University of the State of New York

BULLETIN

OF THE

New York State Museum

VOL. 4 No. 19

NOVEMBER 1898

A GUIDE TO THE STUDY OF THE

GEOLOGICAL COLLECTIONS

OF THE

NEW YORK STATE MUSEUM

BY

FREDERICK J. H. MERRILL, Ph. D., *Director*

ALBANY

UNIVERSITY OF THE STATE OF NEW YORK

1898

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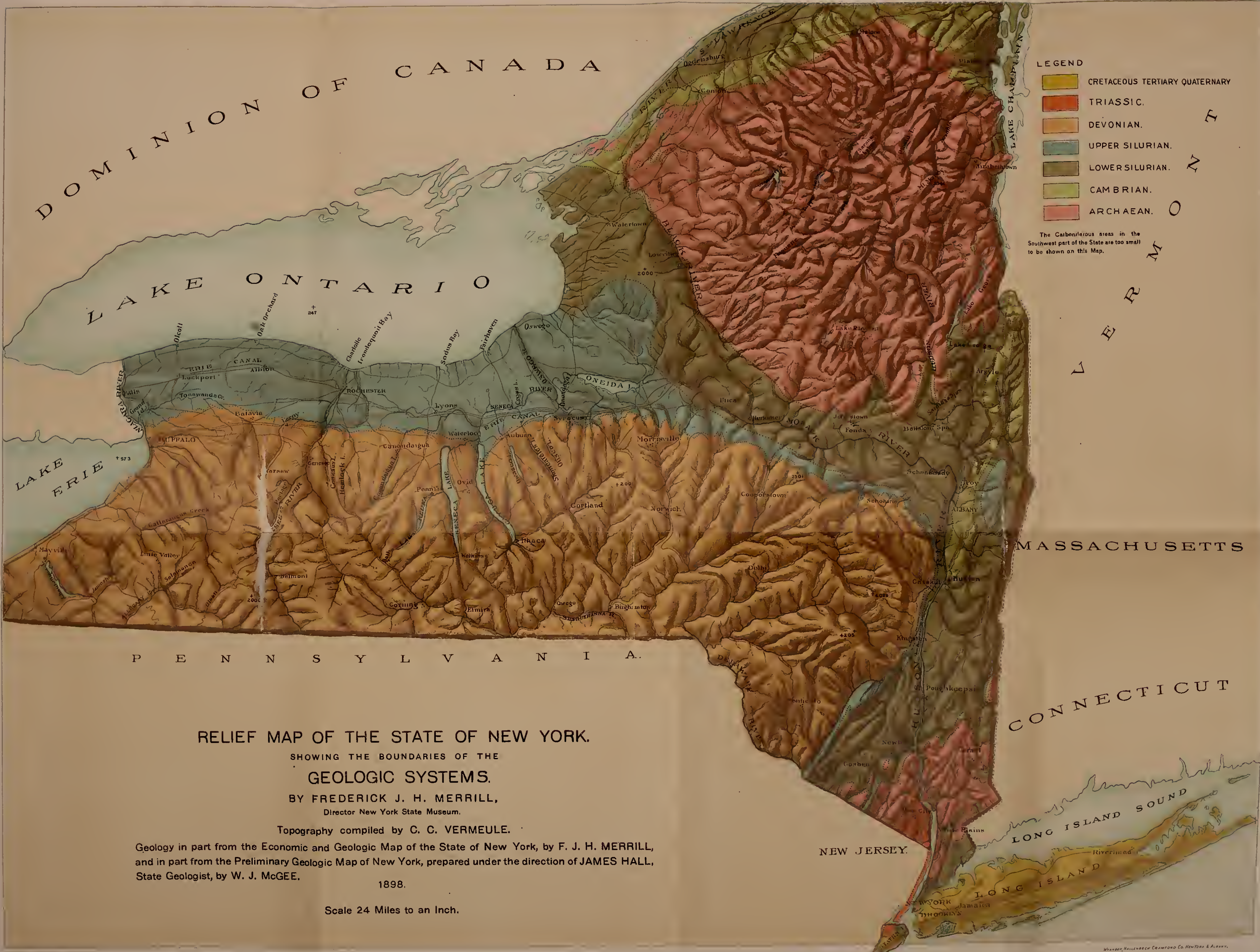
DOMINION OF CANADA
LAKE ONTARIO
LAKE ERIE
VERMONT
MASSACHUSETTS
CONNECTICUT
PENNSYLVANIA.
NEW JERSEY.
LONG ISLAND SOUND
LONG ISLAND
LAKE CHAMPLAIN
LEGEND
CRETACEOUS TERTIARY QUATERNARY
TRIASSIC.
DEVONIAN.
UPPER SILURIAN.
LOWER SILURIAN.
CAMBRIAN.
ARCHAEAN.
The Carboniferous areas in the Southwest part of the State are too small to be shown on this Map.
ERIE CANAL
ONEIDA L.
MOHAWK RIVER
HUDSON R.
BLACK RIVER
ST. LAWRENCE RIVER
Oswego
Rochester
Lockport
Albion
Batavia
Buffalo
Lyons
Syracuse
Auburn
Canandaigua
Ithaca
Cortland
Norwich
Cooperstown
Elmira
Corning
Owego
Binghamton
Utica
Watertown
Lowville
Ogdensburg
Canton
Schenectady
Troy
Albany
Hudson
Catskill
Kingston
Poughkeepsie
Goshen
Belmont
Mayville
Brooklyn
Jamaica
Riverhead
RELIEF MAP OF THE STATE OF NEW YORK.
SHOWING THE BOUNDARIES OF THE
GEOLOGIC SYSTEMS.
BY FREDERICK J. H. MERRILL,
Director New York State Museum.
Topography compiled by C. C. VERMEULE.
Geology in part from the Economic and Geologic Map of the State of New York, by F. J. H. MERRILL, and in part from the Preliminary Geologic Map of New York, prepared under the direction of JAMES HALL, State Geologist, by W. J. McGEE.
1898.
Scale 24 Miles to an Inch.

