is used for this purpose in a few instances. The curbstones are of Goldsboro' brownstone.

ZANESVILLE, OHIO.

The sources for building stone are a ledge of Coal-Measures sandstone, quarried in the immediate vicinity. This ledge is a solid mass, about 40 feet in thickness, so that the supply is abundant; by far the larger part of the stone in and about Zanesville is of this material. It is used exclusively in the construction of canal locks, house foundations, excepting occasionally the top courses, and it furnishes a considerable part of sidewalk pavement. Two or three of the oldest buildings in Zanesville are constructed entirely of this stone. It proves to be durable in the walls of buildings, but does not resist foot-wear so well. The stone work of the Clarendon hotel is of the local sandstone. An abundance of this material, the ease with which it may be worked, and its fair quality for all ordinary building purposes, give it the first place in importance among the building stones found in the neighborhood. Another source of supply is the ferriferous limestone near the same horizon.

CHAPTER VIII.—THE DURABILITY OF BUILDING STONES IN NEW YORK CITY AND VICINITY. (*a*)

BY ALEXIS A. JULIEN, PH. D.

The ravages upon our building stones, by that complex association of forces which we call "the weather", are dangerous and rapid. The indications of interest in regard to the serious results, which are sure to come within a short period, are feeble and evanescent. A brief discussion of the main facts and of the principles involved may aid in forming a basis upon which future investigations may rest. The commissioners, appointed by the Department of the Interior "to test the several specimens of marble offered for the extension of the United States Capitol", said in their report of December 21, 1851:

> Though the art of building has been practiced from the earliest times, and constant demands have been made in every age for the means of determining the best materials, yet the process of ascertaining the strength and durability of stone appears to have received but little definite sc entific attention, and the commission, who have never before made this subject a special object of study, have been surprised with unforeseen difficulties at every step of their progress, and have come to the conclusion that the processes usually employed for solving these questions are still in a very unsatisfactory state.

Over thirty years have passed since these words were written, and the same methods are still largely in use, although new instruments and processes and rich discoveries concerning the structure of stone have been made available within a quarter of a century. The facts presented have been gathered from many sources published and unpublished, and from long personal observation. It is but a question of time when careful and thorough investigation for the purpose of determining the best means to avert the coming destruction will be called for. It is necessary first to understand the number and the character of the natural foes which are making this deadly attack.

All varieties of soft, porous, and untested stones are being hurried into the masonry of the buildings of New York city and its vicinity. On many of them the ravages of the weather and the need of the repairer are apparent within five years after their erection, and a resistance to much decay for twenty or thirty years is usually considered wonderful and perfectly satisfactory.

Notwithstanding the general injury to the appearance of the rotten stone, and the enormous losses annually involved in the extensive repairs, painting, or demolition, little concern is yet manifested by either architects, builders, or house-owners. Hardly any department of technical science is so much neglected as that which embraces the study of the nature of stone, and all the varied resources of lithology in chemical, microscopical, and physical methods of investigation, wonderfully developed within the last quarter-century, have never yet been properly applied to the selection and protection of stone as used for building purposes.

The various suburbs and vacant districts have been gradually approaching a character sufficiently settled to justify the erection of entire and numerous blocks of private residences, huge buildings for business offices in the lower part of the city and for family flats in the central and upper wards, besides large numbers of public edifices, storage houses, manufactories, etc. The failure of stone to resist fire in the business district, and the offensive results of discoloration or serious exfoliation, which the poor durability of many varieties of stone has rendered manifest in all parts of the city, have already largely diminished its proportionate use, in reference to brick. Nevertheless great quantities of stone of many kinds are yet introduced, as ashlar or the trimmings of apertures, into the buildings now in progress, and will soon be further employed, if the present activity in building be continued, not only in the private enterprises already mentioned, but in others of more lasting and public importance; *e. g.*, the projected improvements and additions in connection with our water supply, as aqueducts and reservoirs; the new bridges proposed over our rivers; the replacement of our rotting wooden docks by more permanent structures; and perhaps, we may hope, the huge pedestal to support the statue of Liberty on an island in our harbor. As the kinds of building stone brought to this market for these purposes are increasing in number and variety, and their selection and mode of use, as it seems to me, are irregular and indiscriminate, whether from the ignorance or the carelessness likely to prevail in a busy, money-getting community, it would appear proper that a voice of warning should now be heard, calling attention to the dangers involved in the use of bad stone or the bad use of good stone; in the enormous waste and expense soon required for repairs in our severe climate, or in the consequent disuse of stone in favor of brick, by a natural reaction, to the injury of the beauty and comfort of our city.

a From the commercial relations of New York to the quarries of this country and of foreign countries, and from the enormous scale on which the practical value of building materials is tested in that city, this chapter, though local in title, forms the best available summary upon the durability of building stone for the United States, and is therefore placed in the present order.

There are three classes in the community to which such a warning is addressed:

1. A considerable number of house-owners, to whom it seems to come too late, since they have already expended tens of thousands of dollars in temporary repairs, patching and painting decayed stone, and many of whom have doubtless made rash vows to use hereafter, in construction, brick, iron, terra-cotta, wood—anything but stone.

2. House-owners, not yet aware of the coming dilapidation, and who can yet take precautions to delay or prevent its arrival—or others about to build, and who have implicit faith in the eternity of building-stone, since it comes from the "everlasting rock", or at least in a duration which will last their lifetimes—and also a certain proportion of builders and architects willing to learn, and who have much to learn, since the practical scientific study of building stones is yet to be made.

3. And lastly, the architects, builders, and contractors, who know all about the subject, or who do not care what happens to the houses they build, and that large part of our population who never expect to own any houses. To all these the decay of the stone in this city is a matter of indifference, and the quotation presented below—"scarcely a public building of recent date will be in existence a thousand years hence"—few of them, indeed, over a century or two, in fair condition—is only a matter of jest.

1.—EFFECTS OF WEATHERING UPON THE BUILDING STONE OF NEW YORK, ETC.

In foreign countries the subject of the attack of atmospheric agencies on building stones has received much attention, particularly within the last half century, and much earnest effort, though as yet ill-systematized and ill-regulated, has been exerted for their protection by means of the new light and facilities of modern sciences. The contrast between the durability of the stone buildings erected in modern and in the most ancient times is strongly marked:

In modern Europe, and particularly in Great Britain, there is scarcely a public building, of recent date, which will be in existence a thousand years hence. Many of the most splendid works of modern architecture are hastening to decay in what may be justly called the infancy of their existence, if compared with the dates of public buildings that remain in Italy, in Greece, in Egypt, and the East.—*Gwilt's Encyclopedia of Architecture.*

In England this is largely due to the general use of soft freestones, both sandstones and, especially in London, earthy, loosely compacted limestones. Before the erection of the houses of parliament a royal board of commissioners was appointed for the selection of the proper building stones, and a large amount of information was collected on the subject of the modes and rapidity of weathering of the various building stones throughout the United Kingdom. So difficult and novel, however, was the investigation that the results obtained have been only partially successful, both in the selection of the stone, and, on its incipient attack by the atmosphere of London, in the artificial means suggested for its preservation. Only last year the statement was made, in reference to the building of the royal courts of justice, just erected and inaugurated in London:

What will be the fate of its exterior carvings and frettings after another fifty years of London smoke, all of us can tell. The same may be said of a thousand other buildings, great and small, that the past generation of Londoners has raised as monuments of its own ignorance of the simplest conditions of good building. They carve their fronts with carvings of flowers and fruit, which in a year the soot will blacken past recovery, and in five years corrode beyond recall.

We see important and costly edifices restored in the lifetime of the architects who designed them, and palaces patched with cement and painted over every three or four years, before their builders have passed away. * * * No remedy has been found for the decay of soft calcareous stone in our smoky cities; and yet, in our childish helplessness, we continue to use it daily and year after year, as if we had no warnings of the folly of doing so. (*a*)

In a recent investigation of the subject, founded largely on a study of the stone monuments in the grave-yards of Edinburgh, Dr. A. Geikie, of the geological survey of Great Britain, has pointed out that in a town the weathering action differs from that which is normal in nature; on the one hand in the formation of sulphuric acid from smoke, causing more rapid decay of stone-work; on the other in the inferior range of temperature in towns and less severe action of frost.

Dr. Geikie also found that sandstones, if siliceous, were sometimes only roughened in two hundred years. When colored the destruction goes on by solution of cement, or of the matrix in which the particles of silica are embedded, *e. g.*, clay, carbonate of lime, and iron and hydrous and anhydrous ferric oxide. In this material he estimated the rate of lowering to amount to three-quarters of an inch in a century.

In the stone of the buildings of New York and adjacent cities the process of disintegration and destruction is widespread, and yearly becoming more prominent and offensive.

GNEISS.—The commissioners of the Croton Aqueduct department, in their annual report for 1862, page 67, make the following statement:

The retaining-walls of the embankments in many cases require extensive rebuilding. Most of these walls have been constructed of the stone found in their immediate neighborhood—often of a very inferior and perishable character. Thus far we have been able to keep these walls in comparatively good order by removing every year portions of disintegrated stone and replacing them with durable material; but during the past year such large portions, and at so many points, are giving way in mass, that an increased amount must necessarily be expended on them during the coming season.

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a The Builder, 1881, p. 708.

MARBLE.—Italian marble has been found incompetent to withstand the severity of our climate, when used for outdoor work; and of this good illustrations are shown in the pillars, once elegantly polished, in the portico of the church on the southeast corner of Fourth avenue and Twentieth street, etc. The same objection has been urged to the outdoor use of American marbles in our cities, supported at least by their rapid discoloration, but the question is yet unsettled.

Professor Hull observes:

From the manner in which the buildings and monuments of Italy, formed of calcareous materials, have retained to a wonderful degree the sharpness of their original sculpturing, unless disfigured by the hand of man, it is clear that a dry and smokeless atmosphere is the essential element of durability. In this respect, therefore, the humid sky and gaseous air of British towns must always place the buildings of this country at a comparative disadvantage as regards durability.

And again:

Under a smokeless atmosphere it is capable of resisting decay for lengthened periods, though it becomes discolored. * * * The perishable nature of the marble when exposed to the smoky atmosphere of a British city, is evinced by the decayed state of the tomb of Chantrey, erected in 1820, in the "God's acre" belonging to St. John's Wood chapel.

Another example of this decay is shown in the group of Queen Anne, etc., erected from Carrara marble, about the beginning of the eighteenth century, before the west front of St. Paul's, in London, England, and which has been covered throughout with a coat of paint in the hope of slightly retarding its inevitable decay. The dolomitic marble of Westchester county has been largely employed in our buildings, and some idea of its character for durability may now be gained. A fine-grained variety was used in the building of the United States assay-office, in Wall street; its surface is now much discolored, and the edges of many of the blocks show cracks. A variety of medium texture was employed in the hotel at the corner of Fulton and Pearl streets, erected in 1823; the surface is decomposed, after the exposure of exactly sixty years, with a gray exterior, in a crust from one-eighth to one-fourth inch in thickness, soft and orange-colored in section. Many crystals have fallen out of the surface on the weathered eastern face, producing a pitted appearance. A very coarse variety has been used in the bank building at Thirty-second street and Broadway, in large part being set on edge; very many of the blocks are more or less cracked, even in the highest story. In the United States Treasury building, in Wall street, a rather coarse dolomite-marble, rich in tremolite and phlogopite, was used, the blocks being laid on bed in the plinth and most of the ashlar, but largely on edge in the pillars, pilasters, etc.; in the latter case vertical fissures commonly mark the decay, but even elsewhere a deep pitting has been produced by the weathering out of the tremolite. The marble used in many other prominent buildings has been improperly laid, *e. g.*, in both of the buildings of the city hall, the Drexel building, at the corner of Broad and Wall streets, the Academy of Design, at Twenty-third street and Fourth avenue, etc. The same process of ultimate ruin in its incipient stages is abundantly shown, even in the marble slabs in Saint Paul's church-yard and monuments of Greenwood cemetery, by discoloration and disintegration of surface. In the United States hotel, on Fulton street, constructed of Westchester marble in 1823, we have the opportunity to study the effect of weathering for over a half century. Though presenting a good appearance at a distance, the stone has become pitted by the falling out of grains, especially on the east side, and is tinged a dirty orange by a crust of decomposition from one-sixteenth to a quarter of an inch in depth.

The horizontal tablets, supported on masonry which has partially settled (*e. g.*, J. G., 1821), generally show a slight curvature in center, only in part, possibly, produced through solution by standing rain-water.

Dolomieu first made the observation on an Italian marble, called betullio, that it possessed a degree of flexibility allied to that of the itacolumite of Brazil. Gwilt states (*Encyclopedia of Architecture*, p. 1274):

Some extremely fine specimens of white marble are to be seen in the Borghese palace at Rome, which, on being suspended by the center on a hard body, bend very considerably. It is found that statuary marble exposed to the sun acquires, in time, this property, thus indicating a less degree of adhesion of its parts than it naturally possessed.

In the white-marble veneering of the façade of St. Mark's, Venice, the same effect has been observed by Mr. C. M. Burns, jr., in the lower half of a slab of veined marble, 2 inches thick, on the south side of the northernmost of the five portals, just behind the columns and about 5 feet from the pavement. The slab is 11 feet 2 inches long, and 1 foot 6 inches wide; it is hung to the backing by copper hooks driven into the brick-work, but the lower part, for a distance of 5 feet 7 inches, bulges out $2\frac{3}{4}$ inches from the backing.

The exposure is directly westward, and I found that it became decidedly warm in the afternoon sun, while the backing would be likely to keep its temperature lower. Though the outer surface is somewhat weatherworn, I could not find the slightest tendency to fracture in any part.—*The American Architect and Building News*, 1882, p. 118.

Also at the palace of the Alhambra, in Grenada, Spain, one of the two doors that have been christened "La Mezquita" exhibits an ancient facing of three slabs of marble, the upper resting as a lintel upon the two others, which form uprights, 11 feet in height, 9 inches in width, and only $2\frac{1}{2}$ inches in thickness. At $18\frac{1}{2}$ inches from the top of the door the slab on the right begins to curve and to detach itself from the wall, attaining the distance of 3 inches at about 3 feet from the bottom. From a subsidence of the material of the wall an enormous thrust has been exerted upon the right, and the marble, instead of breaking or of rupturing its casings, has simply bent and curved as if it were wood.—*La Nature*, 1882.

I have also been informed at Sutherland Falls and other quarries near Rutland, Vermont, that the bending of thin slabs of marble exposed to the sunshine in the open air, and accidentally supported only at the ends, has been there repeatedly observed.

Fleurian de Bellevue discovered a dolomite possessed of the same property in the Val-Levantine, of Mount Saint Gothard. Dolomieu attributed the property to "a state of desiccation which has lessened the adherence of the molecules of the stone", and this was supposed to be confirmed by experiments of De Bellevue, who, on heating inflexible varieties of marble, found that they became flexible.

This change, however, cannot be connected with the remarkably small content of water existing in marbles, but with a peculiarity of their texture, which has been briefly discussed by Archibald Geikie (*Proc. Roy. Soc. Edinb.*, 1880), in an interesting investigation on the decay of the stones used in Scotch cemeteries. He has pointed out that the irregular and closely-contiguous grains of calcite which make up a white marble are united by no cement, and have apparently a very feeble coherence.

It appears to me probable also that their contiguous crystallization has left them in a state of tension, on account of which the least force applied, through pressure from without, or of the unsupported weight of the stone, or from internal expansion by heat or frost, produces a separation of the interstitial planes in minute rifts. Such a condition permits a play of the grains upon each other and considerable motion, as illustrated in the commonly-observed sharp foldings of strata of granular limestones, without fractures or faults. In such cases, also, I have observed that the mutual attrition of the grains has been sometimes sufficient to convert their angular, often rhomboidal, original contours into circular outlines, the interstices between the rounded grains being evidently filled up by much smaller fragments and rubbed-off particles; *e. g.*, in the white marble of the anticlinal axis at Sutherland Falls, Vermont.

These results are confirmed by the appearances, familiar to all lithologists, in the study of thin sections of marble, the latent interstices between the grains of calcite having been often developed by the insinuation of films and veinlets of iron-oxide, manganese-oxide, etc. While a polished slab of marble fresh from the stone-yard may not be particularly sensitive to stains, after it has been erected and used as a mantel-piece over a fire-place, its increased absorption of ink, fruit-juices, etc., becomes strongly marked. On this property are founded the processes, always preceded by heat, for the artificial coloring of marbles.

In the decay of the marble, largely Italian, in the atmosphere of Edinburgh, Geikie has recognized three phases:

1. Loss of polish, superficial solution, and production of a rough, loosely-granular surface. This is effected, Geikie states, by "exposure for not more than a year or two to our prevalent westerly rains". The solution of the surface may sometimes reach the depth of about a quarter of an inch, and the inscriptions may become almost illegible in sixteen years.

In our own dry climate, however, these results do not appear. The polish often survives ten years in our city cemeteries, and even for over half a century, near the ground, in the suburban cemeteries; in one instance, at Flatbush, it has remained intact for over 150 years, on the tombstone of F. and P. Stryker, dated 1730. Inscriptions are decipherable in Saint Paul's church-yard back to the date of 1798, but about one-tenth are illegible or obliterated; the latter effect was never seen in a single instance on the suburban stones, and is evidently due to the acid vapors in the rain-waters of the city.

2. Incrustation of the marble with a begrimed, blackish film, sometimes a millimeter in thickness, consisting of town-dust, cemented by calcium sulphate, and thorough internal disintegration of the stone, sufficient, after a century, to cause it to crumble into powder by very slight pressure.

Neither the crust nor any deep disintegration has been observed in the oldest marble tombstones in the cemeteries of New York; their absence is plainly attributable to the inferior humidity of our atmosphere and the absence of smoke from soft coals.

3. Curvature and fracture, observed in slabs of marble, firmly inserted into a solid frame-work of sandstone. This process consists in the bulging out of the marble, accompanied with a series of fractures, and has been accomplished by expansion due to frost. Tombstones are never constructed in this way in our cemeteries; but the curvature of horizontal slabs, observed in Saint Paul's church-yard, produced by the sagging of the supporting masonry beneath the center of the slab, is simply indicative of the flexibility of the material.

Geikie states:

> The results of my observations among our burial-grounds show that, save in exceptionally sheltered situations, slabs of marble exposed to the weather in such a climate and atmosphere as that of Edinburgh are entirely destroyed in less than a century. Where this destruction takes place by simple comparatively rapid superficial solution and removal of the stone, the rate of lowering of the surface amounts sometimes to about a third of an inch (or, roughly, 9 millimeters) in a century. Where it is effected by internal displacement, a curvature of 2½ inches, with abundant rents, a partial effacement of the inscription, and a reduction of the marble to a pulverulent condition, may be produced in about forty years, and a total disruption and effacement of the stone within one hundred. It is evident that white marble is here utterly unsuited for out-of-door use.

My own conclusion, from observations in New York, is that, in the cemeteries within the city, the polish on vertical slabs is usually destroyed in about ten years; that the inscriptions are only in small part effaced within from thirty to fifty years, and are for the most part perfectly legible on the oldest tombstones, dating 1798; and that, although the reduction of the surface to a loose granular condition may reach the depth of ten millimeters, the actual lowering of the surface seldom exceeds 5 or 6 millimeters, the internal disintegration is never sufficient to affect sensibly the strength of the stone during the periods of exposure which have been noted, and a slight flexure, perhaps to the amount of 12 or 15 millimeters, sometimes affects the center of horizontal slabs, 2 meters in length.

In the cemeteries without the city the polish may often survive near the ground, on the faces of vertical slabs, for over one hundred and fifty years, as the granulation of the surface rarely exceeds a depth of 3 or 4 millimeters; and all the inscriptions remain perfect on the oldest vertical tombstones, suffering partial effacement only on horizontal slabs.

Although these facts show the far greater durability of marble in our dry and pure atmosphere, the frequent obliteration of inscriptions, the general, and often rapid, granulation of the surface, and the occasional fissuring of slabs, show that the decay of marble—in the varieties hitherto long used in New York city—is steady, inevitable, and but a question of time; and with Geikie, I, too, am convinced that, if unprotected, such materials are utterly unsuited for out-of-door use, at least for decorative purposes or cemetery records, within the atmosphere of a city.