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Errata

Page 133, line 14,	"Equisetæ"	should read	"Equiseta."
" 136, " 1,	"periods"	" "	"eras."
" 136, " 2,			
" 136, " 18,			
" 136, " 13,	"Keeweenawan"	" "	"Keweenawán."
" 137, " 12,	"Synopsis"	" "	"Synopsis of Palaeozoic strata."
" 138, " 40,	"latter"	" "	"former."
" 141, " 17,	"Keeweenaw"	" "	"Keweenaw."
" 142, " 3,	"equisetæ"	" "	"equiseta."
" 140, " 9,	"masses"	" "	"mass."
" 142, " 32,	"Dikelocephalus"	" "	"Dikellocephalus."
" 146, " 10,	"Ostracoids"	" "	"Ostracods."
" 151, " 15,	"Lower Silurian"	" "	"Upper Silurian."
" 151, " 24,	"Blue Ridge"	" "	"Blue Mountain."
" 158, " 10,	"equisetæ"	" "	"equiseta."
" 163, " 20,	"Hamilton group"	" "	"Hamilton stage."
" 163, " 25,	" "	" "	"Hamilton shale."
" 170, " 17,	"equisetæ"	" "	"equiseta."
" 200, " 11,	"may"	" "	"many."
" 229, " 11,	"Commerciall"	" "	"Commercially."
" 238, " 12,	"Quarternary"	" "	"Quaternary."

PREFACE

It has been the experience of the Director of the State Museum that a majority of the visitors to the Geological Hall have not had the advantage of an elementary training in geology and therefore do not obtain from the collections such information as they might receive if they fully understood their purpose and value. This statement applies both to the majority of the adult visitors and to the pupils of the various schools who, with their teachers, visit the geologic collections every year. With this fact in view, it seemed important to prepare a Guide to the Study of the Geologic Collections which could be sold at a nominal price and therefore placed within the reach of all who might need it.

As the function of a geologic museum is to aid in the study of geology, the purpose of this guide is to supplement the collections with such general information as cannot be given by cabinet specimens and to direct the visitor to reliable sources for more detailed information.

In 1861, Mr. Ledyard Lincklaen prepared, by direction of the Regents of the University, a *Guidc to the Geology of New York and to the State Geological Cabinet*, which was published in the Fourteenth Annual Report of the State Cabinet of Natural History. This report being now out of print and Lincklaen's 'Guide' having been of much use in its day, though now obsolete in many respects, it seemed desirable to replace the latter so far as possible by the preparation of a new guide to the study of the collections.

In this undertaking the attempt has been made not so much to write a new book as to put into convenient form all information necessary to the purpose in view.

In the following pages the general arrangement is similar to that adopted in most of the geologic text books. The introductory matter is newly written and also the larger portion of the chapters on the Archaean and Cambrian rocks. The Cambrian below the Potsdam was not known as such in Lincklaen's time and was not discussed by him. The description given herewith is taken chiefly from the work of C. D. Walcott, Bulletin of the U. S. Geological Survey No. 81. The Palaeozoic strata of New York from the Potsdam to the Catskill were well known to the members of the original geological corps, Hall, Mather, Emmons and Vanuxem and Lincklaen's interpretations of their published results were so satisfactory that in the present work his descriptions of these formations have been used, so far as practicable, with such corrections and additions as were necessary to express our present knowledge.

In making these corrections, the statements of the original corps of geologists and of the later geologists who have worked in New York have been freely quoted.

The descriptions of the Mesozoic and Cenozoic ages have been newly written.

Lincklaen's descriptions of the fossils of New York are not wholly accurate in the light of modern knowledge and in order to save time in revision and the considerable space needed for a proper presentation of the subject, they have been omitted. References are, however, given to the proper authorities and it is hoped that the State Palaeontologist may prepare a handbook on this important subject.

The chapter on economic geology is abridged from Bulletin 15 of the New York State Museum, with some additions.

The illustrations are, to a large extent, new and it is believed that the representation of typical sections and exposures by photographs is more satisfactory than by the more common diagrams.

It is to be regretted that it was not possible to make a series of photographs complete in each geologic series, but no opportunity was afforded for this. The photographs of Dr. Heinrich Ries and Prof. I. P. Bishop were chiefly made for the New York State Museum. The photographs by N. H. Darton are from the collection of the Geological Society of America, and printed through the courtesy of the United States Geological Survey; many of these have already appeared in the report of the State Geologist. The remainder have been secured from various sources.

For many of the general statements concerning the ages and systems acknowledgment is made to the writer's late friend and teacher Dr. John S. Newberry.

To Prof. James Hall, State Geologist, the writer is indebted for numerous facts and conclusions concerning many of the Palaeozoic strata of New York.

As it seemed desirable to provide a pamphlet which could be distributed at cost price to all visitors to the museum who were interested in the study of the collections, the bulletin has been made as small as possible, but it has much outgrown the dimensions originally contemplated.

Since the geologic collections of the New York State Museum are not yet in a state of final arrangement, no detailed reference is made in this bulletin to the museum cases, but the system of labelling adopted is such as to make it an easy matter to refer from the guide to the museum specimens.

It is hoped that this bulletin may, in its function as a guide and supplement to the geologic collections of the State Museum, prove a useful aid to beginners in geology. It aims, through its text, to place within the reach of those interested, a brief synopsis of the geology of the state, and by its illustrations made from photographs, to show the exact appearance of many typical exposures. It is hoped that its readers will receive from it a general idea of the New York formations and will be led to supplement by detailed study of local geology the valuable general text-books accessible to all.

It is assumed that the student before taking up geology has had a good general training in physics and chemistry, without which no proper understanding of the subject can be had. An elementary knowledge of zoology and botany is also indispensable.

FREDERICK J. H. MERRILL

Albany, N. Y.

January 1, 1898

PART 1.

THE SCIENCE OF GEOLOGY AND ITS HISTORY

Geology includes all knowledge of the origin, history, composition and structure of the earth.

Before commencing to discuss geology in its present state of progress, it is desirable to consider briefly its history as a science.

The origin of the world was a matter of interest to the earliest Oriental philosophers no less than to the sages of Greece, and the speculations of these early leaders in thought seem to indicate the possession of some accurate knowledge, but we must date the beginning of geologic science from the period when geologic phenomena were first observed and correctly interpreted. For a record of these earliest geologic studies we are mainly indebted to the industry of Sir Charles Lyell.[a]

Geology began, about 1000 B. C. with the Egyptian priests who observed that the limestones bordering the valley of the Nile had been cut through by erosion and that marine fossils were exposed. In the sixth century B. C. numerous observations on terrestrial changes are ascribed to Pythagoras, and Xenophanes is said to have observed and mentioned the occurrence of various fossils. Aristotle and others in their writings speak of fossil fishes. Attention was also called by Aristotle to the changing distribution of sea and land in certain localities. From that time to the Christian era, history affords many records of observations on geologic phenomena but no attempt was made to reason from the present to the past or to do more than recognize terrestrial changes contemporaneous with man.