Sandstone.—In regard to brownstone there seems to be a common if not universal opinion—but, in my own view, too hasty, and by no means established—which is presented in the following quotation:

> The days of brownstone fronts for the better class of houses are probably numbered. A thin veneering of soft stone, hooped on to a brick wall, adds almost nothing to the strength of a building. On the exposure of the brownstone fronts for sixty or eighty years to the severity of our climate, in the opinion of intelligent stone-cutters, the majority of them will be in ruins, and the remainder much dilapidated.

In the widely-quoted opinion of one architect, this stone is of no more use for architectural work in this region than so much gingerbread.

Even the brown sandstone of the city hall, originally of a very superior quality, and the crumbling cornices, lintels, etc., of numberless houses which line some of the other streets of the city, evince the progress of the decay. It makes no very great difference whether the stone is laid parallel or perpendicular to its grain. In the former case its destruction is more rapid; in the latter, rottenness soon appears in the lintels, columns, cornices, and other projecting portions of the edifice. Several of the fronts along Fifth avenue, some of them less than ten years old, already look frightful to the experienced eye of an honest stone-cutter.

In regard to the name "Nova Scotia stone", it may be well to explain that it originated many years ago, when grindstone dealers obtained their supplies from some small surface quarries located in and near Nova Scotia. As that stone was of a yellow color, the stone trade has persisted ever since in calling every light-colored stone coming from anywhere in that section "Nova Scotia stone". However, 95 per cent. of the imported stone is derived from New Brunswick (probably 85 per cent. from Dorchester), and the remainder from Nova Scotia and other points. The popular name has been applied to light-colored stones of every quality, quarried at various points of eastern Canada, over a wide section of country, hundreds of square miles in extent, and variously worked out at tide-level, under tide-water, from exposed reefs running out into the sea, or, as at Dorchester, New Brunswick, from a hillside 900 feet high and a quarter of a mile from tide-water. The small quarries usually work out only such stones as they can obtain from outcropping ledges and bowlders, and these are apt to be of bad and varying color, more or less full of iron and other defects; for example, the surface quarries of Hillsboro', New Brunswick, long since abandoned, used in the houses in Forty-second street near Madison avenue, in Second avenue near Fifty-fifth street, some of the bridges in Central park, etc. At the quarries of Dorchester, New Brunswick, it is stated that from 35 to 50 feet of inferior rock and débris are first stripped off to reach the sound rock which is sent to this market. The introduction of this stone into the city as a building material has been too recent to allow any measure of its durability. A little exfoliation may be, however, distinguished near the ground line, and on the sides and posts of stoops, in many cases. Also, in panels, under heavy projecting moldings, cornices, etc., where the sun has no chance to reach and dry up the dampness, the stone molders away slightly over the surface. In the cemeteries it is rarely or never used; in one example, possibly of this material, in Saint Paul's church-yard, (W. J. M., 1841), the decay is plainly beginning around the carvings. The discoloration of good varieties of the stone would be very slow to affect vertical surfaces, properly protected by drips; but on sloping, horizontal, or shaded surfaces, especially near the street-level, street-dust is sure to lodge and cling, all the more after the surface becomes roughened by a slight disintegration; while the rough usage to which the stone of balustrades and stoops is always subjected in a busy street, renders this, as well as all other soft varieties of freestone, liable to chipping as well as offensive discoloration (*e. g.*, in the courses, trimmings, and posts of the church on the corner of Forty-second street and Madison avenue, etc.), and unsuitable for use near the ground line.

These freestones from New Brunswick and Nova Scotia, largely employed in our cities, rarely exhibit a laminated structure, and, though a softer stone than the Triassic sandstone just referred to, is rarely affected by exfoliation to any extent, partly perhaps because its introduction into this district has been much later than that of the brownstone. Many instances occur, however, where already an exfoliation has taken place, especially near the ground line and on peculiarly exposed surfaces, sufficient to mar offensively the appearance of the masonry. This is exceptional it is true, but only a proper investigation or a far longer trial—as yet little exceeding twenty-five years—will establish the fitness of this stone for this climate.

So also the freestone from Amherst, Berea, etc., Ohio, has been used to considerable extent, and in one building (on the corner of Broadway and Barclay streets) has stood well for twenty years. Its rich content of quartz, said to reach 97 per cent. in the buff stone from Amherst, renders this one of the most promising, in regard to durability, of all the freestones of the sandstone class yet introduced here. Buildings constructed of this material in this city since 1857 (*e. g.*, on the corner of Barclay street and Broadway, on the corner of Howard and Crosby streets, etc.), show no decay, but only discoloration. In other instances (*e. g.*, rows of houses on Fiftieth street, west of Fifth avenue, on Madison avenue between Thirty-fourth and Forty-third streets, etc.) the blackened discoloration and frequent chipping of edges of the soft stone are quite offensive. On the other hand, it must be admitted that a stone which cleans itself by the disintegration of its surface, the grains dropping out and so carrying away the dirt, as in the poorer and softer varieties of brownstone or of Nova Scotia stone, is by that very action still more objectionable from its want of durability; and the discoloration of the Ohio stone is offset, at least in part, in the best varieties, by their hardness and promise of durability. Nevertheless, all these light-colored freestones from New Brunswick or Ohio, as well as the light-colored limestones from Indiana, etc., and the light-colored granites from New England, are all open to the special objection of most offensive discoloration (described beyond) shown here in abundant instances as in the cities of the west. This is more likely to affect inclined than vertical surfaces, and those near the level of the street, *i. e.*, within the reach of deposit of street dust; and the objection might be largely obviated by our builders by discarding the light-colored stones of all kinds from projections (cornices, dressings of doors and windows, etc.), and from our stoops, where the additional softness of some varieties renders them liable to disfigurement from wear and blows (*e. g.*, the blocks of Nova Scotia stone fronts in Madison avenue, above Thirty-fourth street).

MEDINA SANDSTONE.—This material is of recent introduction (*e. g.*, Baptist church on Fifty-seventh street, west of Sixth avenue), and its true durability cannot yet be estimated.

BLUE-STONE (graywacke).—This stone is yearly coming into more general use, and, though somewhat somber in tone and difficult to dress, seems likely to prove a material of remarkable durability. In one building in Twenty-fourth street, between Madison and Fourth avenues, its condition appears to be excellent, after fifteen years' exposure perfectly retaining the tool marks. The variety reported to come from the Wyoming valley (*e. g.*, in the building on the north side of Union square) is really derived, as I am informed by Professor H. L. Fairchild, from Meshoppen, Pennsylvania.

The blue-stone or graywacke of central New York and of Pennsylvania has not only been of general use as a flag-stone, but, in compact varieties, has been yearly coming into greater use in our cities for the purpose of water-tables, ornamental bands, window-sills, etc., and, although not a freestone, has recently been introduced even for the fronts of residences (*e. g.*, on northwest corner of Madison avenue and Seventy-second street). It is likely to be one of the strongest and most durable stones, in my opinion, and, to judge by its weathering in outcrops, will be liable, only after a long exposure, to a reddish-brown discoloration.

LIMESTONE.—The Lockport limestone has been used to a small extent in this city, unfortunately for buildings of importance, since it is a loosely compacted mass made up of fragments of shells, corals, etc., extremely liable to disintegration, apparently more from the action of frost than any other cause. To this stone may be applied the observations of Professor F. A. Abel on the fossiliferous bands in the stone of the island of Portland. (*a*)

> Though petrifactions were shown by the results of experiments to impart, in many instances, great additional strength to the stone they frequently give rise by their existence to cavities, sometimes of considerable size, which not only serve to weaken those particular portions of the stone, but may also, if they exist in proximity to exposed surfaces of a block of stone, promote its partial disintegration by the action of frost.

The Lockport stone has evidently owed its rapid disintegration within ten years, wherever used in this city, in part to its careless mode of introduction into masonry. Thus, in the building of the Lenox library, at Seventieth street and Fifth avenue, about 40 per cent. of the material is set on edge, *e. g.*, the alternate receding courses of the ashlar, trimmings of apertures, gate-posts, etc. Consequently it betrayed decay long before the completion, fragments falling out of the face of the stone from the arris of cornices and bands, etc. In the abundant trimmings of the same stone in the building of the Presbyterian hospital in the vicinity the same disintegration is displayed, the surfaces peeling off and filled with fine and deep crevices, and the upright posts, *e. g.*, near the entrance archway or porte-cochère on the south side, in which the bedding-laminæ stand on edge, are already seamed throughout with long cracks, which betoken their steady destruction.

The oolitic stone from Ellettsville and Bedford, Indiana, shows an almost immediate and irregular discoloration, said to be produced by the exudation of oil. The oolite from Caen, France, has also been used in many buildings, and, unless protected by a coating of paint, has shown decay in several instances. Mr. G. Godwin, of London, has stated (*Soc. of Arts*, 1881), that "the Caen stone which was sent to this country (England) could not now be

a The Builder, London, 1863, Vol. XXI, p. 859.

depended on, and ought not to be used for external work". The extensive decay of this, with other oolitic and magnesian limestones, in the walls of Westminster abbey, has recently caused great alarm, and will necessitate the renewal of its outer masonry at enormous expense.

One of the most thorough investigations, in regard to the porosity of a series of American building stones, was made by Dr. T. S. Hunt in 1864, and with the following conclusion (*Chemical and Geological Essays*, p. 164):

Other things being equal, it may probably be said that the value of a stone for building purposes is inversely as its porosity or absorbing power. From the results given on 39 specimens, the following may be here quoted as pertinent to stones used in New York city:

No. of specimens.	Absorption. Percentage.
1. Potsdam sandstone, hard and white	0.50 to 3.96 *a*
2. Medina sandstone	3.31 to 4.04
3. Ohio sandstone	9.59 to 10.22
3. Caen limestone	14.48 to 16.05

Of course the proviso, "other things being equal," covers a great deal of important ground, including the solvency of the material of a stone in the acidified rain-waters of a city. Some of the most impervious and non-absorbent readily decompose; while others, which are porous or even cellular, may afford an excellent resistance to decay. But judged in regard to both points, porosity and solvency, the Caen stone may be safely rejected hereafter as unfit for our climate.

Other limestones, oolitic or fine granular, have been brought into use in small quantity, but remain as yet untested by the conditions of our climate.

GRANITE.—As to granite, its tendency to decomposition, termed the "maladie du granit" by Dolomieu, depends chiefly upon climatic conditions. These differ vastly, it is well known, in this region and in that of the great granite-builders, the Egyptians. The obelisk of Heliopolis has stood for three thousand years, and is still in good condition. So, too, the obelisk of Luxor had stood for forty centuries in Egypt without being perceptibly affected by that climate, but since its transport to Paris, in the reign of Louis Philippe, it is reported as the result of but forty years' exposure—

It is now full of small cracks, and blanched, and evidently will crumble into fragments before four centuries have passed.

We have transported another obelisk, "Cleopatra's Needle", from Egypt, and, in defiance of the still greater dangers incident to our severe climate, have erected it, covered with delicate carvings, upon a hillock in Central park, exposed to our blazing sun, pelting rain, and biting frost, often successively within twenty-four hours—a monument to the public ignorance in regard to the protection of even our prized possessions—that indifference of our community to the practical value of science which was exemplified through its officials by wantonly paving the walks of the same park with the fragments of the restoration casts of Saurians, after their construction for three years by Waterhouse Hawkins. Granite is also found in many other of our larger buildings, both public and private, but as few of these exceed forty or fifty years in age, and all contain the most durable varieties of that stone, the effects of weathering are only beginning to appear. The bluish variety from Quincy, Massachusetts, has been used in many buildings and rarely shows as yet many signs of decay. In the United States custom-house, on Wall street, most of the huge blocks appear laid "on bed", but, nevertheless, show some pitting in places, by the attack and partial removal of the larger grains of hornblende. In the church at Fourth street and Lafayette place, erected in 1830, a little exfoliation has been produced by street-dust on the faces of some steps. In the Astor house, at Barclay street and Broadway, no decay was observed.

In the fine-grained granite from Concord, New Hampshire, employed in the building on the southeast corner of Twenty-third street and Sixth avenue, many of the blocks are set on edge, but the only change yet seen is that of discoloration by street-dust and iron oxide from the elevated railway.

The light-colored and fine-grained granite of Hallowell, Maine, has been used for the construction of the city prison, the "Halls of Justice" or "Tombs", in Center street. This stone consists of a white feldspar, which predominates, a grayish-white quartz, which is abundant, and a considerable quantity of a silvery white mica, thoroughly intermixed. The rock possesses several properties—fineness of grain, homogeneity of structure, and freedom from iron, as shown by the color of the feldspar—likely to render it durable; the only unfavorable conditions are the predominance of feldspar and the laminated structure. The rock is a granitoid gneiss, with lamination often clearly marked; these markings at once show to the eye that most of the blocks are set, not on bed, but irregularly on edge.

The building is square and occupies an entire block. On a study of the weathering the south face was found to present an exfoliation to the depth of from one-eighth to one-quarter of an inch at many points, up to the very summit of the building, particularly on the sides of the pillars at the southeast entrance, on the ashlar near the southwest gate, under and over the cornice and string-pieces. In some places the stone was loosened or peeled off in sheets of the area of a square foot. The west front presents much exfoliation all over the surface, though always thin; it seems to begin chiefly along and near the joints. In places fragments have separated from the corners of the blocks. The north front exhibits very little exfoliation; so also the east front, in a few small scattered spots.

a Usually about 1.

The exfoliation appears to be the result directly of the sun's heat, exerted most intensely on the southern and western sides of the building. An examination of the disintegrated material shows but little decomposition; a little kaolin may be distinguished in films, but the bulk of the feldspar, the weakest constituent, remains with bright facets, without change in color or luster. It is by no means characteristic of the "*maladie du granit*", first described by Dolomieu and later studied by Dr. T. Sterry Hunt; but here the action seems to be mainly and simply a disintegration of the grains, initiated by expansion under the sun's heat, during the summer, and developed by the expansion caused by frost during the winter. An architect of the city recently stated that he had built several large granite offices, and considered Quincy granite the most durable of all building material. He thought the weathering of granite would hardly amount to one thirty-second of an inch in a hundred years. According to that calculation many buildings might hope for a longer span than the thousand years spoken of by the professor.

However, it is a well-known fact that the weathering of granite does not proceed by a merely superficial wear, which can be measured or limited by fractions of an inch, but by a deep insinuation along the lines of weakness, between grains, through cleavage-planes, and into latent fissures. Thus, long before the surface has become much corroded or removed, a deep disintegration has taken place, by which large fragments are ready for separation by frost from the edges and angles of a block. When directly exposed to the heat of the sun an additional agency of destruction is involved, and the stone is suddenly found ready to exfoliate, layer after layer, concentrically. As yet we have little to guide us in the estimation of durability in years, since the best known granite monuments are those which have been exposed to the exceptionally mild climate of Egypt; but even there some exfoliation has been noticed, *e. g.*, on the inner walls of the so-called Temple of the Sphynx.

In the cemeteries within the city and on Long island much granite is now used in slabs and monuments, but its introduction has been everywhere of too recent a date to afford any measure of its durability. Geikie remarks:

> Traces of decay in some of its feldspar crystals may be detected, yet in no case that I have seen is the decay of a polished granite surface sensibly apparent after exposure for fifteen or twenty years. Even the most durable granite will probably be far surpassed in permanence by the best of our siliceous sandstones. But as yet the data do not exist for making any satisfactory comparison between them.

GNEISS.—The oldest building in this city in which this material has been used appears to be that of Saint Matthew's Lutheran church, on the northeast corner of Broome and Elizabeth streets, erected in 1841. The stone is the micaceous gneiss, in part hornblendic, from excavations on the island, with trimmings, string-pieces, etc., of brownstone, the latter, as usual, being in a state of decay. On the west front the gneiss is in excellent condition, occurring in small blocks, mostly laid on the bedding plane. In the south front many of the quoins are set on edge and are much decayed along the joints, sometimes with splitting or exfoliation, fracture of corners, and irregular chipping out of the surface to the depth of one-half to one inch below the level of the projecting cement joints.

SERPENTINE.—This rock has been of limited application as a building material, but the evidence thus far is not in favor of its durability in a city. For example, the serpentine of West Galway, Ireland, called "Connemara marble", has been used both externally and internally in the new museum of Trinity college, Dublin, but "does not withstand the influence of a smoky or gaseous atmosphere". "Small tablets let into the outside wall of the museum have become tarnished within the space of ten years". In Hoboken this stone has been used to some extent for unimportant masonry, and shows in places discoloration and disintegration.

Other stones which may prove to be more durable, and as yet rarely exfoliate, have already, however, become more or less disfigured by discoloration. In the Nova Scotia and Ohio sandstones this is universally seen in black films, streaks, and blotches, of which both the cause and the means of removal are but little understood. The marbles used for house fronts also soon assume a dirty yellow hue. This is sometimes produced by the exudation of salts of iron, as in the walls of the new court-house; sometimes by the adherence of smoke and street-dust. It has been removed by occasional scraping of the whole surface of the building, as has already been done on the old court-house, the new cathedral at Fiftieth street, etc.

2.—EXTERNAL AGENCIES OF DESTRUCTION.

The external agencies which slowly but insidiously and steadily accomplish the disintegration and destruction of our building stones are of three classes, chemical, mechanical, and organic.

A. CHEMICAL AGENCIES.

These chiefly consist of acids which attack and dissolve every constituent of stone except quartz, but, with particular rapidity, any stone into which carbonates enter as chief constituents or as cementing materials. Thus the abundant solution of lime from the stone as well as the mortar of one of our marble buildings may be shown by catching some of the rain-water which trickles down its sides, and adding a few drops of ammonium oxalate, the solution becoming clouded by a milky-white precipitate of calcium oxalate. The following may be enumerated:

SULPHUR ACIDS, *i. e.*, SULPHUROUS AND SULPHURIC ACIDS.—Of these Dr. Angus Smith found in the rain of Manchester from 1.4 to 5.6 grains per gallon. The gases are daily absorbed into the atmosphere of a large city from the consumption of illuminating gas, coal, and all kinds of fuel, the decomposition and oxidation of refuse organic matter and sewer-gas, the residuary gases belched forth from the chimneys of dye works, chemical works, and numerous other manufactories, etc.

As coal seldom contains less than one-half per cent. of sulphur, and frequently one per cent. or more, every ton of coal when burned produces from 30 to 60 pounds of oil of vitriol. When one considers the enormous quantities of coal that are consumed in cities, and the correspondingly great quantities of this corrosive agent that are thus disseminated in the atmosphere, we would naturally expect to find appreciable evidence of its effects on building stones.(*a*)

These effects are likely to be most marked in a large city like London or New York, and on certain stones, *e. g.*, the earthy or oolitic limestones and marbles. In London they are revealed in the magnesian sulphate, which imparts a bitter taste, and even forms an efflorescent crust of white crystals upon the disintegrated portions of the Portland stone, and in the calcium sulphate, amounting to 3.4 to 4.6 per cent. in the decayed crust of the Caen stone. (*b*). Little limestone has yet been introduced into New York, and the durability of a variety in a village or small town elsewhere gives no measure of its fitness to resist the corrosive agencies in the atmosphere of our cities.

CARBONIC ACID.—This is a universal product of combustion, but is indeed derived from all the sources above mentioned, as well as from the respiration of millions of men and animals. Dr. Smith found the air of Manchester to contain 0.04 to 0.08 per cent. of carbonic acid, while that of the highlands of Scotland contained but 0.03 per cent. The researches of Daubrée, T. S. Hunt, and others, have shown the active action which this gas exerts in the corrosion of the feldspar of granites.

NITRIC ACID.—Traces of this acid have been commonly found in the atmosphere and falling rain, but most perceptibly during and after thunder storms. It has been suggested that "every flash of lightning not only generates nitric acid—which, in solution in the rain, acts on the marble—but also, by its inductive effects at a distance, produces chemical changes along the moist wall, which are at the present time beyond our means of estimating. (*c*)

So far as its formation is due to electrical agency, it probably increases during the summer; but it is also one of the products of oxidation of the gases arising from the decomposition of organic matter, ammonia, and nitrates, and from our numerous gas works.

HYDROCHLORIC ACID.—This corrosive agent Dr. Angus Smith found in the rain of Manchester, to the amount of 1.25 grains per gallon. It is derived from the fumes of bleaching works, chemical works, potteries, and many factories, and from vicinity to the sea.

CARBOLIC, HIPPURIC, AND MANY OTHER ORGANIC ACIDS derived from smoke, street-dust, sewer-vapors, etc., have not been hitherto recognized, but, in my opinion, are among the most constant and efficient agencies in the corrosion of the building stones of a city. Whether they are present in the atmosphere and falling rain is still a matter of conjecture, though I think it probable; but no series of analyses has yet been made to determine the exact constitution of the air and rain-water in our cities. However, there can be no doubt of their presence, possibly in the smoke and unconsumed carbon which attach themselves to our rougher stones (freestones, marbles, etc.), certainly in the street-dust, chiefly ground-up horse manure, which is blown against our buildings and remains attached to their surfaces, often to a considerable height above the street level. That the corrosion thus resulting is due not merely to mechanical friction, but mainly to chemical action, is shown by the fact that it is sometimes most active on a surface which is sheltered from the rain, and to which the crust of dust can adhere more persistently. For example, I have noticed that the vertical faces of the steps of Quincy granite beneath the portico of the church on the northwest corner of Fourth street and Lafayette place, perfectly sheltered from the rain, and but little exposed to the wind, have been sometimes covered with a film of street-dust beneath which the smooth-dressed surface of the granite is deeply corroded, peeling off to the touch of one's fingers in flakes from 2 to 5 millimeters in thickness. As to the foundations of buildings, these are exposed to the quiet action of the vegetable acids derived from the decomposition of plants and of the humus of the soil.

OXYGEN.—This constituent of the atmosphere, especially in its more active form, *ozone*, attacks the sulphides (*e. g.*, the pyrite in the Vermont roofing slates and in the marble of Lee, Massachusetts, etc.), and, more slowly, the ferrous silicates in certain minerals (*e. g.*, the chlorite, biotite, hornblende, augite, etc., in our granites, gneisses, traps, etc.). The resulting oxygenation and hydration may be expected to produce expansion and a tendency to loosening of the constituents of a stone.

AMMONIA is another product of animal life and decomposition, the fumes of factories, and atmospheric reactions, whose existence in the air and rain-water has been proved, and which must do its part in the disintegration of stone.

COMMON SALT (sodium chloride) is constantly present in the atmosphere along the sea-board, and must affect the solubility of the cement of porous sandstones, etc. An English observer, however, considers that sea air is not injurious to stone, instancing Sandysfoot castle, near Weymouth, of which the stone is in perfect condition, although erected on the sea-shore and constantly washed by the spray since the time of Henry VIII. A comparison of the forms of decay of stone observed in the cemeteries within this city and in those nearer the ocean, *e. g.*, at New Utrecht, yielded no evidence of any results, attributable to this agency, in greater action at the latter locality.

a C. H. Porter: Paper on Building Stones, p. 24. Albany, 1868.
b J. Spiller, *Rep. Brit. Assoc. Adv. Sci.*, 1867.
c U. S. Commission, 1851.

B. MECHANICAL AGENCIES.

Some of these are probably, in our climate and conditions, the most efficient of all in the wear and disintegration of our building stones.

FROST.—The action of severe frost on stone must be usually one of the main causes of its rapid decay. Two elements are involved—the friability of the material and its power of absorption of moisture. The action may be expected to be most active where a material is repeatedly saturated with moisture, rain-water, or water derived from the thawing of snow and ice, and alternately frozen and thawed. The violence of the force resulting from the congelation of water within the pores of a stone may be understood from a recent estimate, that the effect produced by the freezing in a closed vessel, as it takes place very suddenly, resembles the blow of a hammer of 12 tons weight upon every square inch. However, the disintegration of our brownstones cannot be attributed entirely or mainly to this powerful agency, since the same decay is in progress in southern sea-ports where this brownstone has been used as a building stone; and I have been consulted by a correspondent at New Orleans in regard to the best means to arrest this decay in brownstone fronts there.

On other stones, *e. g.*, marble, this force may exert a very slow action; the experiments of Professor Joseph Henry and the calculations of Captain (now General) M. C. Meigs have shown the depth of exfoliation, after fifty alternations of freezing and thawing by artificial means, to amount to very nearly the ten-thousandth part of an inch. (*a*)

VARIATIONS IN TEMPERATURE.—The constant variations of temperature from day to day, and even from hour to hour, give rise to molecular motions which must affect the durability of the material of a building. Recent observations on the pendulum have shown that the Bunker Hill monument at Boston is scarcely for a moment in a state of rest, but is constantly warping and bending under the influence of the varying temperature of its different sides. (*b*)

The climate of New York must be far more trying than that of England, as the temperature may vary 120° or more in a single year, and even 70° in a single day, with many repetitions of similar extremes during the spring and fall, and sometimes during the winter months. The intensity of the direct rays of the sun, particularly in summer, and the frequent passing showers of cool rain-water falling upon the heated surfaces, are important elements in the attack upon the building stones.

The experiments of Colonel Totten, reported by Lieutenant William H. C. Bartlett in 1832, on the expansion and contraction of building stones by variations of temperature, yielded the following results, for the linear expansion, in fractions of an inch, of one inch of stone for 1° of Fahr.:

Granite bowlder at Buzzard's bay	0.000004825
Marble, Sing Sing, New York	0.000005668
Sandstone, Chatham, Connecticut	0.000009532

To apply these results to the case in question, let us suppose two coping stones, of 5 running feet each, to be laid in midsummer, when they have a temperature of 96° Fahr.; in winter their temperature may safely be assumed at zero, so that the total variation of temperature will be 96°.

The distance by which the ends of the stones would be separated would amount, for granite, to 0.027792 inch, giving a crack a little wider than the thickness of common pasteboard. For marble, this crack would have a width of 0.03264, nearly twice the thickness of common pasteboard; and for sandstone 0.054914, nearly three times the thickness of pasteboard. These cracks are not only distinctly visible, but they allow water to pass freely into the heart of the wall. The mischief does not stop here: by this constant motion, back and forth, in the coping, the cement, of whatever kind the joints might be made, would be crushed to powder, and in a short time be totally washed by the rains from its place, leaving the whole joint open.

WIND.—A gentle breeze dries out the moisture of a building stone and tends to preserve it, but a violent wind wears it away by dashing sand-grains, street-dust, ice particles, etc., against the face. The extreme of such action is illustrated by the vast erosion of the sandstones in the plateaus of Colorado, Arizona, etc., into tabular *mesas*, isolated pillars, and grotesquely-shaped hills, by the erosive force of sand-grains borne by the winds; in the window-panes of houses on Nantucket island, converted into ground-glass by flying sand; and in the artificial process of manufacture by the "sand-blast", carried on in our cities. A violent wind also forces the rain-water, with all the erosive acids it conveys, into the pores of stones, carries off the loosened grains from the surface, and so keeps fresh surfaces of stone exposed.

In this climate, buildings are most attacked by weathering agents on their north, northeast, and east fronts (the very reverse of the conditions prevailing in Great Britain), and, in this view, it is of course important to select stone of the greatest durability for the fronts into which the prevailing wind thus drives the rain, *i. e.*, those on the west sides of the avenues and the south sides of the cross-streets in New York city.

Again, the swaying of tall edifices by the wind, whose amount can only be appreciated by ascent of our church spires during a gale, must cause a continual motion, not only in the joints between the blocks, but among the grains of the stones themselves. Many of these have a certain degree of flexibility, it is true, and yet the play of the grains must gradually increase and a tendency to disintegration result.

RAIN.—The attack of rain on building stones depends upon its solvent action, partly due to the solvent agencies before mentioned, which it conveys, and upon its mechanical effect in the wear of pattering drops and streams

a Joseph Henry, *On the Mode of Testing Building Material.* *b* United States Commission, 1851.

trickling down the face of a building. In dry weather a stone is therefore less attacked, chiefly because the destructive acids cannot penetrate so deeply. The proportion of rainy days, and above all of frequent alternations of dry and rainy days, in any climate must exert a great influence on the durability of stone.

Professor Hull states:

In India, ancient temples formed of laterite—a modern deposit of gravel cemented by lime—are still in perfect preservation. Such examples, and many more which might be produced, all go to prove that even in regions subjected to very heavy periodical rains, provided the air be pure and free from acids, buildings of even friable and calcareous materials are capable of withstanding atmospheric disintegration for a lengthened period. Rains which fall at long intervals, though with tropical violence, do not act so injuriously on stone structures as those lessv iolent but more frequent. (*a*)

Crystallization by efflorescence.—This effect, too, must largely depend upon the climatic conditions—alternations of dryness and moisture—to which reference has just been made. Examples of efflorescence of various salts, sulphates of magnesium, sodium, etc., are by no means uncommon in New York city and vicinity, though more frequently on brick than stone, walls covered with snow-white powdery coatings having been observed in basements of stores in South street, in cellars of residences in West Fifty-second street, etc. The expansion produced by such an exuding crust is likely, slowly but surely, to disintegrate and loosen scales and flakes from the surface of stone.

In an important investigation of this subject by Mr. Wenworth L. Scott, of London, the following results were obtained: (*b*)

Thirty-seven specimens of salt, collected from the surface of various building materials, were determined as follows:

Thirty-one, sulphate of sodium (and traces of other salts).

Three, mainly sulphate of sodium, and of magnesium and aluminium.

Two, mainly sulphate of sodium, with various phosphates and nitrates of sodium and calcium (never over 18 per cent. of the whole).

One, sulphates of sodium and potassium, with small amount of nitrates, and much sodium chloride.

With regard to the preventive means, * * * I cannot help denouncing the too free use of resinous, oleaginous, or tarry matters, as my own experiments have shown me that, in the event of fire, the walls of a building treated with such substances would inflame the moment their temperature was raised to about 200°.

He suggests the prevention of upward percolation of moisture by a seam of asphalt, laid on every wall when 2 to 4 feet from ground, as used in St. James' hall, etc., London. He has cured the efflorescence of sulphate of sodium or magnesium by application of a weak solution of barium chloride.

Sulphate of ammonium has not an injurious effect until it meets with substances capable of converting it into the sodium salt.

Sulphurous acid or sulphite of ammonium exerts no harmful effect, but rather a preservative influence, occurring in too small quantity to produce efflorescence. The process of osmosis in building materials has been greatly exaggerated, and is probably very slow. It is important that mortars should be carefully chosen, that they may not contain efflorescent salts.

Pressure.—A large number of experiments have been carried on to determine the crushing weight of building stones, and the strength thereby indicated. However,

It is generally laid down that the compression to which a stone should be subjected in a structure should not exceed one-tenth of the crushing weight as found by experiment. Practically, however, the compression that comes upon a stone in any ordinary building is never sufficient to cause any danger of crushing. * * * The working stress allowed in practice upon ashlar blocks should not exceed one-twentieth of the crushing weight. (c)

Nevertheless it may be expected that when an ashlar block has become weakened by weathering, the rapidity of its disintegration and decay may be hastened by the superincumbent pressure, especially if unequally applied by the settling of the foundations.

Friction.—This agency of wear most commonly affects pavements, sidewalks, stoops, the facing of piers, etc. It may be derived from the impact of human feet, of wheels, or of the hoofs of animals; the handling of freight; the removal of dirt, snow, and ice; the flow of tidal currents; the blows of the waves of the bay and river, etc.

Fire.—The fierce trials to which building materials of all kinds have been subjected, in the great fires in Chicago and in Boston, during the last decade, have shown that there are none, not even brick, which can withstand, in the form of thin walls, without warping or utter destruction, the tempest of flame evolved from the great magazines of combustibles gathered on every side in an American city.

It is a remarkable instance of the prevailing ignorance on this subject that there exist many varieties of sandstone (*e. g.*, the buff freestone from Amherst, Ohio, etc.), graywacke, and perhaps other rocks, which possess a fire-proof character that enables them to resist a white heat, as the linings and hearths of iron-furnaces, and which would seem to specially fit them for the ashlar of buildings desired to be fire-proof, or at least the window-sills, etc., of business buildings, storage houses, etc. It must be considered, however, that experiments are highly desirable to

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a *Building and Ornamental Stones*, p. 312.

b On Salification, etc., *Jour. Soc. Arts*, 1860, Vol. IX, p. 274.

c *Notes on Building Construction*, p. 6.

determine the character of resistance of these and other stones, not only to the lateral application of flames or radiation of intense heat, when exposed in a building with a backing of brick, but also to the alternations, rapid and violent, of sudden expansion and contraction, produced by the sudden application of cold water from the streams of fire-engines upon the heated masonry. So far as present observations have gone, however, in regard to such sandstones, I see no necessity to reject the abundant materials supplied by nature, and will present additional reasons on a later page.

C. ORGANIC AGENCIES.

These are of a vegetable nature, in their attack upon the materials of building construction on land, and of animal nature in regard to the erosion of submarine walls.

VEGETABLE GROWTHS.—In regard to the influence of lichens on the durability of stone, very opposite views are held. On the one hand, it is acknowledged that, in the case of marbles and limestones, some lichens exercise a decidedly corrosive action, and Professor J. C. Draper, in a paper on the decay of stone and brick in New York city, maintains that the same "minute lichen, *Lepra antiquitatis*, grows with remarkable freedom on such hygroscopic rocks as the sandstones, as any one may satisfy himself on examining the houses on the cross, or east and west, streets of our city". (*a*)

So far as my observation has gone, lichens are markedly absent from the decayed stone-work of this city, and it is probable that the reference applies to some other form of vegetation. Thus they never occur in the church-yards of Trinity church and Saint Paul's chapel, though found abundantly in those of New Utrecht and Flatbush; *e. g.*, three species were distinguished upon a single tombstone (Rutgert Denyse, 1795) at New Utrecht. On their removal, the surface of the stone beneath is not found corroded, but only retains a fresh color.

In a report on the selection of the oolitic limestone used in the houses of parliament in London, the subject has been thus discussed by one of the commissioners:

A question has frequently been raised with reference to the effect of vegetation on the surface of stone-work. By attentively examining the magnesian limestone buildings of this part of the country, it would appear that lichens exercise a sort of pernicious influence. At Bolsover castle, the keep of which seems to be constructed with magnesian limestone, similar to that of Steetley, wherever lichens have vegetated on the exterior of that edifice, decomposition has certainly taken place; and where they were then growing, upon removing them, we found that the surface of the stone, for about one-sixteenth of an inch in thickness, was reduced to a state of white powder. In such instances the lichen seems to possess some inherent power of chemically acting upon the stone; but whether the plant appropriates only the carbon to its own use and leaves the lime and magnesia, or whether it takes up the carbonate of lime and rejects the carbonate of magnesia, is a question of great interest, although it has not yet been investigated by a scientific observer. (*b*)

The opposite view, advocating their beneficial influence, is represented in the following quotations:

Lichens are in many cases a protection from the weather, and tend to increase the durability of the stone. (c)

In the report on the selection of stone for the houses of parliament it is stated:

Buildings situated in the country appear to possess a great advantage over those in populous and smoky towns, owing to lichens, with which they almost invariably become covered in such situations, and which, when firmly established over their entire surface, seem to exercise a protective influence against the ordinary causes of decomposition of the stone upon which they grow.

Many blocks of stone quarried at the time of the erection of St. Paul's, in London, but left in the quarries, and now covered by lichens, still retain their sharp edges and tool marks beneath the lichens, while those on the exposed fronts of the cathedral are now moldering away.

The sandstone of Tintern abbey (thirteenth century), in part laminated, is covered with gray and green lichens, and is, for the most part, in perfect condition. In Tisbury church (thirteenth and fourteenth centuries) the ashlar, constructed of calciferous limestone, is, where undecomposed, covered with lichens.

The exact action of the lichens needs investigation, and will doubtless be found to differ widely according to the species and the material on which they grow. Few of our buildings in this district are sufficiently old to present much growth of this kind.

There is another vegetable growth, however, that of the *confervæ*, of which no notice seems to have been taken, but which flourish in damp weather all the year round, in New York and vicinity, upon shaded surfaces of our freestones, often coloring the vertical faces of the steps and the sides of stoops, and the lower portion of the ashlar, near the ground-line, and under the shadow of heavy copings and cornices, especially on the north shaded fronts of the houses on the south sides of the streets. Upon brownstone their eroding influence is shown in the common roughening of the dressed surfaces. Upon the Nova Scotia or Dorchester stone their action is apparently still more active, as shown in abundant instances on the walls and carved work throughout Central park, *e. g.*, the pillars of Albert quarry stone at the head of the steps at the end of the mall, where shaded surfaces are alternately seen colored green with *confervæ*, and again bare and crumbling, at different seasons of the year, and have needed frequent redressing. It may also be remarked that the heavy growth of vines trained up over the fronts of houses, sometimes seen in this city, would be apt to favor such growths and the decay of soft freestones.

The well-known destructive agency of the roots of grasses and higher plants on the durability of masonry is fortunately not a danger to be considered in our American cities.

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a *The Manufacturer and Builder*, 1872, IV, 170.

b C. H. Smith: *Lithology, or Observations on Stone used for Building*, p. 26. 1845.

c *Notes on Build. Const.*, Part III, 10.

Boring mollusks, sponges, etc.—The serious danger of the attack of these forms of animal life may be illustrated by the following example:

A limestone from Creston, near Plymouth, England, was originally employed in the construction of the Plymouth breakwater, but the boring mollusks (*Pholas dactylus*) so perforated the stone, between high and low water, that it was thought necessary to replace the blocks by granite. (*a*)

Little masonry is yet exposed in our bay and along our river fronts to the attack of these enemies; but the cargoes of Italian marble sunk off the harbor, which have been found thoroughly perforated and honey-combed by such agency, *e. g.*, that of a steamer sunk in 1871, and the similar erosion of the gneiss of Westchester county, along the sound, by marine sponges, as pointed out by Mr. J. D. Hyatt, of the New York Microscopical Society, indicate the dangers which may be in store for the bases of the piers of the New York and Brooklyn bridge, and for the masonry which will be hereafter introduced into our piers and docks. Birds also serve as destructive agencies; the sparrows and other small birds by their droppings deposited in abundance on cornices and projecting moldings, and the pigeons, as in the London Exchange building, by pecking away the cement between the blocks of masonry.

3.—INTERNAL ELEMENTS OF DURABILITY.

The durability of a building stone depends upon three conditions, the chemical and mineralogical nature of its constituents, its physical structure, and the character and position of its exposed surfaces.

A. CHEMICAL COMPOSITION.

In this view the following conditions need consideration:

Solubility.—The presence of calcium carbonate, as in the more calcareous forms of our Westchester dolomitic marbles, and in the earthy limestones (*e. g.*, that from Indiana recently introduced), is likely to render such materials liable to rapid attack by acid vapors. On the other hand, in England pure dolomite is considered extremely durable as a building stone, as is shown, for example, in the Norman part of the Southwell church, in Yorkshire.

The hydrated form of ferric oxide which acts as the cement in all the Triassic sandstones (*e. g.*, the brownstone of New Jersey and Connecticut) is far more soluble, and so may be more easily removed, to the injury of the stone, than the anhydrous or less hydrated ferric oxide predominating in the cement of our Potsdam sandstone and many foreign sandstones, which seem likely on that account to be better resistants to disintegration. The sandstones whose cement is siliceous (*e. g.*, the Craigleith stone of Great Britain, and some varieties, almost quartzitic, of our own Potsdam sandstone in this state) are likely to be the most durable, and hereafter the most sought for, where durability is appreciated, in spite of their difficulty in working and dressing.

Tendency to oxidation, hydration, and decomposition.—In the case of a roofing slate, the presence of a sulphide (*e. g.*, marcasite, more decidedly than pyrite) is likely to be very injurious; in a granite or marble (*e. g.*, the marble of Lee, Massachusetts, in the new court-house, New York city) the results may be confined to the discoloration and less objectionable. Nevertheless there are abundant instances, which yet need investigation, in which the pyrite occurs in a highly-crystalline condition, even in roofing slates, by which it has been enabled to resist decomposition during centuries. If the pyrite is uniformly and minutely distributed in small quantity, its presence may be even advantageous; thus, the marbles of Berkshire county, Massachusetts, when first cut, are cold gray, but by long weathering acquire a tint of exquisite warmth and transparency. (*a*)

The biotite in many of our granites seems peculiarly liable to decomposition, and apparently to the weakening of the surrounding stone. The brown freestones of New Jersey and Connecticut contain everywhere minute scales of biotite, though in much less proportion than that of muscovite, and the freestones of New Brunswick contain similar scales of a chlorite; both minerals in a state of decomposition more or less advanced.