Some Arabian writers of the 10th century A. D. are credited by Lyell with accurate observations on the origin of mountains and certain changes of sea level, but not till the 16th century

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a *Principles of Geology*

did Christian nations give any attention to geologic phenomena, and one of the first men to appreciate and assert the true origin of fossils was Leonardo da Vinci, the famous painter. In his time, public sentiment, influenced by monastic teachings, was so biased that persons who held the opinion that fossils were the remains of living forms, were subjected to persecution. The orthodox view then was, that fossils were freaks of nature produced by the influence of the stars and other mysterious agencies. As various religious interests were supposed to be jeopardized by the more scientific deductions, much animosity was aroused by them.

After 100 years wasted in fruitless discussions on the source of fossil forms, in the beginning of the 18th century the theory occurred to some that the shells which were found in the rocks were relics of the Noachian Deluge and consequently the idea of their organic origin was adopted by many as a confirmation of Biblical history. This new hypothesis lasted for nearly 150 years and those who dared to assert their disbelief in it were exposed to persecution as unbelievers in the Holy Scripture.

During the last half century an invincible array of facts has been developed by diligent scientific workers of many nations in geology, biology, physics, chemistry and astronomy. These facts have been classified into the science of to-day.

ORIGIN OF THE EARTH AND ITS CRUST

The history of the origin of the earth is not found in the study of the earth itself.

Geologic history, properly speaking, begins with the period of the earliest geologic record. But no portion of the first solid crust of our globe is known to be exposed to view nor does it seem likely that any portion of it will ever be revealed. From the kindred sciences of physics, chemistry and astronomy, in many ways, we obtain light upon the origin of the earth prior to the commencement of the geologic record.

The earth is to man, one of the two most important members of a group of celestial bodies held in relation to each other by gravitation, which we call the solar system. The center of this system is the sun, about which revolve the planets with their satellites and the planetoids, and without which as a source of light and heat, no life could exist on earth.

To explain the origin of the solar system the *Nebular hypothesis*[a] was suggested by Swedenborg and Kant and elaborated by Laplace. Although not completely proven it is highly plausible, and answers most of the conditions. According to this hypothesis our solar system originated as a vast nebula, similar to nebulae which now exist, in the form of an immense volume of incandescent gas rotating in space from west to east, of which the limits extended beyond those of the present solar system which is about 5,500 millions of miles in diameter.

As this mass slowly parted with its heat and contracted in obedience to physical laws, its velocity of rotation would increase and in the peripheral or outer portion the centrifugal force would overcome the attraction toward the center, causing it to separate from the central portion in the form of a ring. This ring through unequal condensation would subsequently be broken, its fragments uniting by gravitation into a body revolving about the nucleus and ultimately forming a planet or in one instance a zone of small planets, that of the planetoids or asteroids. This process is supposed to have continued until the various members of the system were set free; the remnant of the much diminished but still intensely heated nucleus remaining as our sun which now has a diameter of 860,000 miles. The primary rings after condensing into planets are believed to have formed secondary rings which subsequently broke and became satellites, except in the case of Saturn which still retains two rings.

Inasmuch as some of the planets near the sun are denser than those more distant, it has been suggested that in the rotation of the primal nebula its components arranged themselves in lay-

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[a]See Young, *General Astronomy*, p. 515-25.

ers of different densities, the rarer substances to some extent occupying the outer portion of the mass.

If, as this hypothesis suggests, our earth is an integral part of the solar system we should expect to find its component elements in the sun and in the other heavenly bodies, and this expectation is confirmed by two distinct sources of information. Chemical analysis of the meteorites which fall to earth shows that these bodies contain many minerals which occur in the earth's crust[a] and that they do not contain any elements which are unknown on earth. Of late the application of the spectroscope to the study of the sun and stars has established the fact that these celestial bodies are largely composed of the elements already known on earth. There are however some lines in the solar and stellar spectra which are not matched by the lines in any terrestrial spectrum.

The conclusion to which we are led by the nebular hypothesis, viz.: that the earth originated as a rotating mass of incandescent gas, is corroborated by its present form, which is that of a spheroid of rotation or of a plastic body which, by rotation, has become flattened at the poles. The difference between the polar and equatorial diameters of the earth is about 27 miles.

Chemical science has established the fact that all forms of matter are composed of one or more of the elementary substances or elements, of which there are 74. These are all found either in the earth's crust, or in its atmosphere; they also occur in the sun, stars and other heavenly bodies. Most of these elements are very rare and do not come to the notice of the geologist. Only 11 are important as constituents of the earth's crust. These more common elements are given in the following table[b] with their proportionate percentages as components of the earth's crust:

Oxygen	50
Silicon	25
Aluminum	10
Calcium	4.5
Magnesium	3.5
Sodium	2

[a] The *crust* is the superficial portion of the earth.

[b] Prestwich *Geology*, p. 10.

Potassium	1.6
Carbon	2.4
Iron	
Sulphur	
Chlorine	
Other elements	1
	100

Chemical History of the Earth

In whatever manner our earth came into being, every known fact indicates that in the beginning it must have been intensely heated and in a gaseous condition. In obedience to the laws of matter such a mass would constantly lose heat, and with this loss of heat would come a gain in density, first at the surface only, but gradually progressing toward the center till at that point its constituent matter had reached at least a fluid condition. This may be the present condition of the earth's interior. As an eminent chemist has observed, here commences the chemistry of the earth, and the probable course of events can best be stated by quoting from the words of the late T. Sterry Hunt. As long as the earth's component matter remained in a gaseous condition and its temperature was sufficiently high to prevent the elements from combining, these elements remained separate, but as the temperature was reduced, chemical combinations of these elements became possible, and those would be first formed which were stable at the higher temperature. The oxides of silicon, aluminum, calcium, magnesium and iron were probably among the first substances formed. At some early stage of the earth's existence the bases alumina, lime, magnesia and oxide of iron were probably all combined with silica and that which represented the earth's crust was a fluid mass similar to a lava. The carbon, chlorine, sulphur and water vapor only existed in the primeval atmosphere, which must then have been too acid to permit the existence of any form of life, as it would probably have destroyed animal or vegetable

[a] Chemical and Geological Essays, pp. 37 et seq.

tissue. As the primeval temperature fell, the acid atmosphere would react on the lava-like crust and where the temperature fell below the boiling point of the acids which composed the atmosphere, the water of the globe would be highly charged with salts resulting from the chemical action. With the continued fall of temperature the chlorine and sulphur would be gradually removed from the atmosphere until the composition of the latter became similar to that of the present day, though containing more carbonic acid gas.