The orthoclase, which largely enters into the composition of the Triassic and the Carboniferous sandstones, and of all the granites in this market, is the feldspar of most ready decomposition. It is found, on microscopic examination of a brownstone or granite, in various stages of alteration, from a mere dimming of its cleavage planes to a cloudy or opaque mass of the usual structure, and finally to a siliceous shelly network, with its interstices filled with iron oxide. In this condition the mineral has lost all its strength and ability to resist either pressure or atmospheric attack, and a stone in which it prevails must have reached the last degree of disintegration and decay.

The albite, oligoclase, and other feldspars are much better resistants to decomposition, and their abundance in granite or sandstone may be an important element in their durability.

Inclosure of fluids and moisture.—The thorough drying of a stone before, and the preservation of this dryness after, its insertion into masonry are commonly recognized as important adjuncts to its durability. But the exact nature of the process of seasoning, and of the composition of the "quarry-sap" thus removed by thorough drying, have never been investigated. The "quarry-water" may contain little else than ordinary well-water, or may be a solution more or less nearly saturated, at the ordinary temperature, with carbonate of calcium, silica, double salts of calcium and magnesium, etc.; in the latter case, hardening results by the drying and an exact knowledge of its nature might throw important light on the best means for the artificial preservation of stone.

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a Gwilt's *Encyc. Arch.*, p. 492.

a *Am. Arch. and Building News*, 1881, X, 13, 17.

Again, water may exist in large quantity in chemical combination in the silicates (*e. g.*, chlorite, kaolin, etc.), or in the hydrated iron oxides which constitute the cement of a building stone. Many hydrates of ferric oxide are known to exist, and of these a considerable number occur in nature, in concentrated form, as ores.

We do not yet know how these or other hydrates of ferric oxide are isolated or mixed in their distribution through the brown sandstones. I have elsewhere (*a*) pointed out the probability that, to a large extent, the red cement of the sandstones of most recent or Tertiary age may be probably referred to limonite or limnite, *e. g.*, those found in eastern New Jersey and to the southward along the Atlantic and Gulf sandy plateau; that of the sandstones of the Mesozoic period to turgite and limonite (possibly in part göthite?), *e. g.*, the brownstones of New Jersey and Connecticut; and that of the bright red sandstones of the Carboniferous and older rocks to anhydrous ferric oxide, *e. g.*, the red freestones of New Brunswick and of Scotland, the red sandstones of Potsdam, New York, etc. However, these distinctions cannot be drawn sharply, and the subject awaits investigation. Changes in the degree of hydration are constantly going on in stones of this character, and the absorption of water may exert a force for expansion and disruption. In regard to the vast amount of water feebly locked up in combinations such as these, the query has been recently offered:

> We venture to suggest, as a subject for careful chemical analysis how far the existence of water or the elements of water, not as moisture, but as chemically combined with lime, magnesia, or other elements in a stone, may render it susceptible to the attacks of frost. (*b*)

The more recent results of microscopic lithology have also established the fact that certain minerals, especially the quartz, in very many of our most common building stones abound in small cavities partly or wholly filled with fluids, viz, water, brine, and liquid carbon dioxide. These cavities vary in size from microscopic minuteness up to a diameter of several millimeters, and are often very abundant, so that a fragment of quartz clouded by them may explode on the application of heat. The varieties of our building stones in which they are known to particularly abound are the following: Brownstone—New Jersey and Connecticut; freestone—Dorchester, New Brunswick; biotitic gneiss and fibrolitic gneiss—New York island and Westchester county; granite—Quincy, Massachusetts, Clark's island, Maine, Mount Beatty, Connecticut, Fitzwilliam, New Hampshire, Saint Lawrence county, New York, etc.

The question of the influence of these cavities on the durability of the rock, when exposed to frost or to the intense heat of the summer sun or to fire, is one that yet awaits investigation. The violent explosions which attend the exposure of granites to fire, as illustrated in the great fires of Chicago and Boston, may imply some connection, in part, with the sudden expansion and rupture of such inclosed fluid cavities; while the similar action of frost seems to be suggested by the interesting paper of Mr. W. E. Hidden on the fracture of quartz with liquid cavities in North Carolina. (*c*)

B. PHYSICAL STRUCTURE.

This varies widely in the crystalline and sedimentary rocks; but three conditions, common to both, will be first discussed, then two confined to the former class, and finally two confined to the latter.

SIZE, FORM, AND POSITION OF THE CONSTITUENT MINERALS.—It has been established that the resistance to compression—and it may be supposed in some degree the durability—of a finely-granular rock exceeds that of a coarsely-crystallized variety of the same. Dr. J. S. Newberry has also pointed out that "mica is soft and fissile, and hence is an element of weaknesss. Where it exists in any considerable quantity the stone is easily crushed and unfit for use".

The scales of mica in a laminated sandstone, *e. g.*, the common micaceous variety of brownstone, lie largely in the plane of lamination, and diminish the strength of the rock when pressure is applied in the direction of the latter plane, *e. g.*, on edge, on account of the feeble adherence between their surfaces and the rock in contact. So also when used as ashlar, the expansion caused by frost tends to produce the first separation along those planes.

However, both in a granite and in a freestone, it is probable that a moderate amount of mica—much more an abundance of a tough and fibrous mineral, like hornblende, augite, fibrolite, etc.—may serve as an excellent binding material, like hair in mortar, and add to the strength of the rock, if uniformly mixed, with little or no parallelism of planes. Peculiarities of crystallization in crystalline rocks or of arrangement of tabular flakes of minerals in sedimentary rocks may also produce a coincidence in the position of planes of stronger cleavage, *e. g.*, of feldspar in granites or in feldspathic sandstones, which will diminish both the strength and durability of a rock. The disintegration of the freestones of the Triassic age is favored by both these conditions—abundance of mica and parallel position of feldspar plates.

POROSITY.—Bischoff has thrown much light on the percolation of water through the interstices and fissures of rocks. Even in the densest crystalline rocks, as trap and basalt, spots of moisture can be discovered on freshly fractured surfaces, generally connected with minute fissures. In the loosely-cemented material of the freestones the percolation must be far more free.

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a On the Geological Action of the Humus Acids, *Proc. Am. Ass. Adv. Sci.*, 1878.
b *The Builder*, 1882.
c *Trans. N. Y. Acad. Sci.*, I, 1882.

The excessive porosity of a building stone thickens the layer of decomposition which can be reached by the acids of the atmosphere and of the rain, and also deepens the entrance of the frost and its work of disintegration. This is illustrated, in the case of brownstone, in numberless instances throughout New York city, in the sills and lintels of windows, the projecting string-courses of stone in brick buildings, the steps of stoops and sills of doors, etc., with their edges rounded, their material pitted, honey-combed, fretted, and furrowed by the ridges of projecting or eroded laminæ, or the whole mass of the stone worn away flush with the front of the house, *e. g.*, in the older brownstone houses of the district styled "Greenwich village", in the Eighth ward, and in the old streets on the east side of the city. Even, too, in houses less than ten years old, the flat ceilings of the porticos, surfaces which appear to be perfectly sheltered from the weather, are peeling away into successively-loosened layers, *e. g.*, in the houses on the west side of Fifth avenue, between Forty-sixth and Fiftieth streets. In all these cases we plainly see the effect both of rain, and, above all, of water, derived from the thawing of the snow which is caught and rests upon the projecting ledge of stone, soaking down into the spongy mass below during the day, and again partially thrust out by the expansion of freezing during the night. With a light-colored stone an unusual and undesirable power of absorption is often indicated by its discoloration in streaks and circular patches. Several kinds of discoloration may be distinguished, all more or less dependent on the absorptive character of the stone. The one consists of a white calcareous efflorescence, very common in new masonry, in blotches spreading around the joints, and doubtless derived by permeation of the stone with solutions of calcium carbonate from the fresh mortar or cement. It appears to be usually of a temporary character, disappearing after a few years. This is sometimes seen in brownstone, but more frequently in the Ohio and the New Brunswick freestones; *e. g.*, in the fronts and stoops of most of the houses first built of that stone in Madison avenue above Fifty-fourth street, etc. Another form of discoloration is due merely to the street-dust and soot which are deposited upon the projections of a stone front. It results in long gray or blackish streaks, running down the front at either end of the window-sills and from below the line of projecting bands and cornices, and as a general blackish-gray discoloration of the surfaces of sheltered moldings of apertures, the pediments of porticos, etc.

The earlier stages of this discoloration may be easily studied in numerous instances among the older buildings constructed of light-colored freestone, *e. g.*, in the houses on the northwest corner of Sixth avenue and Twenty-ninth street, and between Thirty-seventh and Thirty-eighth streets, and in the building on southeast corner of Christopher street and Greenwich avenue, etc.; the sloping window-sills of the orphan asylum at Fifth avenue and Fifty-first street are thus blackened, while the vertical faces of the same stone in the façade are washed clean and uncolored.

A similar discoloration affects most of the varieties of white marble used in our city, *e. g.*, in several buildings on the north side of Murray street, between Church street and West Broadway; in the new court-house on Chambers street; the cornices, sills, and seams of the rusticated stone-work of the Union Dime Savings bank, at Sixth avenue and Thirty-second street.

Another form of discoloration, commonly associated with the preceding in the same light-colored freestones, presents black stains and streaks, whose material has not yet been identified, but apparently consists of manganese-oxide, probably derived from the decomposition of the feldspar and chlorite in the rock. This is of a more permanent and objectionable character, increasing both in extent and depth of color with the age of the masonry. Its progress is most rapid on stone surfaces exposed to the prevailing winds and rains, *i. e.*, the northeast. An illustration of this appears in the church on the corner of Fifty-seventh street and Madison avenue, whose faces fronting the south and west are entirely free from discoloration, while the spire, freely exposed above, is beginning to be tinted all around and from top to bottom.

Other forms of discoloration are shown in yellowish stains on the light freestones, certainly due to iron, and in films of confervous growth, which are green during rainy and damp weather, and become blackish-gray when dry.

HARDNESS AND TOUGHNESS.—Resistance to weathering does not necessarily depend upon hardness, since some soft rocks of peculiar composition (*e. g.*, some steatites, chlorite schists, etc.) are known to withstand atmospheric attack very well. However, a hard material of close and firm texture is, in those qualities, specially fitted at least to resist friction and artificial wear, as in stoops, pavements, sidewalks, and road metal, and the natural friction of rain-drops, dripping rain-water, the blows of the surf, etc. The graywacke and blue-stone of New York and Pennsylvania, is, in the form of flagging, unexcelled for paving, etc.; and no reason is apparent why its thicker beds should not be further applied as a material for ordinary construction. So far as yet introduced for this purpose, within a few years past, it preserves perfectly the arris in dressings, quoins, etc., without either chipping or discoloration.

CRYSTALLINE STRUCTURE.—Experience has shown that the crystalline structure in a stone is a better resistant to atmospheric attack than the amorphous. The following statement is made concerning this characteristic in an oolitic limestone of England:

> The Steetley stone is remarkable for its light specific gravity, great power of absorption, and yet extremely durable; its resistance to atmospheric influences may be attributed to its beautifully sparkling crystalline structure, without having any dusty incoherent matter in its formation, the crystals being all well cemented together. (*a*)

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a C. H. Smith, *op. cit.*, 32.

It is also well illustrated in New York city in the better class of crystalline building stones, *e. g.*, the granite buildings in Murray, Warren, and other of the older streets, the Astor house, etc., which are not yet perceptibly affected by the tooth of time. The same fact is generally true with the sedimentary rocks also, a crystalline limestone or good marble resisting erosion better than an earthy limestone. Only the oolitic varieties of the latter seem to possess, in that structure, an advantage over those that are entirely earthy or amorphous. The durability of a limestone like that of Indiana, recently introduced into this city, must depend upon these conditions. So, too, the highly-crystalline varieties of the Potsdam sandstone, in New York, Wisconsin, etc., abounding in glittering facets which the microscope reveals to be in part quartz crystals of exceeding minuteness, may be expected to have in that respect a greater likelihood of durability, if well cemented, than the ordinary variety made up of rounded grains.

TENSION OF THE GRAINS.—A crystalline building stone (*e. g.*, granite, gneiss, marble, etc.) is made up almost entirely of imperfect crystals of its constituent minerals (of calcite, in a marble—of quartz, feldspar, etc., in a granite) closely compacted together, originally with intense mutual pressure. Sometimes no cement intervenes, but any two grains remain in close contact at an impalpable invisible line. Such a condition must be sensitive to very slight influences, the surfaces of the grains in a building stone being alternately pressed still more tightly together or separated to disruption, *e. g.*, by variations of temperature, above all at the extremes of severe cold and frost, of burning sunshine, and of fire. A good illustration is found in those marbles which seem to contain no cement in their interstices, *e. g.*, the coarse Tuckahoe marble, which soon becomes seamed with cracks, as in the building on the corner of Thirty-second street and Broadway.

In England it has been found that—

> All varieties of Carrara marble have perishable qualities which ought to preclude them from being ever applied to external purposes in this country. After exposure to the weather for thirty or forty years, disintegration through its entire mass, but mostly on or near the surface, evidently takes place; after the lapse of about a century, more or less, according to the quality of the marble, the entire substance falls into a kind of sparkling sand. (*a*)
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> Frequent changes of temperature also tend to destroy Carrara marble more rapidly than atmospheric influences; thus the mantel of a chimney-piece is invariably disintegrated long before any other part.

CONTIGUITY OF THE GRAINS.—The principle which obtains in the application of an artificial cement, such as glue, in the thinnest film, in order to gain the increased binding force, by the closest approach of the cemented surfaces, finds its analogy in the building stones. The thinner the films of the natural cement, and the closer the grains of the predominant minerals, the stronger and more durable the stone. One source of weakness in our brownstones lies in the separation of the rounded grains of quartz and feldspar by a superabundance of ocherous cement. Of course, the further separation produced by fissures, looseness of lamination, empty cavities and geodes, and excess of mica, all tend to deteriorate still further a weak building stone.

HOMOGENEITY.—A great difference of the hardness, texture, solubility, etc., in the material of the grains of a rock and of their cement, or of the successive laminæ, renders the weathering unequal, roughens the surface, and increases the sensibility of the stone to the action of frost. So also softer patches, of more easily decomposed veins and layers in the stone, produce unequal weathering, hollows, furrows, and projecting ridges. Even a hard crystalline and otherwise durable stone may be materially weakened by these defects. Illustrations of this are found in the same varieties of the dolomitic marbles, with irregularly mixed constituents, from the old quarries at Kingsbridge, on New York island, and in Westchester county.

C. CHARACTER AND POSITION OF SURFACE.

The rough or polished condition of the surface of the stone, its inclination from a vertical plane, and the position in which it stands with reference to the sun and to the prevailing direction of the wind, all constitute important elements of its durability.

SMOOTH DRESSING OR POLISH.—It is generally assumed, and rightly, in the climate of New York, that a smooth or polished surface tends to protect a stone by facilitating the rapid discharge of rain-water from its surface. The present condition of most of our smoothly-dressed granite fronts seems to confirm the general accuracy of this opinion. Nevertheless some anomalies occur. It has been observed in London that, in the modern buildings, decay progresses far more rapidly than in the ancient, and it has been queried whether this may not in some way be due to the application of machinery.

A series of observations by Professor Pfaff, of Erlingen, Germany, in reference to granite, syenite, etc., have shown, among other results, that the superficial loss in a century, by exposure to the weather, may amount, on unpolished granite, to 0.0076^{mm}, on polished granite to 0.0085^{mm}.

These conclusions in regard to the more rapid weathering of polished granite yet need confirmation by more extended observations in other localities. But an investigation is yet needed to determine whether the vibration of the surface of a stone, produced by the jar of the machinery employed in sawing or polishing, as well as the bruising produced by the friction of the sand, diamond-saws, etc., and still more, the strain and pressure produced by the impact of the blows of chisel and hammer, in smooth and rough dressing, do not produce superficial changes of tension, minute fissures produced by the separation of surfaces of feeble adherence (*e. g.*, on smooth planes of

a Gwilt's *Encyc. of Arch.*, p. 491.

tabular flakes of feldspar, scales of mica, etc.), cracks in brittle minerals (*e. g.*, quartz), microscopic clefts along cleavage planes (*e. g.*, of the feldspars), slight disruption of grains from the adhering cement, etc. If these actions do occur in stone-working, and especially if they reach a sensible depth, as I believe, they may partly account for the anomalous loss of polish and rapid peeling away of successive layers from the surfaces of dressed granites and freestones. The very dressing, so agreeable to the eye, may actually present the surface of the weaker stones in the worst possible condition to resist atmospheric attack.

On the other hand, a roughness of the surface favors the deposition of street-dust, smoke, etc. In France—

> The beautiful marble sculptures of the park of Versailles will, within the next fifty years, become, through its means, unsightly and ugly masses of dirt, and eventually be irretrievably lost. Dr. Robert recently called attention to the fronts of the Bourbon and Mazarin palaces, that of the legislators, the mint, and others, which by this influence are hastening to decay, and even more rapidly in proportion as the ornamental carvings promote the deposition of dirt and dust. (*a*)

It has been shown that in New York these substances have been observed to exert a deleterious influence by chemical corrosion of the stone on which they rest. Being chiefly organic in material and absorbent of moisture they also furnish a suitable nidus for the growth of minute plants, *e. g.*, lichens, *confervæ*, mosses, etc., whose erosive action has been already mentioned. However, there is no doubt that under certain circumstances, not yet understood, a crust of dirt, smoke, and soot may act as a preservative to the stone, as observed by E. C. Robins and A. Billing, on St. Paul's and on Hanover chapel, London, on the church of St. John's, in Southwark, etc.; the same is true also of at least some of the vegetable growths—certain lichens which flourish in the dusty deposits.

Inclination and position.—Sufficient reference has already been made to the influence of these conditions in many ways on the durability of stone. The illustrations are without number throughout the older streets of our city, in the decayed state of those surfaces of stone which are horizontal, and on which rain-water, slush, snow, and ice may rest; of those on the south side of cross-streets, and the west side of the avenues running north and south, which are exposed to the driving rain of northeast gales, etc. Thus, in the towers of the church on the northwest corner of Clinton and Pacific streets, Brooklyn, the brownstone on its front, which faces the east, is peeling off in patches in many places, while the south face of the towers remains apparently unattacked.

Again, on surfaces which are liable to be water-soaked, but which may be sheltered from the sun and wind, the moisture does not quickly dry out, and here especially the decay may be very rapid. The soffits of arches and lintels, the shady sides of window-jambs, and the shady parts of carvings, etc., are among the first portions of a building to decay. From this cause, or from the leaking of a rain-water leader, the surface of a whole pilaster may peel off, as in the building on the southeast corner of Eighteenth street and Fourth avenue, New York.

Method of pointing of masonry.—The admitted energetic agencies of decay—frost, solution, hydration, etc.—have been largely favored by the imperfect and hasty construction of the masonry throughout the city, its joints when new often admitting a trowel. A cement-mortar of poor quality is largely employed, and, soon dropping out, the joints are often allowed to remain open for years. The atmospheric attack is thus made, as it were in flank, directly through the exposed edges of the outer laminæ of the stone, and the decay rapidly affects the stone to a considerable depth, several inches in many cases, and even throughout the entire block, although the exfoliation may appear superficial.

Erection on edge of lamination.—Instances are very rare in this city where the stone has been laid "on its bed", with a deliberate regard to its durability: *e. g.*, a few houses on Fifth avenue above Fifty-first street, the new wings of the Astor library, etc. On the other hand, from mere convenience in construction, many buildings, especially of our older churches, are fortunately so constructed, the blocks having been small and square and conveniently so laid. In some instances (*e. g.*, the church on the southeast corner of Thirty-fifth street and Fifth avenue) blocks occur in both positions and in both are affected by incipient decay; in others (*e. g.*, the church on southwest corner of Twenty-first street and Fifth avenue) the blocks, although all on bed, are often deeply decayed. In the old city hall, erected in 1812, the north face, although on the side usually least affected by decay, presents the brownstone of its ashlar set on edge and exfoliating in entire sheets, often traversed by fissures across the lamination, parallel to the joints. Notwithstanding these warnings, most of our newest edifices exhibit the same faulty construction: *e. g.*, the sandstone (from Massachusetts) in the trimmings and even partly in the pillars of the Union League Club building, on Fifth avenue, the fine new residences in the upper part of Madison avenue, the trimmings etc., in the huge new buildings for "flats" and business offices throughout the city, often nine to eleven or more stories in height, in whose walls the crushing force exerted upon this soft stone must be excessive.