This chapter in the earth's history has been so well translated by the aid of chemical science that there is no reason to question its accuracy, but we do not know in detail the history of the massive rocks and gneisses which are now the oldest formations known. It also is probable that a long period of time elapsed between the formation of the primeval ocean and the dawn of life therein. Science has not yet taught us how to measure the length of this period or how to recognize the details of earth-building which occurred in it.

Present Condition of the Earth's Interior

It has been found by observations taken in deep mines and wells that in going toward the center of the earth, the temperature increases approximately at the ratio of 1 degree Fahrenheit to 51 feet of depth.* At this rate, a temperature would prevail at the depth of 50 miles at which all known substances would be fused. On this basis rests the theory of a molten interior, which is corroborated by various volcanic phenomena. All through the historic period and through long geologic ages before, volcanoes have poured out from subterranean sources vast quantities of molten rock. Physicists who have investigated this matter claim that if the interior of the earth were fluid, the crust would yield to the attraction of the moon and that the phenomena of tides would occur within the earth itself. It also appears that the great pressure on the internal mass must keep it in a condition of solidity. In this connection it is pointed out that volcanic phenomena occur along

* The extreme ratios are 1 ÷ 40 and 1 ÷ 80.

lines of mountain making and that probably the outflows of molten rock are due to local relief of pressure by some upward movement within the mountain masses.

Envelopes of the Earth

The earth, besides possessing a solid crust and an intensely heated interior, has two fluid envelopes.

The gaseous envelope or atmosphere, which consists of the air we breathe, surrounds the entire globe.

The liquid envelope, of which the various portions are known as oceans, seas, gulfs, bays, lakes, etc., envelops the globe only in part, the exposed portions of dry land being known as islands and continents.

These two envelopes, under the influence of physical forces, are very active agents of destruction, transportation and deposition in their action on the earth's crust.

The present relations of the envelopes to the continents, the forms of the latter, the causes of climate, the origin of the winds and ocean currents are usually discussed under the head of physical geography. As this subject is not at present illustrated in the State Museum, the student is referred to the many excellent text-books on this science.

COMPONENTS OF THE EARTH'S CRUST, MINERALS AND ROCKS

The earth's crust consists of aggregates of matter which occur in stratified and unstratified masses and are known as rocks. The chemical combinations which form these rocks either singly or in mixture are called minerals. The minerals, therefore, all possess a definite chemical composition which can be expressed by formulæ. Rocks vary in composition, as they consist of one or more minerals. The rocks which are mixtures of several minerals vary in composition as the proportions of their components vary; and it is possible for specimens taken from the same rock mass to differ in chemical composition.

Minerals

Minerals are classified by their chemical composition and by the geometric forms which they assume in crystallization, each mineral having a certain range of forms from which it cannot depart.[a]

These forms are grouped in six systems named as follows: Isometric, Tetragonal, Hexagonal, Orthorhombic, Monoclinic and Triclinic. These systems are characterized by and named in accordance with the number and relation of the axes about which the external geometric faces are developed. In physical relation with these axes are distinct optical properties which can be determined by cutting the minerals in very thin slices and examining these by means of optical instruments. While there are over 700 recognized mineral species, only a small number are important to the geologist as rock making minerals. Of these a few are sometimes found to be the single components of entire rock masses.

Quartz, the crystalline form of silica, is frequently found in large masses in mineral veins and, in its fragmental form, constitutes beds of gravel and sand when loose and, when solidified by cementation, forms conglomerates, sandstones and quartzites.

Calcite and **aragonite** are two crystalline forms of carbonate of lime, the former of which is the chief constituent of many great beds of limestone; the latter is usually deposited by water in forms called stalactites, calcareous tufa, travertine, etc.

Dolomite, the double carbonate of lime and magnesia wholly or in part forms extensive strata of magnesian limestone.

Kaolinite, the hydrous silicate of alumina, is also a very prominent mineral in rock masses. In its pure condition it forms beds of potter's clay, and mingled with various kinds of rock-dust it constitutes extensive strata of clay and shale.

Of the minerals which mingle in the formation of rocks, the most important are quartz, the feldspars and the magnesia-iron silicates.

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[a] For an elementary discussion of crystallography as well as of mineralogy the reader is referred to Dana's *Manual of Lithology and Mineralogy.*

The **feldspars** are silicates of alumina combined with potash, soda or lime. The more common species are: *orthoclase* and *microcline,* silicates of alumina and potash.

Albite, silicate of alumina and soda.

Anorthite, silicate of alumina and lime.

Oligoclase, andesite and *labradorite,* which contain both lime and soda, and are intermediate between albite and anorthite.

In crystallization orthoclase is monoclinic, the others named are triclinic.

The triclinic feldspars are usually called *plagioclase* in technical rock nomenclature, and are referred to collectively by this term.

The **magnesia-iron silicates** are classified in three principal groups, the amphiboles, pyroxenes and micas.

The *amphiboles* are monoclinic and comprise hornblende, actinolite and tremolite.

Hornblende is a silicate of alumina, iron, lime and magnesia; it is very tough and somewhat fibrous in fracture, its color varies from dark green to blackish green. This is a very important constituent of granites and other crystalline rocks.

Actinolite is a fibrous variety, generally light green in color and containing less alumina.

Tremolite is usually white and contains but little iron and no alumina. It occurs generally in crystals scattered through crystalline limestone.

Asbestus is a finely fibrous tremolite.

The *pyroxenes* have very nearly the same chemical composition as the amphiboles and are also monoclinic but crystallize with a different prismatic angle.

Augite, which corresponds closely to hornblende in composition and resembles it in many ways, is an important constituent of many eruptive rocks such as diabase, basalt, etc.

Pyroxene is lighter in color than augite and similar to actinolite in composition.

Diopside corresponds closely to tremolite in composition and like it, occurs in limestones.

Besides the above species which are monoclinic, there is an important group of orthorhombic pyroxenes.

These are hypersthene, bronzite and enstatite.

Of the *micas* there are many species. The most important rock-making mica is *biotite,* a silicate of alumina, potash, iron and magnesia. It is brownish black in color and is abundant in the granites and gneisses.

Muscovite, a silicate of alumina and potash, is less important as a rock mineral but is valuable commercially for its thin transparent plates used in stove doors, etc.

The hydro-micas, *margarodite* and *damourite,* are similar to the true micas in composition but contain water.

Olivine, or *chrysolite,* is a silicate of iron and magnesia which occurs usually in small crystals or grains in igneous rocks. It is pale green in color.

Olivine is of special importance because from it, by decomposition, is derived a large proportion of the serpentine rocks.

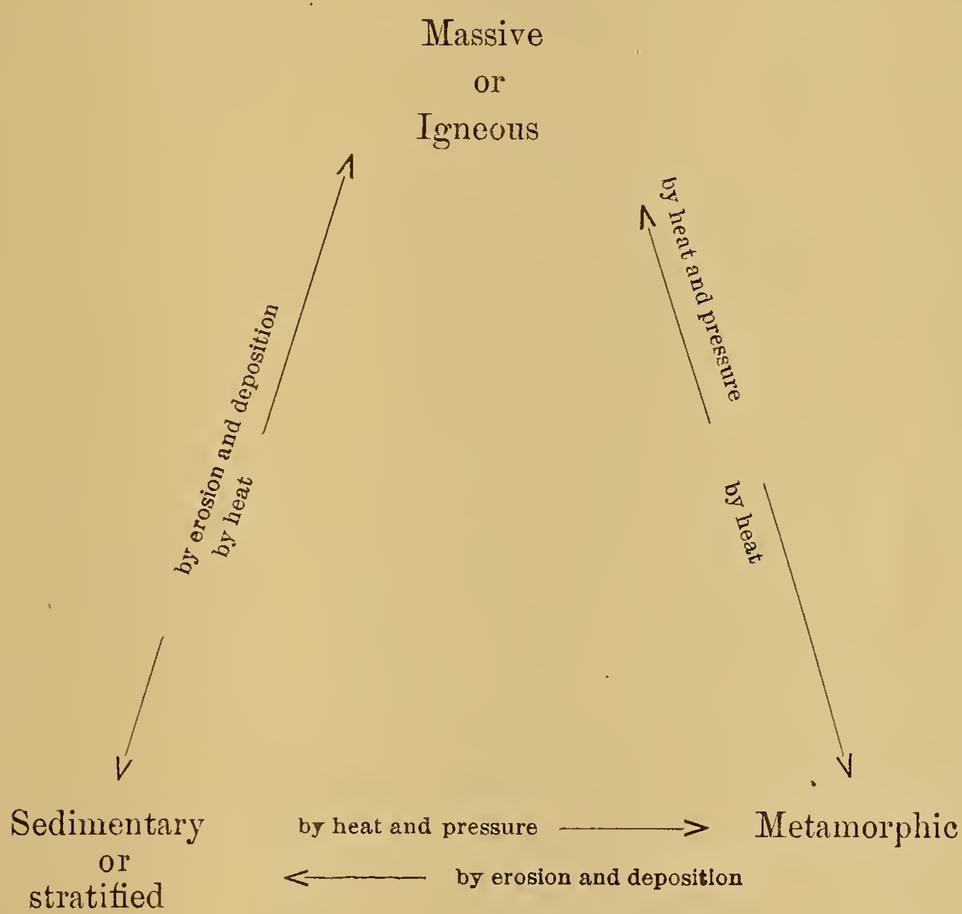
Besides these few minerals which are essential components of rocks and usually by their presence or absence determine the rock species, there are others which are only accessory and while of frequent occurrence do not so invariably affect the name of the rock in which they occur. Such are garnet, zircon and staurolite.

In addition to the rock-making minerals are those which occur in large masses in other rocks and have a commercial value. Such are corundum, or emery, the ores of iron, e. g. magnetite, hematite, spathic ore; coal, asphalt, halite or rock salt, gypsum, the ore of lead and silver, galenite; the ore of copper and gold, chalcopyrite and graphite or black lead.

Of rarer occurrence and great commercial value are the gems diamond, ruby, sapphire, emerald, etc. None of these are found in New York.

Rocks

These are the materials of the strata and other masses which form integral parts of the earth's crust. They may be classified as massive or igneous, sedimentary and metamorphic. The relations of these three natural groups may be shown by a triangular diagram, as follows:



This is meant to show that an igneous rock may, by erosion, be reduced to sediment and laid down in beds, or by heat and pressure may be metamorphosed from its original massive condition and become schistose. A sedimentary rock may also pass through the metamorphic condition, become fused and enter the igneous state. A metamorphic rock may arrive at the igneous condition by heat and pressure, or may become sedimentary through erosion and deposition.

Igneous rocks

The igneous rocks are very numerous, but may be classified in a few groups by mineral composition and texture. The texture indicates usually the conditions of their cooling. If the cooling occurred at a considerable depth, the process was gradual, crystals of the component minerals formed slowly and freely, and the resulting texture is coarse. If the cooling was in the open air, as in a lava bed, the process was more rapid; there was not sufficient time for crystals to form, and the resulting texture is fine or glassy.

The first class is called *plutonic*, the second *volcanic*. Plutonic rocks abound in the regions where old geologic formations are exposed, since there, either the intrusions did not reach the surface or the surface material which cooled as lava was removed by long erosion, and we see only those parts which were deeply covered while cooling. Examples of this are seen in the Palisades of the Hudson; the granite mountains, Anthony's Nose, Storm King, Breakneck and other peaks of the highlands, and in Mt. Marcy, Whiteface, etc., of the Adirondack chain. The volcanic rocks are chiefly exposed in regions of the newer formations because of the deep-seated plutonic masses have not yet been brought to view by erosion. The only good exposure of this character in New York is the mass of red porphyry or trachyte at Cannon's Pt., near Essex, on Lake Champlain.

This statement involves the theory that every volcanic mass has beneath it, or connected with it, a plutonic mass of the same general chemical composition.[a]

The names of a few important igneous rocks and their essential compositions are given below according to the classification of Rosenbusch.[b]

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[a] The accurate classification of rocks dates from about 1873, with the development of methods of study with the microscope. Most of the older books in English are much behind the present German standard of progress.

[b] Mikroskopische Physiographie der Mineralien und Gesteine.

PLATE I.—To face page 124.

H. Ries, photo.

GRANITE DYKE IN HUDSON RIVER SCHIST, SOUTH SIDE OF 192D ST., NEW YORK CITY.

PLATE II.—To face page 124.

H. Ries, photo.

IGNEOUS GRANITE ON LOWER SILURIAN LIMESTONE, 192D ST., NEW YORK CITY.

PLATE III.—To face page 124.

H. Ries, photo.

EXPOSURE OF SERPENTINE ROCK, HOBOKEN, N. J. DERIVED FROM THE CHEMICAL ALTERATION OF AN IGNEOUS ROCK.

PLATE IV.—To face page 124.

H. Ries, photo.

Palisades of the Hudson River, Seen from Hastings, Westchester Co. Triassic Diabase Overlying Sandstone, Which is Concealed by the Talus.