Exposure to the sun.—Again, subjection to wide differences of temperature on different faces, *e. g.*, those produced by the burning heat of our summer sun on the western faces of buildings, renders the stone liable to crack from unequal contraction and expansion, and produces, on a laminated rock, separation along the planes of lamination, and, on a compact rock, an exfoliation in concentric crusts allied to that of common occurrence in nature on outcrops or bowlders of granite and trap. The former is abundantly illustrated in the marked decay and splitting observed on the western faces of the tombstones in Trinity church-yard, the cemetery at New Utrecht, etc., described beyond. The ashlar at the base of the steeple of the church at Thirty-seventh street and Fifth avenue is beginning to decay on the south side, but not on the north or east sides (the west side not being visible). Other examples are

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a *Manufacturer and Builder*, 1871, III, p. 150.

seen on the brownstone stoops of our cross (east and west) streets, where the western face of the dark stone is rapidly disintegrated and exfoliated, while the eastern face remains much longer in perfect condition. The stone balusters of the balustrades of balconies and the sides of high stoops are, from their slender form, peculiarly sensitive; they disintegrate and exfoliate rapidly on their sun-exposed sides, and become split, ragged, and reduced within five years to a wretched condition, especially when the bedding plane is exposed to the sun. Little rule is observed by stone-cutter or builder in regard to the position of planes of bedding in work of such delicate character as the stone rails, balusters, and posts of stoops and balconies, the planes lying and facing in every direction, sometimes uniform in a particular stoop, sometimes differing—vertical, horizontal, or even sometimes oblique, and directed to all points of the compass—though in general the planes are vertical in the balusters of a stoop and stand either parallel or perpendicular toward the front of the building. The decay is much more rapid in the coarse brownstone, though apparent on the light-colored freestones, and affects the western side of balusters on the cross-streets and the southern side on the avenues. It seems to be somewhat delayed wherever the edges of the layers happen to face toward the sun, *i. e.*, to the west on cross-streets and to the south on avenues, in New York city.

In general it may be stated that all the influences of driving winds, acid vapors, pelting rains, burning sun, etc., are less destructive by far than the quiet action of rain-water or thawing snow dripping and soaking down continuously from any projection or hollow in which water or snow may lodge. A good illustration is found in the synagogue on the southeast corner of Sixty-third street and Lexington avenue, in the fresh, unaltered condition of all its vertical faces of light freestone, and the extensive discoloration which has attacked the face of the pediment of its front portico from water soaking through its roof, and the discolored streaks which run down the inner corners of its towers.

4.—METHODS OF TRIAL.

The methods now in vogue are to a large extent so superficial and empirical, so unsatisfactorily confirmed by the practical results attained, as to have elicited from many an opinion akin to that expressed by a member of the London Society of Arts. His impression was, and it was borne out by the opinions of many practical men, "that when a stone was once out of the quarry it was almost impossible to say whether it was a good stone or a bad one". It has long been recognized that there are two ways in which we can form a judgment of the durability of a building stone, which may be distinguished as the natural and the artificial.

A. NATURAL METHODS.

These must always take the precedence wherever they can be used in any locality, because they refer, first, to the exact agencies concerned in the atmospheric attack upon a stone, and secondly, to long periods of time far beyond the reach of artificial experiment.

A memorable investigation, in which the main dependence was rested apparently upon this class of methods, was that instituted by the British parliament in the royal commission appointed in 1837 for the selection of the stone to be used in the houses of parliament. This commission consisted of four persons: the architect, Sir Charles Barry; two geologists, Sir Henry De La Beche and Dr. William Smith; and Mr. C. H. Smith, a practical man, well acquainted with the working of stone, occasionally assisted by Dr. Buckland and Professor Phillips, and, in the chemical department, by Professors Daniell and Wheatstone. From the study of the outcrops in neighboring quarries and the weathering in several old buildings in Yorkshire, the commission recommended the use of the stone from the Norfal quarries, North Anston, ten miles east of Sheffield, and were discharged. The execution of this recommendation was put in incompetent and irresponsible hands, without government superintendence. Consequently the stone of the Norfal quarries having been adjudged too small for the purpose, and also those of a neighboring quarry, resort was finally had to a stone not covered by the report of the commission, and of this the houses of parliament were mainly erected in 1840. It proved of such inferior character that the decay, immediately setting in, attracted attention even in 1845, and has since led to extensive and costly efforts for the purpose of repair and preservation.

Examination of quarry-outcrops.—Much information of the highest value may be obtained, especially in the northern United States, where the results of ancient decomposition have been planed off by glacial action, from a study of the old natural exposures of a stone to the atmosphere at or near the quarry from which it was taken, with allowance for the conditions which may there prevail at present, or which probably existed in pre-glacial time. However, it has been pointed out that "the length of time they have been exposed, and the changes of actions to which they may have been subjected, during, perhaps, long geological periods, are unknown; and since different quarries may not have been exposed to the same action, they do not always afford definite data for reliable comparative estimates of durability, except where different specimens occur in the same quarry". (*a*) Within the district allotted to this report only three building stones are found in place: The trap of the Palisades and of Staten island, whose exposed surfaces are almost always smooth, and whose crust of disintegration, rarely reaching a half inch in thickness, implies a power of excellent resistance to atmospheric attack; the gneiss of New York and Long islands, which often becomes deeply discolored along some planes, but even then, in its common siliceous variety, retains most of its toughness and strength; and the dolomitic marbles of the old quarries of Kingsbridge

a Report of Commission to Test Marbles for the Extension of the United States Capitol, p. 589, 1851.

and Morrissania, no longer worked, and of Westchester county, in which a wide variation is shown on the exposures, some surfaces being disintegrated to a pulverulent mass or loose sand, while others remain firm and hard.

EXAMINATION OF OLD MASONRY.—A study of the surfaces of old buildings, which have been exposed to atmospheric influences for years or centuries, is one of the best sources of reliable information concerning the durability of stone, and frequent references to such observations have already been made in this report; unfortunately no buildings of great antiquity have resisted the iconoclasm of our period and remain for study. Following, however, the example of Professor Geikie, of Great Britain, in his study of a grave-yard of Edinburgh, I have made some studies in those of New York and vicinity. It may be remarked that the varieties of stone used in cemeteries for the dead are usually for the most part identical with the building material employed in the houses of the living at the same period. Nor could any method be devised for testing so thoroughly, by natural means, the elements of durability in any stone as that by which, in the form of a tombstone, it is inserted partly in the moist earth, entirely exposed above to the winds, rain, and sun on every side, with its bedding lamination standing on edge, and its surface smoothed and polished and sharply incised with inscriptions, carvings, and dates, by which to detect and measure the character and extent of its decay.

The present edifice of Trinity church was constructed during the years 1841–'46 (the first building having been erected on that site in 1696). Saint Paul's chapel was erected in 1766, and, although this structure is older than that of Trinity, its cemetery is much more recent in its origin.

Trinity church-yard, New York city.—A variety of materials is found in the tombstones of this cemetery, one of the oldest inclosed in the city. The observations made on the present condition of the stones have been grouped together according to the material, disregarding as carefully as possible all stones which showed evidences of repair and recutting. Most of the stones are erect, and stand with their planes in the meridian, *i. e.*, their inscribed faces fronting the east.

Red sandstone, compact, hard, and fine-grained, apparently identical with that of the church building, and forming the largely predominating material for the stones: Tomb of Matthew Daniel (1820), west side split off, but general condition otherwise good, and inscriptions sharp; also, several tombstones in vicinity in same condition, with more or less splitting along lamination on their western faces, *e. g.*, those of John Child (1808), John Wilson (1805), Peter B. Ustick (1791), Jane Slidell (1770), John Waddell (1762), Joseph Penn (1763), Charles Burleigh (1757), and many others; tombstone of children of John and Mary Bard (1796), much eroded, and splitting on both sides. Two of the oldest stones, those of Jeremiah Reding (1722) and Richard Churcher (1681), are in very fair condition, the inscriptions being sharp, and only a slight tendency to splitting beginning to show on the west side of the top of the stone.

Graywacke or blue-stone, probably from the Catskills or central New York: Tombstone of Remington Stephenson (1730), in excellent condition, but west side beginning to decay; that of Mary Corrin (1730), perfect on both sides; inscriptions sharp on both stones.

Black slate, probably imported: Tombstone of John Daley (1774), in very good condition, only a slight decay roughening the west side; that of Anne Churcher (1691), both faces and edges perfect and the inscriptions sharp.

Gray slate, perhaps from the Catskills: Tombstone of George Carpender (1730), inscription sharp, slight erosion on west face.

Green hydromicaceous schist, probably from western part of Connecticut or Massachusetts: Tombstone of Joshua Amy (1742), in excellent condition, only the west face being slightly worn.

White oolitic limestone, fossiliferous, probably imported from England: Tombstone of John and James Searle (1736), in excellent condition.

Fine white marble, apparently from Carrara, Italy: Inscription and date obliterated, full of minute cracks on both faces.

White marble, probably from western Massachusetts: Tombstone of Lars Nannestad (1807), and that of Alexander Hamilton (1804), both in fair condition, but worn on the north face.

Saint Paul's church-yard.—One variety of fine-grained sandstone predominates, dating from 1813 back to 1768. The finest-grained and most compact are often in perfect condition (J. J., 1768), but many coarser or more laminated stones, and sometimes fine and compact stones, are very badly split, and show exfoliation near the ground (A. Van B., 1813), sometimes with fissures across the stone (J. A., 1813). The splitting begins, as usual, near the west face and near the edges.

As to marble, the stones here date from 1851 back to 1798, and consist of a coarse white marble. It weathers grayish-white, and becomes roughened. Only a small proportion of the stones are split. About one-tenth have their inscriptions entirely obliterated, and this fact, due doubtless to the acid rain-waters of the city, was not observed in the suburban cemeteries; in one case (A. W., 1851) it has been largely affected in a little over thirty years.

The old Dutch cemetery at New Utrecht, Long island.—At this little village, which lies on the southern outskirts of Brooklyn, most of the tombstones are erect, in good condition, and face the east. The materials used are the following:

Fine-grained sandstone, of a warm red to reddish-brown color, resembling the stone of Little Falls, New Jersey. As a rule the stones of this kind are in excellent condition, especially in proportion to their fineness of grain, and universally preserve the sharpness of their inscriptions. Their dates observed range from 1812 back to 1743, and out of twenty-five noted the following may be referred to: Jacques Denyse (1811), very fine-grained, inscriptions and tool marks perfect; John Van Duyne (1801), in perfect condition; Rutgert Denyse (1795), very fine-grained stone, inscription remarkably perfect, even to the finest flourishes; Jacques Denyse (1791), in good condition, a small fragment lost from top edge; Jacobus L. Lefferts (1785), very fine-grained, and in perfect condition; Abraham Duryee (1743), stone perfectly preserved.

Graywacke, light gray, and thinly laminated: S. Barre (1852), stone split throughout, especially on the west face.

Blue marble: Catharine Groenendyke (1797), stone in excellent condition, hard and smooth on the west face, but slightly roughened and pulverulent on the east face.

Mottled black and white marble: Mercy Grenendyck (1794) and Nicholas Grenendyck (1795), in perfect condition in both form and sharpness of inscription, the west undressed face being hard, but the surface of the east face, top, and sides being somewhat roughened and pulverulent.

Red laminated sandstone, probably from New Jersey: W. W. Barre (1854), the east face in perfect condition, but the top and west face beginning to split; Cornelius Van Brunt (1850), the faces in good condition, but a fissure in the lamination behind the east face; Ann Schenck (1824), stone split along the lamination next the west face, and also with a vertical fissure across the lamination of the stone near and parallel to the north edge; William Barre (1826), and Rebecca Johnson (1821), a stone with alternating red and gray laminæ (like that used in the Flatbush cemetery), thoroughly split up throughout, along the lamination, and with fragments lost from the top.

White marble, rather fine grained, and for the most part from Vermont, stones dated from 1847 back to 1828, with usually their inscriptions perfect (for example, the stone of Thomas Clark, 1831), their west faces in good condition, but their tops, sides, and east faces more or less roughened and pulverulent; the stone of J. Lefferts (1828), is in good condition except on the west face, which is much split, apparently by the sun.

Granite from Quincy, Massachusetts, and Aberdeen, Scotland, in a few stones dating only from 1876 back to 1856, and of course in perfect condition. The varieties of stone have been arranged above in about the order in which they seem to have come into general use. In regard to their durability it may be stated in general:

1. The fine-grained red sandstone, probably from Little Falls, New Jersey, has presented a remarkable resistance to weathering, always proportioned to its fineness of texture, generally in excellent condition after a period of more than a century.

2. The laminated sandstone, brought later into use, has been a poor material, yielding miserably, apparently to the heat of the sun, in less than a half century.

3. All the marbles used have resisted the sun in almost every case, but show by the roughened, pulverulent condition of their sides and eastern faces that their decomposition is slow but gradual, and only a question of sufficient though perhaps long time.

A point of difference between the stones of this cemetery, in an open country village on the outskirts of Brooklyn, and those of Trinity church-yard, in New York city, is shown in the abundance of lichens which are found in the former. Three varieties seem to occur: one, a bright green, confined in its growth to the top of the stones; another, of orange color, scattered over the upper part of the west face, exposed to the afternoon sunshine, and rarely seen on the east face; and another of light green color, abounding as a crust over the east face. No particular effect of corrosion by these growths was noticed, either upon sandstone or marble; on their removal the surface beneath was found to be fresh, and had apparently been only protected from weathering.

Flatbush cemetery.—In the old cemetery of the village of Flatbush, Long Island, on the northeastern outskirts of Brooklyn, the tombstones are nearly all vertical, and face the east. White marble predominates largely, but the oldest stones consist of sandstone.

Red sandstone, usually very fine grained and compact, and apparently the variety from Little Falls, New Jersey. The stones vary in date from 1804 back to 1754: Rebecca Suydam (1797), and Marrytie Ditmarse (1797), both faces of these stones in excellent condition; Hylletie Martens (1779), a light reddish-gray stone, in good condition, only the top being a little roughened; Abraham Lott (1754), the inscription perfect, and only a few fragments chipped from the top.

Red laminated sandstone, often very fine grained, largely made up of two materials, reddish-brown and light reddish-gray, in thin alternations from one-half to 1 inch thick. The stones vary in date from 1822 back to 1754: Maria Allen (1820), with sharp inscription, but many fissures in the lamination; Peter Neefus (1820), the stone in excellent condition, covered with sections of long cylindrical markings, perhaps fucoidal; Leffert Lefferts (1800), the stone traversed by fissures along the lamination, and also vertically across it in lines parallel to the edges and about an inch from the edge; Adriantie Lefferts (1761), like the preceding; Gelijam Cornel (1754), decidedly laminated in structure, but in excellent condition.

Tremolitic white dolomite marble, perhaps from the old quarries of New York and Westchester counties, fine-grained to quite coarse in texture, and often sprinkled with grains and flakes of tremolite, sometimes several inches in length. The stones vary in date as follows: E. Aldworth (1851), the stone facing westward, and with minute fissures abounding over the top and the southern edge; A. Lloyd (1847), the stone in good condition, still retaining most of its polished surface, even on the tremolite; J. F. Neefus (1847), surface of stone rough and pulverulent, so that the rough, gray appearance usually distinguishes stones of this material from some distance; Mary Van Siclen (1832), the top and west face roughened one-third of the way down, the remainder being much less roughened; W. Riley (1811), smooth for a height of about a foot from the ground, and roughened above.

Fine white marble, probably of Carrara, the stones varying in date from 1859 to 1801; E. Duclois (1836), somewhat rough and pulverulent all over the surface; N. R. Cowenhoven (1809) and J. Vanderbilt (1801), both horizontal tablets, more or less blackened in spots by a minute lichen (probably the *Lepra antiquitatis*), etc.

Fine white marble, sometimes with gray streaks, probably from Vermont; the stones are of recent date, from 1855 to 1730: Charity Van der Veer (1836), the entire surface of the stone pulverulent, rubbing easily off into fine sand; Femetie and Peter Stryker (1730), roughened down to a foot from the ground, where the polish remains.

The lichens abound here also on the tops of the stones, but have been mostly cleaned off their faces. The same general conclusions may be here deduced, in regard to their durability, as in the similar varieties observed at New Utrecht. It is a curious circumstance, in all these cemeteries, that the stones display no exfoliation or decay near the ground, the polished surface often remaining perfect; above, the action of the sun on the western faces, and of northeast storms on the eastern faces, are apparent as usual.

B. ARTIFICIAL METHODS.

The various text-books on building-construction describe in detail many methods of trial of building stone; *e. g.*, of solubility in acids; of absorptive power, by soaking in water and determination of increase of weight; of power to resist the expansion due to frost, by actual freezing, or by saturation in saturated solution of sodium-sulphate (Brard's method); of strength to resist crushing, bending, or tension, by the application of pressure or force in various ways, etc.

It is unnecessary to make any reference here to these descriptions, except in regard to their antique and unsatisfactory character, and to the apparent ignorance of the appliances now within the reach of students of the modern science of lithology, which can readily be used to reveal the true nature of a building stone and the elements of its durability, *e. g.*, the study of its surface under the microscope, or of slices ground so thin as to be transparent, or of its individual mineralogical constituents separated by means of their difference in specific gravity, or by means of the almost endless resources of micro-chemistry. The careful and well-digested circular of the department of building stones, issued by the late curator of the National Museum, Mr. George W. Hawes, whose recent decease has been universally deplored as a great loss to science and to the work now in progress in this field, has given a suggestion of the wide departure from the old and incomplete methods which is at last called for, in order to advance our knowledge of the proper application and practical use of building stones, under the light of modern discovery.

One important method, long in use, is the determination of the absorptive powers of a stone. A granite which absorbs water to over half of 1 per cent. of its weight is open to the suspicion of doubtful durability. Similar caution needs to be observed in the choice of freestones in our own climate.

Any sandstone weighing less than 130 pounds per cubic foot, absorbing more than 5 per cent. of its weight of water in twenty-four hours, and effervescing anything but feebly with acid, is likely to be a second-class stone, as regards durability, where there is frost or much acid in the air.

It is here pertinent to refer briefly to some significant results obtained by Professor John C. Draper, of this city, in experiments on two of our most common building stones, in comparison with brick.

Fragments of each of the materials were soaked in a saturated solution of sodium sulphate for four hours, then allowed to dry and crystallize for twenty hours, then freed from loosened material by washing off by means of a fine jet of water from a wash-bottle. This operation was repeated eight times, *i. e.*, eight days, with the following results, the first column of figures representing the loss of substance, by weight, in 10,000 parts:

	Loss.	Ratio.
Nova Scotia stone	441	18
Brownstone	191	8
Red brick	74	3
White brick	24	1

As Professor Draper has pointed out, these results only tend to show that frost is not the main agent of the initial disintegration in the climate of New York, since it is not the Nova Scotia stone, but the brownstone, which suffers the most severely and rapidly from decay.

A quicker method employed was to heat the specimens to a temperature of about 600° Fahr., and quench them, while hot, in cold water. This method of trial yielded the following comparative results:

	Loss.	Ratio.
Nova Scotia stone	597	14
Brownstone	202	5
Red brick	82	2
White brick	43	1

These results appear very significant, especially in relation to the power of brick and stone to resist the destroying action of great conflagrations.

Again, to determine the extent of the action of acid vapors in the air upon the building stone, fragments of the same materials were digested in dilute acids, and the following results were obtained:

	Loss.	Ratio.
Brownstone	216	30
Nova Scotia stone	66	9
Red brick	33	5
White brick	7	1

On this subject Professor Draper remarks:

From this it would appear that the reason the brownstone disintegrates so rapidly in our city is its greater susceptibility to the action of the acid products of organic decomposition and combustion; where the cementing material is dissolved or weakened, and pores and fissures in the rock being opened, it is less liable to resist the attack of frost. The Nova Scotia stone, on the contrary, is a more friable material than the brownstone; yet, being less acted upon by the acid waters, it resists the process of decay better.