Orthoclase and hornblende		Plagioclase and hornblende		Plagioclase and augite		Plagioclase and hypersthene
With quartz	Without quartz	With quartz	Without quartz	With olivine	Without olivine	
			Plutonic			
Granite	Syenite	Quartz diorite	Diorite	Olivine diabase	Diabase	Norite
			Volcanic			
Quartz porphyry rhyolite	Trachyte	Quartz porphyrite	Andesite porphyrite	Basalt	Augite andesite	Hypersthene andesite

Sedimentary rocks

These are, for the most part, deposited in water, and are of three classes, mechanical, chemical and organic.

The principal examples of these are:

Mechanical:
1 Sand, gravel, sandstone and conglomerate. These are the debris of rocks containing quartz.
2 Clay and shale. These are formed of the debris of feldspar and the residuum from impure limestone.
3 Tuffs. Deposits of loose volcanic materials.

Chemical:
4 Rock salt (chloride of sodium), deposited by evaporation from bodies of salt water.
5 Gypsum (sulphate of lime), deposited by evaporation from bodies of salt water. All sea water contains sulphate of lime.

Organic:
6 Limestone, deposited in oceans from debris of marine animals, corals, mollusks, etc.
7 Coal, formed from accumulations of vegetation in marshes.

Metamorphic rocks

These have been subjected to heat and pressure usually in the presence of moisture, and have lost their original form and structure. They include the following:

Gneiss, which ordinarily has the same composition as granite,[a] with a foliated or schistose structure.

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[a] In modern usage the word *gneiss* designates only the schistose or foliated structure and any massive rock made schistose by metamorphism is called gneiss.

Schist, mica schist, hydromica schist, talcose schist, etc. Various members of the mica group play an important part in the schists.

Slate. This is mainly shale hardened by metamorphism and rendered fissile by pressure. The roofing slates are good examples.

Crystalline limestone. This is sedimentary limestone made crystalline by heat and pressure.

All kinds of igneous rocks may become schistose by metamorphism and then receive names indicating their composition and structure.

HISTORIC GEOLOGY

Historic geology treats of the succession of geologic deposits and is based on the study of sedimentary rocks.

It is estimated that the geologic series consists of about 100,000 feet or 20 miles thickness of sedimentary strata. These are beds of sediment chiefly formed by successive invasions of the sea and the transportation and deposition by it of debris detached from the rocks of the mainland by rain, frost, rivers and the ocean waves.

It has been estimated that about 99% of all rocks are sedimentary, and although some of these were formed in fresh water, probably the larger part of the sedimentary rocks were deposited in the ocean. It has consequently been said that 'the sea is the mother of continents.' On our Atlantic coast, as elsewhere, the ocean is both a destructive and a formative agent. As the soundings show, the loose materials washed from the land are spread out about 100 miles from the shore line in a broad, sloping plain of sand and mud. In such submarine deposits, when uncovered by the ocean's retreat, we find the remains of mollusks, fishes and other marine forms of life. Besides, land animals are often drowned and their bodies are carried out to sea and covered with sediment, leaves fall on the water and sink to the bottom. Therefore, in rocks formed in the sea we sometimes find remains of land animals and plants, besides the marine forms which we expect. The unceasing action of rain and frost, rivers, waves and currents through all time has led to the deposition of a succession of strata which on the whole are unbroken in their sequence, though they have varied so much in the areas of their deposition that in no region do we find the series complete. There has been a break of continuity in those areas which for a time were elevated above the sea, but the continuity of the geologic series has always been maintained in one area or another. Contemporaneous strata are found only in those areas which are simultaneously depressed and which were submerged during the same time.

Contemporaneous strata may differ widely in composition owing to differences in material and the conditions of their deposition. Thus the Potsdam sandstone in northern New York is contemporaneous with a limestone in Saratoga and Dutchess counties.

As a result of the alternating invasions and retreats of the ocean over the land, we find in various geologic systems what is known as a trinity of formations,[a] viz. a base consisting of *sandstone* or *conglomerate*, a center consisting chiefly of *limestone* and a summit of *shale* or *mud stone.*

The cause of this alternation is not fully known. The sandstones and conglomerates are usually solidified beach and shoal water deposits. The shales are solidified sea bottom deposits consisting of the finer material carried from the shore by waves and currents and also of sediment carried into the sea by rivers.

The limestones were probably formed in many cases as at the present day, in warmer waters, which permitted the luxuriant growth of corals, mollusks and other marine invertebrates which have external skeletons composed of carbonate of lime. In New York there were coral reefs in the Trenton, Niagara and Corniferous periods. Whether corals in Palaeozoic time required the same warm temperature of water as at the present day, we do not know.

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[a] Geikie's *Text Book of Geology,* IIIrd Ed. p. 454.

DYNAMIC GEOLOGY

Under this head there is only enough space to enumerate the different agencies which are productive of geologic change or are associated with it. For a detailed discussion the student is referred to the text-books.

The dynamic agencies of geology may be roughly classified into two groups: *hypogene* or subterranean and *epigene* or superficial. Under the first head the principal agencies are volcanoes, earthquakes, secular changes of level and metamorphism. These, as their group name indicates, are chiefly controlled by forces that work beneath the surface of the earth; the second or epigene group comprises those which are chiefly manifest upon the earth's surface. First among these is the air. Air in motion or wind, is of marked importance as an agent of transportation as manifested in sand dunes, at places where deposits of fine sand occur, chiefly on the sea shore and in deserts.

A more active agent than air is water. By the action of its terrestrial forms, rain, snow and ice and by the cumulative forms of these, rivers and glaciers, the highlands are reduced and vast amounts of material are transported by the aid of gravity.

The oceanic waters are agents of destruction, transportation and formation. Waves beat upon the land and loosen fragments from the rocks upon which they beat. These fragments, carried out within reach of the oceanic currents, are borne along and drop to the bottom forming sand bars and other sub-aqueous deposits. Lastly, animal and plant life, both terrestrial and aquatic, are formidable agents of change, both destructive and constructive.

Resumé

Hypogene or subterranean agencies

Volcanoes
Earthquakes
Secular change of level
Metamorphism

Epigene or superficial agencies

Air

Water { terrestrial
oceanic

Erosion and sedimentation

Animal and plant life.

PALAEONTOLOGY

In studying an extensive series of geologic formations from bottom to top, we find that through geologic time there has been a progressive advance in the development of animal and plant life as well as a change of genera and species. Forms that are abundant at one horizon seem to have ultimately given up the battle for existence and disappeared, their place in nature being filled by others. So by careful comparison of the animal and vegetable remains found in the different systems and groups and in the minor sub-divisions of the groups, we come to regard the fossils as labels by which we may know the age of strata. While there are some persistent types which pass from one system to another without material change, we find that the life characteristics of each group are essentially distinct. It is therefore important for the field geologist who is studying the formations above the Archaean to be familiar with their fossils in order to determine the horizons accurately.