On the other hand, Dr. Page has obtained the following results, by Brard's process, on 1-inch cubes of several building stones used in this city, which do not confirm Professor Draper's results:

Variety.	Locality.	Specific gravity.	Loss in grains.
Coarse dolomitic marble	Pleasantville, New York	2.860	0.91
Close-grained sandstone	Little Falls, New Jersey	2.482	0.62
Coarse-grained sandstone	Connecticut		14.36
Fine-grained sandstone	Connecticut	2.583	24.93
Coarse-grained sandstone	Nova Scotia	2.518	2.16
Light dove-colored sandstone	Seneca, Ohio	2.456	1.78
Hard brick		2.294	1.07
Soft brick		2.211	16.46

Many experiments have been made to determine the crushing strength of building stones, an element which probably bears some relationship, at least in a general way—exactly what, it has never been determined—to their durability. The results in regard to the building stones used in New York, according to various authorities, are given in table on pages 330–335. They have been collected from various publications, mainly the reports of 1874 and 1875, by General Q. A. Gillmore, on the compressive strength, specific gravity, and ratio of absorption of the building stones of the United States, and a report of the results (communicated to me by Mr. F. R. Collingwood, an engineer of the New York and Brooklyn bridge) of the trials by Mr. Probasco, of the dock department of this city, on the stones employed in the bridge. A point yet needing investigation, but apparently as yet disregarded, is whether the crushing strength of a stone, as determined on the bed, may be affected, possibly diminished, by the reversal of its original position; a fact probably of common occurrence, since the original top of a block is rarely marked.

Other experiments have been made, too limited and imperfect for quotation here, such as those by Professor Joseph Henry and the United States commission in 1851, and by Professor Walter R. Johnson in 1852, to determine the amount of material thrown off from American marbles, etc., by repeated freezing and thawing, etc.

In this connection we may refer to the experiments made by Dr. Hiram A. Cutting, of Vermont, on a series of American sandstones, in regard to specific gravity, weight, absorptive power, and resistance to fire. The results on varieties like those used in New York city are quoted in the following table (*The Weekly Underwriter*, 1880, Vol. XXII, p. 288):

Local name.	Locality.	Specific gravity.	Weight of one cubic foot.	Ratio of absorption.	Heated at 600° F.	Heated at 800° F.	Heated at 900° F.	Heated at 1,000° F.	Heated at higher temperatures.
			Pounds.						
Freestone	Portland, Connecticut	2.380	148.7	1 + 27	Not injured.	Not injured.	Friable	Tender	Ruined.
Freestone	North of England	2.168	135.5	1 + 27	do	do	Cracks badly	Spoiled	
Montrose stone	Ulster county, New York	2.661	166.3	1 + 314	do	do	Not injured	Slight injury	Stands well.
Freestone	Belleville, New Jersey	2.350	146.8	1 + 27	do	do	Cracks	Friable	
Freestone	Nova Scotia	2.424	151.5	1 + 240	do	do	do	do	
Carboniferous sandstone	Br. Philips, Nova Scotia	2.353	147.0	1 + 19	do	do	Crumbles	Cracks and crumbles.	
Freestone	Dorchester, New Brunswick	2.363	147.7	1 + 26	do	Cracks	Cracks and crumbles.	do	
Berlin stone	Cleveland, Ohio	2.210	*138.1	1 + 22	do	Not injured.	Slight cracks		Stands well.
Berea stone	Berea, Ohio	2.254	140.8	1 + 20	do	do	do	Crumbles	Do.
Amherst stone	Amherst, Ohio	2.200	*137.5	1 + 18	do	do	Changes color	Friable	Do.
Brownstone	Hummelstown, Pennsylvania	2.346	146.6	1 + 28	do	do	Cracks	Crumbles	
Potsdam sandstone	Beauharnois, Quebec	2.512	157.0	1 + 38	do	do	do	do	

* It is claimed that these figures understate the true weight, which is said to approximate 155 pounds.

5.—MEANS OF PROTECTION AND PRESERVATION.

We have next to consider, first, the natural principles, very commonly neglected, which should be considered in the construction of stone buildings in the climate of New York city, and, secondly, the artificial means which may yet be applied for the preservation of our crumbling edifices.

A. NATURAL PRINCIPLES OF CONSTRUCTION.

These may be simply divided as follows:

SELECTION.—British architects have sometimes become so discouraged at their ill-success in fighting the elements for the safety of the materials they employ in construction, that the recommendation has been made to discard the soft freestones commonly in use, and resort entirely to the "igneous rocks", so called, in polished blocks, *e. g.*, granite, basalt, serpentine, etc.

Mr. C. H. Smith, one of the commissioners on the houses of parliament, makes a statement (*a*) which is as applicable in the latitude of New York as in that of London.

The chief cause of defective stone being used rested with the architects. A young architect would like to make as much display as he could for little money. To make a great show, he used a cheap description of stone. It was generally put into the contract that the best materials only should be used, but it might be a question whether young architects, or even old practitioners, knew what was really good stone, and they would not apply to those who did. The builder naturally preferred a soft stone, because it was easily worked and yielded him the largest profit.

One of the most important principles in the selection of stones for our climate is that "porous stones should not be used for the copings, parapets, window-sills, weather-bed of cornices, plinths, strings, or other parts of a building where water may lodge". Such rocks when used should be carefully tested for absorptive power; a granite which absorbs water to over one-half of 1 per cent. of its weight, is open to the suspicion of doubtful durability. Similar caution needs to be observed in the choice of freestones in our own climate.

Any sandstone weighing less than 130 pounds per cubic foot, absorbing more than 5 per cent. of its weight of water in twenty-four hours, and effervescing more than feebly with acid, is likely to be a second-class stone, as regards durability, where there is frost or much acid in the air.

The following statement by an English authority is of interest, not only because Caen stone has frequently been brought to New York in small quantities, and was once employed in construction of the fronts of the old building of the Nassau bank, corner of Nassau and Beekman streets, and of others, and is still used for interior work, but from its applicability to our native soft limestone-freestones:

Experience proves that Caen stone will not resist the dissolving power of water charged with carbonic acid gas; and as the rain-water of our large towns contains a considerable quantity of that gas, it is not expedient to employ this stone in any situation where water is likely to lodge or even to be taken up by capillary action, unless indeed the projecting parts be protected by metal. In upright walling above the plinths, and in the sheltered portions of cornices, it can be employed when judiciously selected; and in internal work, with safety and economy. The bedding of the stone should be observed.

Mr. G. Godwin, F. R. S., of London, England, states, in regard to this stone, that much of it is really good, but affords only small blocks. That which is brought into England—

cannot be depended on and ought not to be used in external work. With regard to Buckingham palace, where Caen stone was used, that was perhaps the most remarkable failure that ever was witnessed. He recollected seeing the new front of that palace about a year or a year and a half after it was finished (1847), and he found many parts in a state of perfect ruin. Large masses of stone were in the habit of falling from the cornices, to the great danger of the sentinels below, and the result was the necessity of knocking off vast portions of the decorations and making them good with cement, painting them several times, with a frequent necessity for repeating that costly process.

Again, in regard to Westminster abbey, an English writer (*b*) remarks:

Of the exterior I will say nothing. All its old features had perished by the end of the seventeenth century, when they were vilely renewed, and this base restoration is now in its turn decayed.

The abbey had been built about A. D. 1245, its foundations of ragstone from Maidstone, and the rest of the building, of several limestones (Gatton, Caen, etc., and the firestone from Reigate and Godstone). It was afterward repaired with Bath and Portland stones. The greater part of the exterior is now in an advanced stage of decay.

Again there are certain rules of selection, often of local peculiarity, which are yet to be worked out, which refer to the adaptation of a stone to durability in certain positions, exposures, or parts of a building. A few such rules may be suggested as indicated by the study of the forms of decay in this city.

1. No temptation of cheap cost or facility of carving should permit the use—almost universal here—of a soft freestone in the stoops, balustrades, etc., where exposed to sun, street-dust, and wear, unless protected at least by some artificial means.

2. The finest-grained varieties of brownstone, with imperfect lamination, may be introduced with advantage for the projections and those parts most liable to decay, even where coarse material is generally employed in the front.

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a *Jour. Soc. Arts, London*, 1860, Vol. 8, p. 249. *b* Gilbert Scott: *Mediæval Architecture*, Vol. I, p. 176.

3. The life of a brownstone is more apt to be prolonged in a shady but dry exposure, *e. g.*, on the south side of an east and west street, or the west side of a north and south avenue, the shady side of a stoop, etc., if care is taken to prevent the dripping of rain or thawing snow; if not, this position may render it the more liable to decay. Accordingly, a light-colored or more durable stone may be best selected for sun-exposed faces, where possible.

A porous absorbent stone should not be employed at or below the ground line, and the absorption of moisture from below should be prevented by the interposition of some impermeable material, as a damp-proof course. Attention to this rule would have prevented the decay which is shown at the base of most of our brownstone buildings of the earlier construction, usually to a height of one or two feet above the ground line, but sometimes two or three yards, as in the building on the southeast corner of Eighteenth street and Fourth avenue; almost the only decay visible in the excellent sandstone used in Trinity church, New York, is of this nature, extending about a yard above the ground. This experience has borne some fruit in our city, and the insertion of the close-grained compact graywacke or "blue-stone", or sometimes a granite, into the base of most of the recently-erected brownstone fronts, even as a narrow band at the earth line, probably tends to prevent, by its less porosity, the rise of water into the sandstone, and so to delay its disintegration.

Seasoning.—Vitruvius, the Roman architect, two thousand years ago, recommended that stone should be quarried in summer when driest; that it should be seasoned by being allowed to lie two years before being used, so as to allow the natural sap to evaporate, and that it should be tested as to its wasting. Little regard seems now to be paid to this condition, the stone being hurried from the quarry into the building.

It is a notable fact that in the erection of St. Paul's cathedral in London, England, Sir Christopher Wren required that the stone, after quarrying, should be exposed to season for three years on the sea-beach, before its introduction into the building. No such exhibition of carefulness can be witnessed on any sea-beaches in the vicinity of New York city.

Position.—It has already been stated that, in order to resist the effects of both pressure and weathering, a stone should be placed on its "natural bed". This usually indicates the plane of original deposition, but not always, contrary to the general statements of the text-books; (*a*) for the lamination may simply be the result of the last period of pressure, *e. g.*, slaty cleavage, in which Sorby and others have shown a rearrangement of the particles, scales, and flakes of the constituent minerals into a stable condition of parallelism. This is illustrated in the constitution of some varieties of our slates, schists, and "blue-stone", and the injury, caused by neglect of this consideration, in the rapid decay and ruin now in progress in the ashlar of our freestone fronts. The stone of one of our oldest buildings, Trinity church, New York, probably owes its excellent preservation in part to the careful attention which was given to the position of the blocks, while in others of comparatively recent erection, though constructed of small blocks of brownstone mostly laid "on bed", the surface of the stone has begun to exfoliate, but not so rapidly and deeply as in occasional blocks standing on edge; for example, many stones below the projecting string-courses in the west front of the church on southeast corner of Thirty-fifth street and Fifth avenue. In many of the most recent buildings the proper mode of construction is seen: *e. g.*, the blocks of gneiss in all churches of that material; the Indiana limestone in the house on corner of Fifty-seventh street and Fifth avenue; the Potsdam sandstone, usually in the new buildings at Columbia college; the brownstone in residences at Fifth avenue and Fifty-first street, and in the lately-erected wings to the Astor library, etc. On the other hand, no attention is paid to the matter in the common stone fronts throughout the city, whether brownstone or Nova Scotia stone. Many prominent buildings of recent erection show the same disregard of the principle, *e. g.*, the marble ashlar of the Union Dime Savings bank, in which a large number of the blocks stand on edge and are in many cases fissured; the Lenox library, in which about 40 per cent. of the ashlar consists, in the alternate receding courses, of blocks of the Lockport limestone set on edge; the Drexel building, on the southeast corner of Wall and Broad streets, in which all the white marble ashlar dressings and even the projecting quoins stand on edge, etc. Indeed, in this city the proper arrangement of building stones in this respect, where apparently observed, has really been rather a matter of the builders' convenience, due to the small size or square form of the stones employed, than of any scrupulous attention to the conditions of durability. Other phases of the principle involved in the position of stone in a building have been already sufficiently discussed.

Form of projections.—The following statement by an English authority possesses even greater claim to consideration, in the exigencies of our more severe climate:

> In this climate water will invariably accumulate upon an exposed projection, and from thence, by the natural laws of gravitation, will run downward upon the surface beneath. * * * The continued permeation by water must materially injure the durability of any structure. Upon brick and stone, especially in winter, is this effect noticeable, when the repeated alternate freezing and thawing rapidly affect the quality of materials, and by a disintegration of particles impair the strength of the entire mass. * * * All projections from a building exposed to the weather should be "throated", that is, a narrow groove should be cut, extending the entire length, upon their under side. The water gathering upon the upper part of the window-sill, or whatever the projection may chance to be, flows over the upper edge to the lower and to the under side of the sill, when, instead of following the surface by the attraction of cohesion and finally running down the wall, it is stopped by the groove, and from thence falls to the ground, being unable to further continue its progress upon the surface. The complete efficacy of this device and the ease with which it is adopted are most apparent, and, though it has long been in use, is rarely introduced among the specifications of an architect. (*b*)

a *Notes on Build. Construction*, Part III, p. 9.

b *The Architect*, London, England, 1870.

The severity of our climate even requires the further care that the upper surface of projections should be so cut as to prevent the lodgment or long retention of deposits of either rain-water or snow. It is immediately above and below such deposits that the ashlar of our fronts is most rapidly corroded and exfoliated, an effect evidently due mainly to the repeated thawing and solution, freezing and disintegration, which are caused by the water, slush, and snow which rest, often for weeks, upon a window-sill, balcony, cornice, etc. Thus from the initial and inexcusable carelessness in the construction and form of the projections, and, later, the neglect of the house-owner, due to ignorance of the results involved, to remove the deposits of snow, etc., as fast as they accumulate on the projections, is derived a large part of the discoloration of the marble, Nova Scotia stone, or light-colored granite, and especially the exfoliation of the brownstone beneath the window-sills, balconies, etc., by the water alternately trickling down the front and freezing, by day and by night, for long periods.

The benefit of this plan is well illustrated on the east, south, and west sides of the city hall of New York city, the heavy projecting marble cornice of the string-course above the first story being deeply undercut, and affording a complete protection from the rain to the line of dentilated decoration immediately beneath it. Accordingly the latter displays no evidences of decay. On the other hand, the general need of this device is testified by a study of the course of the decay which attacks the stone fronts of our buildings. In almost all cases the first part of the ashlar to decay is that immediately beneath the windows. If the projecting stone sill is horizontal, or inclines slightly outward and downward, the rain-water falling upon it, and, still more, that derived from the thawing of the snow which lodges in winter upon the sill, flows over the front edge of the sill, over its under surface, and down the surface of the ashlar to the lintel of the window below, in a band as wide as the sill above, or sometimes farthest along a line beneath the middle of the sill, and so produces a triangular or rectangular patch of moisture on the stone, with the apex reaching partly or entirely to the lintel of the window below. If, however, the sill inclines inward toward the house, the water trickles from one or both ends of the sill in a narrow band down the ashlar. After a storm, when the house-front has become rapidly dried, partly from the wind, partly from the free drainage down the lamination-planes of the ashlar standing on edge, the stone sill remains water-soaked from the horizontal position of its laminæ, or from the thaw of the snow lodged upon it, and these triangular patches or the lateral streaks are kept moist, it may be, for days afterward. Throughout that portion of the ashlar, therefore, chemical action by day and the work of frost by night continue in progress alternately far longer than elsewhere upon the front. If the material is brick the surface is first discolored, the mortar removed from the joints, and at last the surface of the brick itself is eroded under the patches or streaks of moisture. Examples of this are seen in the brick fronts of the older streets.

If marble, the surface assumes a dirty yellowish color, the joints are widened, and the surface soon becomes roughened. Examples are seen in the marble fronts on the north side of Murray street, between Church street and West Broadway, etc.

If light-colored freestone, a blackish-gray, irregular discoloration begins, which may become very disagreeable to the eye, and a serious decay ensues. Examples are seen in fronts on the corner of Christopher street and Greenwich avenue, etc.

If brownstone, the discoloration hardly precedes the rapid disintegration, the surface peeling off in thin sheets over the triangular patches below the windows, or in long vertical streaks or bands on either side to the depth of 1, 2, or 3 centimeters, even while the general area of the front still retains, in sharp contrast, the smooth surface of its original dressing. Examples of this destruction are seen in its first stages all along the lower part of Fifth and Madison avenues below Forty-second street, and, still farther advanced, in the older streets.

If granite, discoloration has been often produced, but the use of this excellent material is too recent in our modern city to furnish the evidences, sure to follow, of deeper disintegration.

Again, the surface of the ashlar exhibits a similar decay just above the lines of projections, *e. g.*, of long business sign-boards, heavy string-courses, cornices, the lintels of doors and windows, etc., peeling off in the same way as the lowest courses of the front just above the ground line. This, too, seems to be chiefly due to the snow which lodges on these surfaces, and, in thawing, keeps moist the surface above. So, also, balconies bring speedy destruction to the stone surfaces beneath them, especially if their flooring permits the trickling of water down the front, and at the same time shelters it from the sun and wind. Thus, one may see in our streets, for several days after a snowfall, entire blocks of the finest residences with their fronts spotted with snow on all projections, constantly thawing and freezing, with corroding streams of water trickling their way down the front. In most cases these snow deposits on window-sills, lintels, etc., could be as readily swept from their lodgment by means of a broom, as they are always removed from the sidewalk. The neglect—which, if applied by our servants to the destruction of furniture within the same houses, would be denounced as slovenly carelessness—is simply due to ignorance.

It requires, therefore, but little observation of our buildings to recognize that, like the beak of the pelican tearing its own breast, the sills and similar projections are serving to eat away the material of the front lying below. A clear understanding of the nature and progress of the erosion, as above described, is first desirable; and this seems to indicate the advisability of adopting, for prevention, some simple device in regard to the window-sills, such as the choice of impervious material not easily water-soaked (perhaps blue-stone), cut in such form above as to prevent the easy lodgment of rain-water or snow, and throated with a groove underneath the projection to prevent the continuous trickling of water down the front. No such attention appears to be given to the character of the window-sills of most buildings by our architects, though the desired result has been obtained, where a properly throated string-course or cornice coincides with the sills of a line of windows (*e. g.*, in many churches, in a new building of Columbia college, on Forty-ninth street, and also in some churches recently erected), by dispensing with any projection beneath a window and replacing it by a long slope from a narrow, protected sill into the vertical plane of the front—*e. g.*, in the churches on northeast corner of Sixty-sixth street and Madison avenue, etc.

B. ARTIFICIAL MEANS OF PRESERVATION.

Many methods, mostly empirical, have been suggested for the artificial prevention of the decay of building stone, which may be here briefly considered, particularly those which have been resorted to in New York and the adjacent cities. The descriptions of the processes in detail are given in the text-books, (*a*) and it will be necessary to give in this report only the details of processes locally employed. The preparations recommended for this purpose are of two classes, organic and inorganic, according to the nature of the materials used.

1. ORGANIC PREPARATIONS.—All the preparations of this class, depending on the application of a coating of paint, etc., or on the injection of fatty matters, are in their very nature of a temporary character. They have been properly denounced as only costly palliatives, needing frequent repetition, and, therefore, exerting an influence toward the destruction of delicate carving. G. R. Burnell remarks on this subject: (*b*)

The objection to oil paints consists in the fact that, in proportion as the oils which serve as their vehicles evaporate the particles of the stone they originally protected become again exposed, and even the absorbent powers of the stone itself contribute to this action. It, therefore, becomes necessary to repeat the painting trequently, and thus, in the end, the delicacy of any moldings or carving must be effaced. The unequal rates of expansion of the stone and of the oil paints in time of frost tend to increase the danger of irregular and unequal exposure above attributed to the evaporation of the oil.

Professor Ansted, F. R. S., observed on the same occasion:

It was easy to see that if a stone could be coated in such a way that moisture could not get into it, and provided there was no moisture in the stone already, the thing was done. But the difficulty was to manage this, and it arose from the fact that no paint, no substance that contained organic matter, could, by any possibility, be long of any use. It might last for a time, but if it was capable of being acted upon by the atmosphere, and became oxidized, then after a time it failed; the surface peeled off and the moisture got in. The moment the moisture got into the stone the mischief began, and the work of destruction would go on as much as if the stone had never been covered at all. The difficulty was to find some material which would form a permanent coating upon the stone, preventing the entrance of atmospheric moisture, and doing so in such a manner that it was not liable to decay from the atmospheric influences to which the stone was exposed.