In the older formations, plants were few and elementary and, containing but little mineral matter, have not been well preserved so that we depend more on fossil animals than plants for the identification of the Palaeozoic strata. From the Mesozoic on, impressions of land plants are more abundant and become of much value in palaeontology.

As shown by the fossil remains discovered in rocks of different ages, the development of animal life has been a gradual one, but we are not yet acquainted with any formation which contains the earliest forms of life. We begin our study, as it were, at a somewhat late period of life development, the Cambrian, for the fossils of the pre-Cambrian rocks are not yet well known. Somewhere and at sometime, an opportunity will be afforded for the study of pre-Cambrian life. West of the Rocky mountains, stratified deposits of great thickness are known beneath rocks of Cambrian age and these may, in time, when carefully searched, yield an abundant fauna.

Development of Life

ANIMALS

In classifying the animal kingdom, we find that by the presence or absence of an important feature it is possible to place most of the forms in two great sub-kingdoms: the invertebrates and the vertebrates; those without a backbone and those possessing one.

The animals without backbone are considered lower in the scale of development, as they have, in general, less intelligence and fewer resources. They are usually dependent for protection on an external skeleton or armor which encloses their soft bodies.

The vertebrate animals are, in general, characterized by relatively higher intelligence and have, at their command, more ways of protecting themselves and securing a living. The soft parts of their bodies are built around a bony skeleton and they depend for self protection more generally on their activity and intelligence than upon mere mechanical means of protection such as shells or armor.

Among the invertebrates the cuttlefishes were and are still the most highly developed type in regard to size and power though the crustaceans are considered to be more highly organized; among the vertebrates, man is supreme.

As we do not know the whole history of life development, we cannot show accurately in a diagram or scheme the relations of the different groups. The older arrangement which is still used in many text-books of geology is as follows:

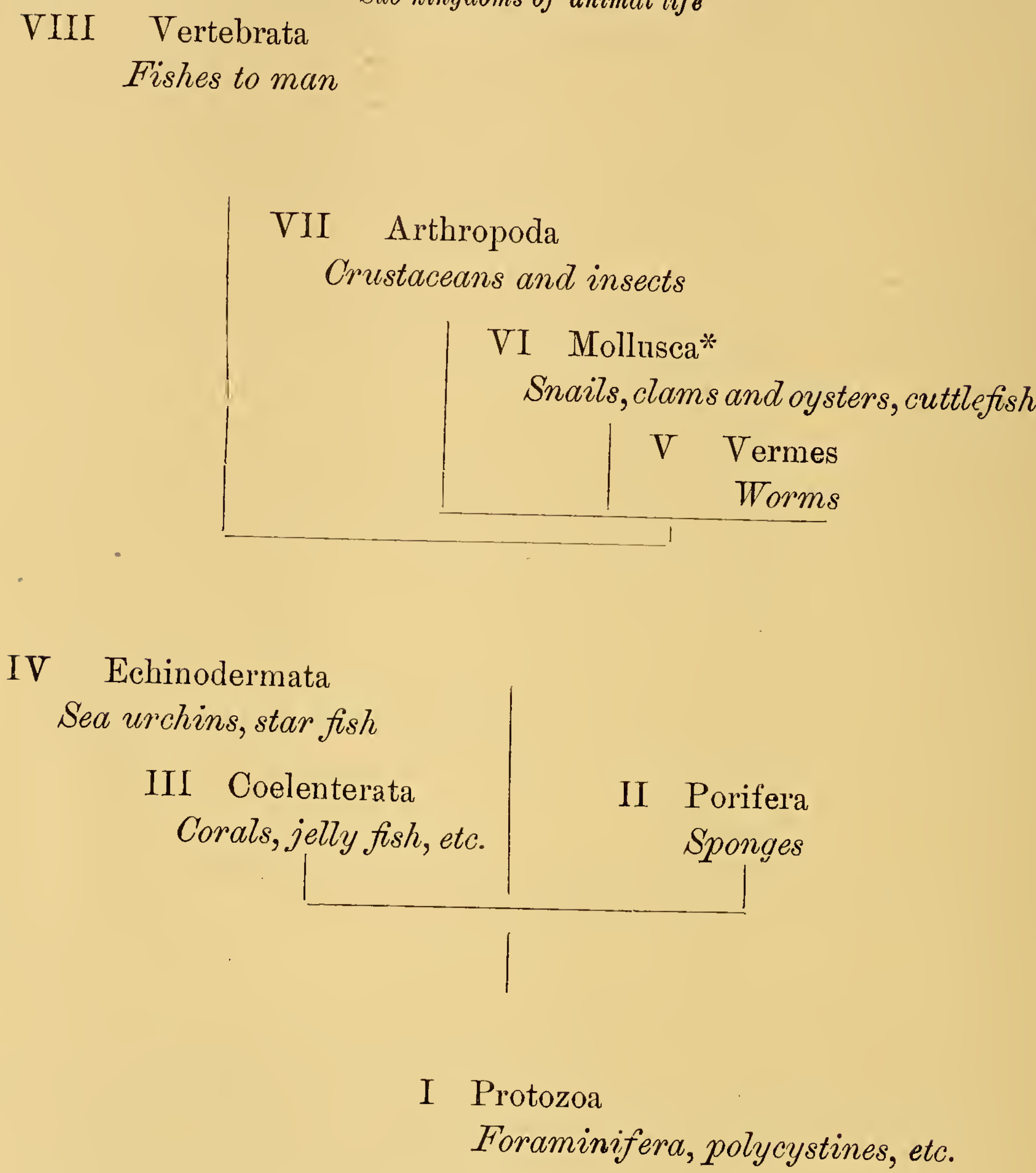
Classification of Animal Life

Sub-kingdoms		Classes	Examples
Vertebrates		Mammals	Man, cow, horse, sheep, dog, whale, etc.
		Birds	Owl, turkey, hawk, sparrow, etc.
		Reptiles	Serpents, lizard, tortoise
		Amphibians	Frog, toad, salamander
		Fishes	
Invertebrates	Mollusks	Cephalopods	cuttlefish
		Pteropods	
		Gasteropods,	snail, etc.
		Lamellibranchs,	clam, oyster, etc.
		Brachiopods	
		Tunicates	
		Bryozoans	
	Articulates	Crustaceans,	trilobite, crab, lobster
		Insects	
		Worms	
	Radiates	Corals, starfish, etc.	
	Protozoa	Sponges, foraminifera, etc.	