Coal-tar.—This has a special use in the protection of foundations of weak materials from moisture, the walls and masonry of tanks from acid vapors, etc. (*c*) New York city is fortunately provided with an abundance of excellent material for foundations in the underlying gneiss of the island.

Paint.—In New York I believe this has very rarely been employed for the protection of stone, and could have no lasting effect. By its use in repeated coats, however, the durability of the fronts of Caen stone of several buildings in the lower parts of the city (*e. g.*, the old building of the Nassau bank, the Tontine building, etc.), has been preserved for many years. At Washington a portion of the base of the stone front of the old Capitol, consisting of Potomac marble, was found to be crumbling from rapid decay, and the Secretary of the Interior reported in 1849 that "if left wholly unprotected from atmospheric influences for one-third of the time that marble structures are known to have stood, the noble structure would become a mound of sand". It was subsequently painted, as well as the marble of other public edifices, the President's house, etc. In London, paint has been employed to protect the Caen stone of Buckingham palace, erected in 1847, etc.; the Portland stone of many private and public buildings; the marble of monuments, *e. g.*, that in front of Saint Paul's, etc. A coat of paint is said to last hardly three years.

Oil.—This always discolors a light-colored stone, but only produces a darker shade on our brownstone. For this it has been applied to several buildings, *e. g.*, the first house on south side of Fifty-fourth street, west of Fifth avenue; a house in Sixtieth street, between Fourth and Madison avenues; Trinity church, Brooklyn, etc.

The following is the method employed in its application: The surface of the stone is first washed thoroughly clean, allowed to dry, then painted with one or several coats of boiled linseed oil, according to the taste of the owner, and finally with a weak solution of hartshorn in warm water to produce uniformity of tint. The oil has been found to sink about a quarter of an inch into the stone. Any new block afterward inserted into a front thus oiled, in undergoing repairs, will need to be oiled in the same way. A front treated by this process may be recognized by its darker color and by the fact that during a rain the water freely runs down the surface, which afterward dries more rapidly than an ordinary front. The experience of several builders and house-owners testifies that such a coating of oil will last four and even five years, very rarely longer, then becomes grayish, partially disappears and requires renewal, and so on repeatedly from period to period. Whenever such a front is taken down, it is found also that the greasy coating interferes with the free dressing of the block of stone.

Paraffine dissolved in coal-tar naphtha (1½ pounds to the gallon) and applied warm. This also discolors a light stone, and, although more lasting than oil, the protecting coats are gradually detached from the stone and

a *Notes on Build. Construction*, Part III, etc. *b* *Jour. Soc. Arts, London*, 1860, Vol. 8, p. 245. *c* *The Manufacturer and Builder*, 1870, I, p. 78.

require renewal as frequently as those of paint. An apparently better method, which has been employed in our western cities, consists in brushing over the surface of the stone- or brick-work with melted paraffine, and then deepening its penetration by heating the surface by means of a broad charcoal stove or of a flame. By this the outer pores are thoroughly filled, with little or no discoloration; but the absence of injury to sharp edges, through the direct application of heat, and the permanence of the protection, are yet to be established.

Soap and alum solutions (Sylvester's process), consisting of three-quarters of a pound of mottled or soft soap in a gallon of boiling water, and a half pound of alum in 4 gallons of water. In England "this has been repeatedly tried and answers well in exposed situations, but requires a fresh application about every three or four years".

Beeswax in coal-tar naphtha, or, better, to preserve the color of the stone, white wax in double-distilled camphine.

Rosin in turpentine, oil, wax, tallow, or other fatty substance, used as a boiling solution into which the stone is immersed and impregnated to the depth ordinarily of one inch after two hours. Also a solution of rosin in spirits of wine or naphtha, mixed with a solution of gutta-percha in naphtha. A common receipt consists of rosin, tallow, and oil, consisting of 1½ pounds common rosin, 1 pound Russian tallow, and 1 quart linseed oil; applied hot. By this the stone becomes water-proof, the damp cannot enter, and vegetable substances are prevented from growing upon it.

However, all such wax and oil varnishes are costly, liable to rapid oxidation, and sometimes impair in a high degree the color and the natural characteristics of the stone. In New York city only oil and paint have been used for the purpose, to my knowledge, and are objectionable, not only on account of their transient effect, but because a surface, once so prepared, is rendered ever after incapable of absorbing preparations of the next class (inorganic), from which alone can be expected permanent protection of the durability of a stone.

2. INORGANIC PREPARATIONS.—*Water-glass, potassium or sodium silicate* (Kuhlmann's process), applicable only to the preservation of soft limestones and marble, or stones in which calcium carbonate predominates. The surfaces are previously colored to avoid discoloration. The silicate of alkali used should not be the ordinary water-glass with an excess of alkali, but one with the greatest possible amount of silica.(*a*). This was applied to the new houses of parliament, London, England, but the stone was so bad, or the water-glass so alkaline, that the result was not as satisfactory as was expected; also to the Louvre and cathedral of Notre Dame in Paris, France, Versailles, Fontainebleau, the city hall in Lyons, the cathedral at Chartres, etc.

St. Charles church in Vienna, Austria, was fast going to destruction, but the decay has been arrested by means of this process. Potassium silicate was used, though more costly, because less likely to effloresce than the sodium salt; the two coats applied were perfectly transparent and left the color and the natural qualities of the stone unchanged. (*b*)

Water-glass and chloride of calcium or of barium (Ransome's indurating solutions). The following directions are given for this process: Render the surface of the stone clean and dry; dilute the potassium or sodium silicate in from 1 pint to 3 pints of soft water, just thin enough to be absorbed freely by the particular stone. Apply with a whitewash brush, say a dozen times, leaving no excess on the face, till it ceases to penetrate, and is about to remain glistening on the surface; allow it to dry perfectly, a clear day or so; then apply freely the solution of calcium chloride, brushing on lightly without froth. (*c*)

Szerelmey's stone liquid. Water-glass, combined with a temporary wash of some bituminous substance.

Petrifying liquid of Silicate Paint Company. *Barium solution*, followed by ferro-silicic acid, or barium solution, followed by calcium superphosphate; soluble *oxalate of aluminium*, applied to limestones. The last three processes produce no efflorescence upon the stone.

Wash of copper salts, as proposed and used by Dr. Robert, in Paris, to arrest the formation and growth of vegetation on the surface of stone. The results already reported imply a considerable aid in the preservation of building material, and may yet be found serviceable in New York to prevent the growth of *confervæ*, etc., which find a favorite habitat as a green film upon the shaded surfaces of Nova Scotia stone, and, as especially observed in Central park, seem to exert a corrosive action upon them.

In New York, various preservative preparations have been used within the last ten or fifteen years, styled "silica petrifying liquid", "duresco," etc., especially on the brick-work, but partly on the brownstone of many buildings (*e. g.*, the brownstone of the *Evening Post* building, four years ago; the brick factory in Twenty-eighth street, between Sixth and Seventh avenues; the brick-work in the rear of the Florence flats, Eighteenth street and Fourth avenue; the brownstone houses on southwest corner of Thirty-ninth street and Fifth avenue; the brick-work of the gables and top bed of all platforms in the balconies of the Union League club in Fifth avenue, etc.). In most cases these preparations, so far as tried, have resulted in complete failure, not arresting the exfoliation.

To my knowledge, no investigation worthy of the name has yet been undertaken in this city for the protection of its stone-work, though there is every promise that a proper and low-priced preservative might be discovered, possibly even in the refuse of some of our chemical factories. If not for the ashlar of the fronts, at least for the

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a For mode of preparation see *The Manufacturer and Builder*, 1871, III, 206: "How to prepare soluble glass."

b *Manufacturer and Builder*, 1869, I, 82

c *The Am. Arch. and Builder*, 1877, II, 21, 38.

hewn stones employed for window-sills, string-courses, cornices, and moldings, it would seem false economy to use any porous stone, without every condition of protection to be found, in the form of its cutting and in the application of a suitable artificial preservative.

It will doubtless be found that only those stones, which possess a porous texture and strong absorptive power for liquids, will be found particularly available for protection by artificial preservatives. In the spongy brown and light olive freestones, a marble full of minute crevices, and a cellular fossiliferous limestone, a petrifying liquid may permeate to some depth, close up the pores by its deposits, and incase the stone in solid armor; while upon a more compact rock, such as a granite or solid limestone, it can only deposit a shelly crust or enamel, which time may soon peel off.

In this connection, therefore, three suggestions may be offered: 1st, that householders invoke the magic use of the broom on the fronts of their residences as carefully as upon the sidewalks; 2d, that house-builders insist upon the undercutting of all projections, and the exclusion of brackets or other supports to sills and cornices, which only lead to the oozing of water and a line of corrosion down the ashlar; 3d, that house-repairers recut the projections in this way, whenever possible, and entirely avoid the use of paint, oil, or other organic preservatives.

If a rough estimate be desired, founded merely on these observations, of the comparative durability of the common varieties of building stone used in New York city and vicinity, there may be found some truth in the following approximate figures for the "life" of each stone, signifying by that term, without regard to discoloration or other objectionable qualities, merely the period after which the incipient decay of the variety becomes sufficiently offensive to the eye to demand repair or renewal:

	Life in years.
Coarse brownstone	5–15
Laminated fine brownstone	20–50
Compact fine brownstone	100–200
Blue-stone	Untried, probably centuries.
Nova Scotia stone	Untried, perhaps 50–200
Ohio sandstone (best siliceous variety)	Perhaps from one to many centuries.
Limestone, coarse fossiliferous	20–40
Limestone, fine oolitic (French)	30–40
Limestone, fine oolitic (American)	Untried here.
Marble (dolomite) coarse	40
Marble (dolomite) fine	60–80
Marble, fine	50–200
Granite	75–200
Gneiss	50 years to many centuries.

Within a very few years past it has become frequent to introduce rude varieties of rusticated work into the masonry of buildings in this city, or to leave the stone rough and undressed in huge blocks, especially in the basement or lowest stories, where it is under close and continuous inspection, and the results of its decay will be disguised by its original rough surface. Although there are certain large buildings in which such a massive treatment of stone may be appropriate, its common use, with stones of known feebleness or lack of durability, is a disingenuous evasion of responsibility and a mere confession of ignorance, want of enterprise, and despair, in regard to the proper selection of building material and in regard to its protection.

Finally, it may be pointed out that many of the best building stones of the country have never yet been brought into this city: *e. g.*, siliceous limestones of the highest promise of durability, allied to that employed in Salisbury cathedral; refractory sandstones, like some of those of Ohio and other western states, particularly fitted for introduction into business buildings in the "dry-goods district", storage houses, etc., where a fire-proof stone is needed; and highly siliceous varieties of Lower Silurian sandstones, such as occur near lake Champlain, quartzitic and hard to work, like the Craigleith stone of Edinburgh, but possessing the valuable qualities of that fine stone in resisting discoloration, notwithstanding its light color, and in remarkable resistance to disintegration.

As it is, we have many and need many varieties of stone for our various objects, but do not know how to use them. It is pitiable to see our new buildings erected in soft and often untried varieties of stone, covered with delicate carvings of foliage and flower-garlands, which are almost certain to be nipped off by the frost before the second generation of the owner shall enter the house. It is now time for one who loves stone to express his indignation at the careless and wasteful way in which a good material is being misused.

In conclusion, it is a point worthy of attention that there is at present a strong tendency among many owners of property, and therefore many builders and architects in New York, to entirely reject or greatly limit the use of stone in construction, both in the commercial district and in that which includes the better class of residences.

In the commercial district granite was for some time a favorite material, and constitutes many of our most important buildings. Later it was largely supplanted by the white marbles brought from numberless quarries in Westchester county, western Massachusetts, and Vermont; but of late another change of taste and judgment has occurred, and it has been observed:

> The architects of the present generation found commercial New York an imitation of marble, either in cast-iron or in an actual veneer of white limestone. They are likely to leave it brick.

This city, and, to a large extent, Brooklyn, have passed the period in which frame buildings were permitted, though they never were as abundant as in the newer cities and towns of the west, on account of the large supply of brick-clays along the Hudson river, and the easy importation of bricks from Europe and from points along our own coast. In the reports of the fire-underwriters, the stone is disregarded as a mere veneer, and all such buildings are properly classified as brick.

Less than 1 per cent. of our building material consists of stone, so that New York is now practically a city of brick. Examples of the preference now largely given to this material are found in many conspicuous structures which have recently risen in this city and Brooklyn: *e. g.*, the storage buildings at Forty-second street and Lexington avenue; the Produce Exchange building in lower Broadway; that of the Long Island Historical Society in Brooklyn, etc.

The definite character and use of many of the most important avenues and entire districts are yet unsettled; and there are abundant indications of cheap display, in fragile veneer and constructions of a temporary character, which are rendering this a period of shams. There are evidences, however, of the gradual recognition of the practical business advantages, in the way of credit and continuous patronage, which are derived from durable massive buildings, with solid and imposing façades, with which the business and names of firms may yet be associated for centuries. The general acceptation of this idea will form the last period—that of stability—in the history of our great metropolis, and then there will be a proper and intelligent use and increased demand for the several varieties of stone.

The present preference for brick is mainly due to the failure of granites and marbles to resist fire in the furious conflagrations in the tinder-boxes at Chicago and Boston—although brick walls as well become warped and useless in the re-erection of the buildings—and to a conclusion which appears to me hasty and uncalled for, from the unfavorable results of the experimental and unnatural trials, in fiery furnaces, of series of our building stones, by several investigators. Such a conclusion seems to be unwise and unfair, so long as our present habit of internal construction is aptly represented by the following description:

> Our buildings are, in truth, ingenious combinations of flues, greater or smaller, mostly of combustible substance, and commonly of thin material, set side by side across our floors and up our walls, opening out here and there into hollow spaces walled with wood, and out of our reach. Every fire that occurs gives us new warning that our way of building is unsafe. All our common methods have been developed in the effort to attain one class of qualities—lightness, quickness, and ease of construction, and economy, or rather cheapness. As usually happens to people whose aims are one-sided, we have got into trouble. Our buildings do not last; often they will not bear the use we put them to; they burn like straw. Other people have found out how to build better than we, but we like our own way, and we will learn nothing from them. We box our floors with thin plank set edgewise, our partitions with smaller pieces of the same stuff; we fur our walls with strips of the same. Then we case all in with thinner boards and friable plaster on still thinner lath. The building is a series of communicating flues partially protected outside, but wholly exposed within, through which fire and vermin may play at will, and through which we cannot trace them till they have done their mischief. All this is convenient and cheap, for it is quickly put up and takes little material. If we use iron, as we must, we make it hollow also for strength's sake. This would do no harm if the hollows were no larger than they need be, and were properly closed in; but we build great boxes to simulate masses of stone, and we expose them to the fires of blazing wood which we know will destroy them. At the persuasion of underwriters we put up cornices of galvanized iron, which will not themselves burn, but which are thin shells turned upon wood, and will at once convey the fire behind them. (*a*)

Add to all this our hatchways and elevator-shafts, by which a fire, starting in the basement, is conveyed at once to the attic, the beams of the wooden flooring often resting upon girders in the center of the building, as it were, a very house of cards—these girders, too, supported merely on slender stone piers in the basement, and on light iron pillars in the upper stories, and every floor filled with a mass of combustibles, especially in the "dry-goods district"; and we find an accumulation of materials in false and improper conditions, whose combustion will overcome the most refractory walls, and which should never be permitted to endanger human life and property in a so-called metropolitan city. On inquiry, I find among insurance men a unanimous conviction, decidedly and strongly expressed, that there is not in the city of New York a single absolutely fire-proof building—not one whose walls may not crumble before a storm of fire from without, or in which either flooring or partitions, or both, will not probably yield to the internal conflagration of their ordinary contents. A few edifices may approach the conditions required, but even in one of these a recent fire on the seventh floor, fed merely by office furniture, shriveled up the flimsy so-called "fire-proof" partitions and gutted the entire floor. The very material, perforated brick, which was used in these partitions, is still being hurried into new "fire-proof" buildings, now in process of construction in Fiftieth street and elsewhere. Nevertheless, it is generally admitted that much progress and great improvement have been made, during the last few years, both in the choice and arrangement of building materials for the protection of our buildings from fire; with an enlightened public opinion, much more may be expected. We have, fortunately, at our very doors, vast tracts of fire-proof materials—the belt of brick-clays along the Hudson river, and the still more extensive band of clays stretching across New Jersey, excellently adapted for all varieties of bricks, terra-cotta, and tiles, to say nothing of the resources of our commerce in the importation of similar materials from the whole Atlantic coast—which we ought to and must use for interior construction as a matter of the wisest economy, and, in association with which, our building stones, in all their variety and enormous supply, will find their proper place. When, at least in the business districts of the city, the interiors of the buildings are generally supplied with a minimum of wood, subdivided with tile, slate, or concrete flooring and doors, and sufficient partitions of brick or terra-cotta,

a *The Arch. and Build. News*, 1879, V, 49.

and roofed with tile, slate, or concrete upon fire-proof backing or supports, the nature of the stone used for the exterior will matter little, so far as concerns protection from fire, since it will not be exposed then, as now, to the unnatural and unnecessary furnace-test of furious flames from neighboring buildings.

The other objection to the use of stone, and one which has been specially prompted by the decay of the brownstone ashlar employed extensively in our buildings for private residence, is founded upon its lack of durability and speedy dilapidation or discoloration. The hasty statements of despairing architects, in denunciation of the brownstone, are sufficiently answered by reference to the texture of the still softer oolite, which mediæval architects were content to employ, and whose fragility seems to have been at last counteracted by modern devices. When proper investigations shall have been made, it is probable that the very porosity of the stone, which now renders it particularly sensitive to atmospheric attack, may best avail for the absorption of some cheap and durable mineral preservative, and that the present use of such stone in its raw, crude, and unseasoned state will be hereafter considered merely an evidence of the unintelligent and wasteful way in which we now work up our materials. Surely, since our city is placed in a region occupied on every side by inexhaustible supplies of sedimentary and crystalline rocks, remarkably well fitted for building construction, their surfaces scraped nearly bare by ice-action during the great glacial period, and thus most favorably exposed for economical exploitation, and the whole region is crossed by a radial network of routes of transportation by water and rail, at the least cost, centering in this city, the natural materials for building thus offered to us should not be hastily neglected or rejected, before their nature has been thoroughly understood.

APPENDIX.

APPENDIX

EXPORTATION OF STONE.

Slate is now being quite largely exported to Australia and New Zealand; some to England and Germany, and some to South America and the West Indies. The most extensive exportations are perhaps to Australia. School slates are quite largely sent to Germany. Marble is exported to the British North American provinces, to the West Indies, and to Cuba; and the reports of the Philadelphia custom-house show that in 1878 marble was exported to England; in 1879 to Belgium, England, and Ireland; in 1880 to Belgium, England, and Japan. Soap-stone has been exported to England. Quite a large amount of Carrara marble is brought to the port of Boston and from there distributed to the British North American provinces. The reason why this is done under the double duty instead of being shipped direct to the market where it is consumed, is because large amounts of marble are shipped constantly to this country while these other markets receive but a small amount at a time; also because ships will bring cargoes for less money to Boston than to Halifax on account of being more certain of procuring a return cargo. These conditions account, in part at least, for the stone of foreign production that is shipped from the different ports of the United States.

IMPORTATION OF STONE INTO THE UNITED STATES.

The custom-house reports show the importation of stone into the United States from nearly every country in the world. It is well known, of course, what stone comes from Scotland, England, Ireland, France, Germany, Belgium, the British North American provinces, and from Italy, and it is also known that onyx has been imported from Mexico, marble from Spain and Portugal, etc., and that marble has been imported from Sicily, granite from Norway and Sweden and Russia, and marble from Africa, but it is not so easy to account for the stone that is imported from British West Indies, Honduras, Central America, Cuba, Hayti, South America, Holland, and Turkey.

The only countries from which stone is constantly in the market in this country are Italy and Nova Scotia. The granite and sandstones from Scotland are imported for special orders. The same may be said of the granite imported from England and Ireland and the colored marbles from France and Germany—the brown sandstone of Germany, and the Caen stone of France.

The statistics of the Philadelphia custom-house show a large amount of dressed marble imported from England. Some stone is brought as ballast from Brazil, and marble and manufactures of marble from the Danish West Indies and the Netherlands, Brazil, Belgium, Cuba, British West Indies, Sweden and Norway, and some manufactures of slate from Germany. It is also stated that marble has been imported from Nova Scotia and from Canada. Some stone is entered on the custom-house books as "imported manufactured product", which consists of various carved figures picked up by tourists in different parts of the world. This fact may account for stone imported from any country; for instance, if a figure is carved in China and finds its way to Turkey, and is shipped from there to the United States, it will appear as the manufactured product of stone from Turkey. What the manufactures of stone are that have been shipped from South America and the West Indies could not be determined. Marble comes mostly in the unmanufactured state. The cost of labor is so much less in Italy than in this country that the Italian marble, after paying the cost of transportation and a duty of 50 cents per foot and 20 per cent. ad valorem, can be sold in New York about as cheap as the Rutland marble. The cost of transportation from Carrara, however, does not differ much from the cost of transportation of a like amount from Rutland, Vermont.

IMPORTS AND EXPORTS OF MARBLE AND STONE, BY COUNTRIES, FOR THE YEAR ENDING JUNE 30, 1881.

IMPORTS.

Countries from which imported.	Marble and stone, and manufactures of, not elsewhere specified.	Countries from which imported.	Marble and stone, and manufactures of, not elsewhere specified.
Total	$927,752	Quebec, Ontario, Manitoba, and the Northwest territory	$17,420
		British West Indies	89
Belgium	11,809	Hong-Kong	857
China	92	Italy	554,210
France	26,842	Japan	84
French West Indies	89	Mexico	1,603
French possessions in Africa and adjacent islands	28	Netherlands	4,487
Germany	42,305	Spain	55
England	70,802	Cuba	5
Scotland	77,178	Sweden and Norway	74
Ireland	98	Turkey in Asia	2
Gibraltar	40	United States of Colombia	25
Nova Scotia, New Brunswick, and Prince Edward island	119,558		

EXPORTS.

Countries to which exported.	MARBLE AND STONE. Rough or unmanufactured.	MARBLE AND STONE. Manufactures of.	Countries to which exported.	MARBLE AND STONE. Rough or unmanufactured.	MARBLE AND STONE. Manufactures of.
Total	$220,362	$409,433	Hong-Kong		$150
			British possessions in Africa and adjacent islands		12,003
Argentine Republic		4,131	British possessions in Australia	$9,100	77,530
Belgium	176	2,407	Hawaiian islands		4,363
Brazil	2,500	1,833	Hayti	331	3,846
Central American states		1,500	Italy		350
Chili		2,688	Japan		338
China		45	Liberia		679
Denmark		7,649	Mexico	25	10,948
Danish West Indies	42	126	Netherlands		8,225
France	35	6,145	Dutch West Indies		439
French West Indies	84	7	Dutch Guiana		715
Miquelon, Langley, and St. Pierre islands		129	Dutch East Indies		130
French possessions, all other		136	Portugal		234
Germany	3,220	23,207	Azores, Madeira, and Cape Verde islands		198
England	4,581	113,320	Russia, Asiatic		148
Scotland	280	5,563	San Domingo		359
Ireland		7,849	Spain		38
Nova Scotia, New Brunswick, and Prince Edward island	5,517	5,963	Cuba	15	14,339
			Porto Rico		2,969
Quebec, Ontario, Manitoba, and the Northwest territory	194,061	59,942	Spanish possessions, all other		163
			Sweden and Norway		718
British Columbia		1,667	United States of Colombia	32	5,418
Newfoundland and Labrador	363	253	Urugnay		910
British West Indies		13,390	Venezuela		3,946
British Guiana		1,577	All other countries and ports in South America not elsewhere specified		262
British Hondnras		488			

EGYPTIAN BRECCIA.

The very celebrated universal breccia of Eygpt is composed of rounded pebbles of most diverse forms, color, and material. It occurs about 12 leagues to the east of Kéné, in the Arabian chain of mountains, not far from the valley of Kossier, and on the railroad going from the Nile to the Red sea. The Egyptians have extracted from it some immense blocks—such as the antique sarcophagus of Alexander, which was 15 millimeters in circumference, and which was covered with hieroglyphics and delicate sculptures. The Romans carried away from Egypt a great number of such monuments at the time of the Pharaohs, and they themselves quarried this breccia. One can regard the universal breccia of Egypt as one of the hardest stones, one of the richest in color, and one of the most beautiful. Almost all the museums in the world contain statuary or ornamental constructions of some kind cut from this rock. The variety which appears to have been most admired by the ancients had a green color. The essential components of this variety were fragments of argillitic schist and porphyry, with here and there a pebble of granite, which, being much harder than the others, rendered the rock very difficult to work. This rock is not at all uncommon or confined to Egypt; a Grecian rock has been brought into the market which very closely resembles it. From Hainaut, in Belgium, a rock has been obtained which is nearly the same as that found in the Devonian formation in the southern Vosges; and at still other places this rock has been obtained.

We can increase the list by calling attention to some of the American varieties (Boston conglomerate). (Delesse, p. 24.)

CHLORITE ROCK.

Rocks composed of chlorite are found in various parts of the world, and are used for ornamental constructions, especially for making smaller objects which can be turned with a lathe. These are the stones which are called by the French *pierres ollaires*. No rocks of this nature have thus far been brought to our attention in the United States. A chlorite from Potton, in Lower Canada, has been used. It is found in beds of Lower Silurian age lying immediately upon the Laurentian rocks; it is associated with dolomite or serpentine, and, like the latter rock, it contains some chromate of iron. (Delesse, p. 27.)

ALGERIAN ALABASTER.

In his geological explorations of the province of Oran, M. Ville found at Aïn Tembalek, near the Ysser, five deposits of a very curious alabaster. M. Delmonte, who was a marble-worker at Carrara at one time, who had admired this marble in ancient monuments, the origin of which was unknown to him, explored it and introduced it into market, and it is now called the Algerian alabaster. It is a fibrous calcite, veined and translucent, and has especial properties. It has a horizontal stratification, while the ordinary alabaster is concentrically banded—a circumstance arising from its concretionary formation in cavities, or often stalactites. Heated, it becomes brown, owing to its contents of iron carbonate; some specimens are red, some golden, yellowish, or brown, some pure white, and some a mixture of all these colors; specific gravity, 2.728. It is so compact that it is more difficult to cut than ordinary marble. It stands the weather very well, as a column found in an ancient quarry demonstrates. It forms extensive beds, which are regularly and horizontally formed, having a post-Tertiary origin, since it rests on Tertiary deposits, and lies between layers of a sweet-water formation, or travertine, which is abundant in little basins in the province of Oran; and the Algerian alabaster is simply a modification of this travertine.

The Romans, who brought the materials for decoration from all parts of the world, have explored the Algerian alabaster upon a grand scale. The Turks also explored the same quarries, and adorned their mosques with materials from them. It has been used in mosaics, and even for statuary.

ITALIAN MARBLE (CARRARA).

According to Consul Robert W. Welsh, (*a*) from 125,000 to 150,000 tons of marble are sent out from Carrara to various parts of the world every year, but it is all sold for cash. The sale of the marble, the delivery of it at the railway station or at Leghorn or Genoa, and the receipt of the cash equivalent, make up the entire commercial business of the place.

Carrara marble is a luxury, and the demand for it depends upon the condition of "the times" in the various countries to which it is exported. The condition of the world has been such that the only country with which dealers in Carrara marble had a good trade in 1879 was the United States.

STATEMENT OF THE EXPORTATION OF MARBLE FROM THE CONSULAR DISTRICT OF CARRARA IN THE YEAR 1879.

	Tons.
Block marble	76,370
Sawed marble	20,526
Worked marble	37,538
Total	134,434

STATEMENT OF THE EXPORTATION OF ALL KINDS FROM 1872 TO 1879, INCLUSIVE (CARRARA).

	Tons.
1872	116,061
1873	117,115
1874	117,282
1875	121,774
1876	103,511
1877	118,938
1878	105,019
1879	134,434
Total	934,134

The above statements are taken from the *Corriere Carrarese*.

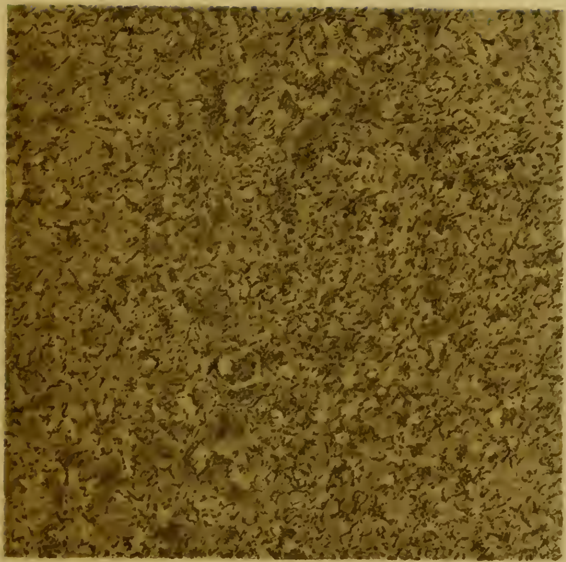
a Report to State Department, October 31, 1880.

BIOTITE GRANITE

RED BEACH, MAINE

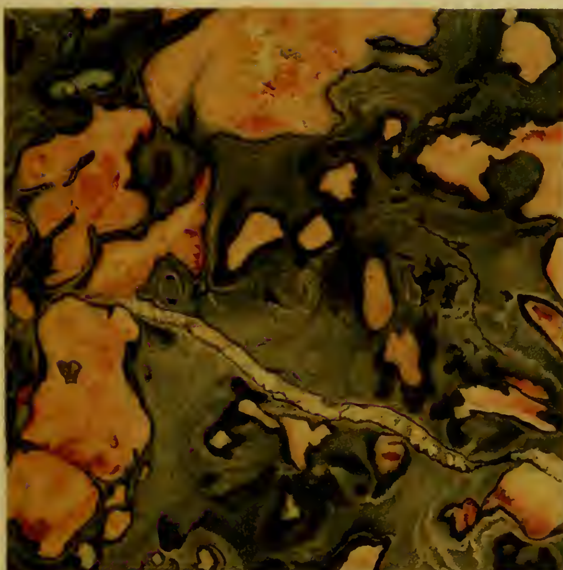
BIOTITE GRANITE WITH EPIDOTE

LEBANON, GRAFTON CO., N. H.



MARBLE

MALLETT'S BAY, VT.



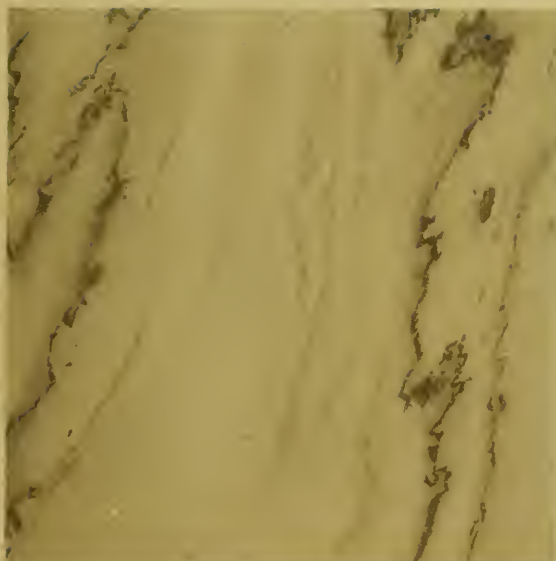
MARBLE

MALLETT'S BAY, VT.

Julius Bien & Co. Lith.

"LEPANTO" MARBLE

ISLE LA MOTTE, GRAND ISLE CO., VT.

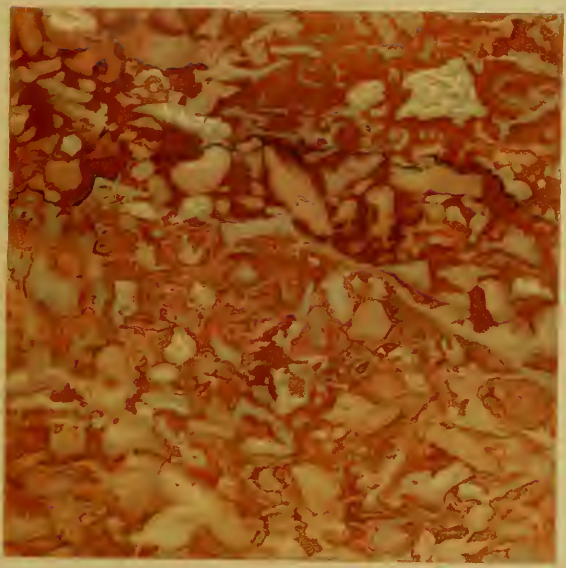


MARBLE

SUTHERLAND FALLS, VT.

MARBLE.

SWANTON VT



MARBLE

MALLETT'S BAY VT

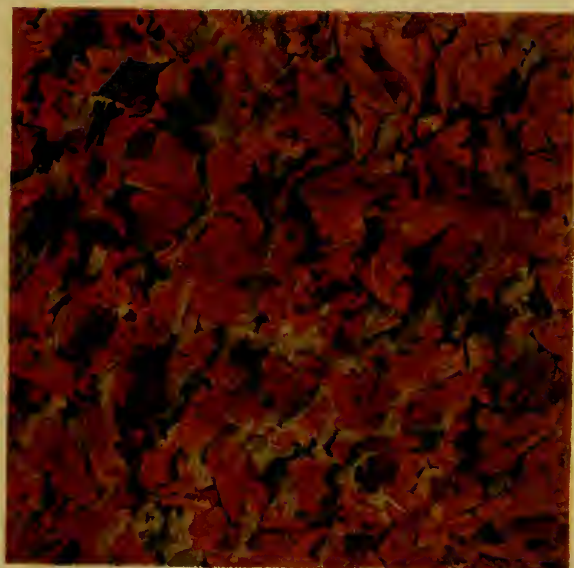
HORNBLENDE GRANITE

PEABODY MASS

Bureau Bros & Co Lith

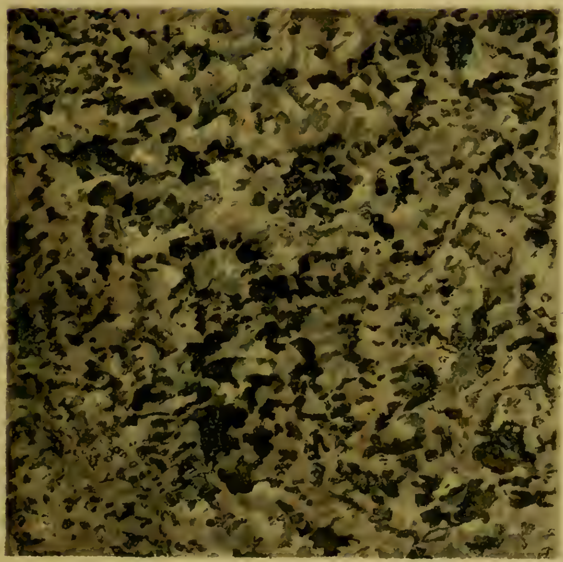
BIOTITE GRANITE

WESTERLY, R.I.



HORNBLENDE GRANITE.

GRINDSTONE ISLAND, JEFFERSON CO., N.Y.



MARBLE

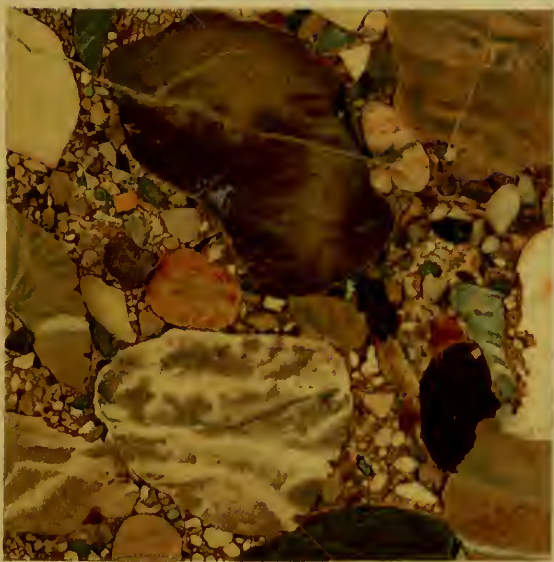
PORT HENRY, ESSEX CO., N.Y.

SANDSTONE

HUMMELSTOWN, DAUPHIN CO., PA.

TRIASSIC SANDSTONE

SENECA CREEK, MD.

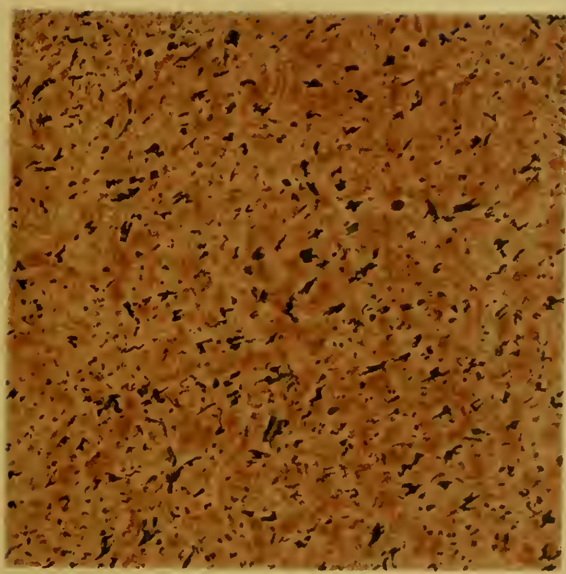


LIMESTONE BRECCIA.

POINT OF ROCKS MD

SERPENTINE

HARDFORD CO, MD



BIOTITE GRANITE

BENNETT CO. TEXAS.

MARBLE

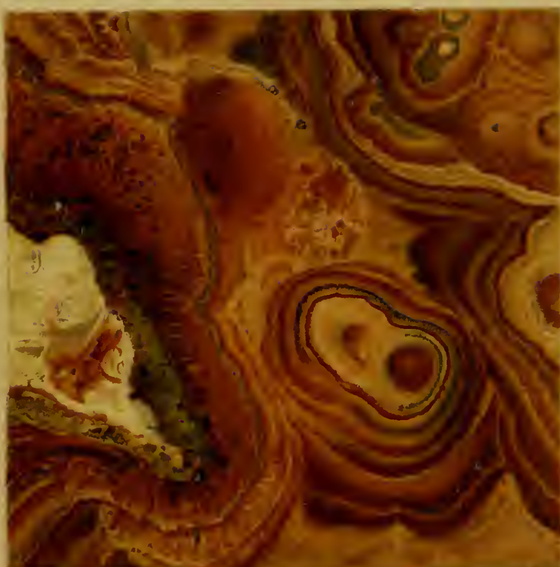
ROGERSVILLE, HAWKINS CO., TENN.

BIOTITE GRANITE

IRON TOWNSHIP, IRON CO. MO.

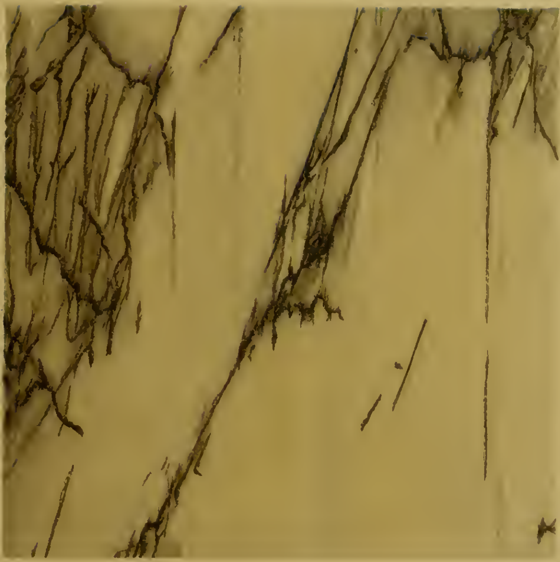
MARBLE

PAYSON, UTAH



STALAGMITE MARBLE

SOLANO CO. CAL.



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N.

Y.

Z.