This classification though time-honored and convenient in elementary palaeontology, has been superseded among zoologists by one slightly different, which indicates more truthfully the relations of the various groups or branches in point of development.

The following diagram by Packard[a] may be taken as representing the modern view.

Sub-kingdoms of animal life



[a] *First Lessons in Zoology*, p. 10

* The Brachiopods, Tunicates and Bryozoans are now separated from the Mollusca into the group of Molluscoida.

PLANTS

The following classification will give a general idea of the development of vegetable life.

- 4 Phanerogamia or Spermatophyta
  - Angiosperms
    - Dicotyledons or Exogens
      - Most of the forest trees and shrubs, oak, ash, etc.
    - Monocotyledons or Endogens
      - Palms
      - Lilies
      - Grasses, etc.
  - Gymnosperms
    - Conifers, pine, spruce, etc.
    - Cycads

- Cryptogamia
  - 3 Acrogens or Pteridophyta
    - Lycopods or Club mosses
    - Ferns
    - Equisetae or Horsetails
  - 2 Anogens or Bryophyta
    - Mosses
    - Liverworts
  - 1 Thallogens or Thallophyta
    - Fungi — Mushrooms, etc.
    - Lichens
    - Algae
      - Sea weeds
      - Diatoms

This classification is not now used in the more modern books on botany, but is followed in most of the text-books of geology.

PHYSIOGRAPHY AND STRUCTURE

In order to appreciate the position and attitude of the geologic formations in New York, it is necessary to form a mental picture of its physiography. For the purpose of reference the following terms may be adopted to describe the principal physiographic divisions of the state:

I The Adirondack upland, comprising the Adirondack mountain region and the adjacent territory.

II The southern upland; west of the Hudson river and south of the line of the Mohawk valley prolonged to Buffalo.

III The Highland-Taconic range; the mountains of granite crossing the Hudson river near West Point, and those of mica schist along the New England border.

IV The Central valley, consisting of the valley of the Mohawk and the low land extending from it to the Niagara river.

V The Hudson-Champlain valley, including the basin of Lake Champlain.

VI The Coastal plain, including Long Island and southern Staten Island.

As the geologic map shows, the principal Palaeozoic outcrops in New York have three principal positions and directions:

1) In zones encircling the Adirondack upland. These zones are much disturbed locally by faults, so that the outcrops are irregular. 2) In lines parallel with the Highland-Taconic range. This mountain axis has a northeast direction in the Highlands of the Hudson, changing gradually to north in the Champlain valley, where the Green mountain uplift is tangent to that of the Adirondacks. 3) In east and west lines across the southern upland from Albany county to the Niagara river and Lake Erie, locally intersected by river and lake valleys.

That portion of the state bordering on the Pennsylvania boundary is a high plateau, with summits about 2000 feet above tide. Its surface slopes gradually northward toward Lake Ontario and its component rock strata slope or dip southward.

From this it results, that, as we go southward from Lake Ontario, we ascend in vertical altitude and also in the geologic column. Our youngest Palaeozoic rocks, which are Lower Carboniferous, are near the Pennsylvania boundary.

These physiographic features are well shown on the accompanying relief map of New York.

For a detailed discussion of the geography of New York see Examination bulletin 11, University of the State of New York, by Wm. Morris Davis.

GENERAL CLASSIFICATION OF GEOLOGIC TIME AND STRATA

It must be realized by the student at the outset that all classification is to some extent arbitrary. There was throughout the earth as a whole a continuous process of erosion and sedimentation and a continuous chain of life. Locally, through changes of level, sedimentation was varied and life interrupted from time to time. For convenience in discussion, a scheme of arrangement has been adopted which is based on the more conspicuous of these breaks in life and sedimentation.

According to the classification most generally accepted, the principal divisions of the geologic time scale are called *aeons* or *times* and designated by the following names which are based on the principal features of life development:

Cenozoic, latest time, characterized by forms closely related to those of the present day.

Mesozoic, middle time of life development.

Palaeozoic, early time; ancient forms of life well developed.

Proterozoic or **Agnotozoic**, life not well known as yet.

Archaean time of the most ancient rocks with only suggestive traces of life.

The *aeons* are subdivided into *periods* as follows:

Æons	Periods	Prevailing types of animal life
Cenozoic	Quaternary or Pleistocene Tertiary	Mammals
Mesozoic	Cretaceous Jurassic Triassic	Reptiles
Palaeozoic	Carboniferous Devonian	Fishes
	Upper Silurian Lower Silurian or Ordovician	Mollusks
	Cambrian	Crustaceans
Proterozoic or Agnotozoic	Keeweenawan Huronian	Not known in New York
Archaean, not yet sub-divided	Laurentian	

The rock formations of the aeons are called *series* and of the periods, *systems.*

The systems may be described in general terms as those divisions of the series which are world-wide in their differentiation. The subdivisions of the systems which are called *groups* are chiefly local and variable. The groups are divided into *stages.*

PART 2.

GEOLOGIC FORMATIONS OF NEW YORK

New York is the mother state in geologic nomenclature, and the names chosen by its early corps of geologists have been adopted in a large degree throughout the whole of the United States. It has moreover, exposed within its borders, a more complete and extensive series of the formations below the Carboniferous and above the base of the Cambrian than any other state in the Union. It is therefore evident that a complete and representative collection of the New York rocks is of no small importance and the description of its formations is a matter of much interest.

SYNOPSIS

System	Group	Stage
Carboniferous		Olean Conglomerate of Allegany and Cattaraugus counties. This is the Pottsville Conglomerate of Pennsylvania.
Devonian	Chemung–Catskill	
	Portage	Portage sandstone Naples beds Gardeau shale and sandstone Cashaqua shale
	Hamilton	Genesee slate Tully limestone Hamilton: Encrinal limestone; Ludlowville shale Marcellus shale
	Corniferous	Corniferous limestone Onondaga limestone Schoharie grit Cauda galli grit
	Oriskany	Sandstone

System	Group	Stage
Upper Silurian	Lower Helderberg	Upper Pentamerus limestone Delthyris shaly limestone Lower Pentamerus limestone
	Salina	Shale, limestone, salt and gypsum
	Niagara	Niagara shale and limestone Clinton sandstone, limestone and shale
	Medina	Medina sandstone Oneida conglomerate
Lower Silurian	Hudson river	Pulaski and Lorraine shales Frankfort slate Utica slate
	Trenton	Trenton, Black river, Birdseye, Chazy limestones
	Calciferous	
Cambrian	Potsdam	Sandstone and limestone
	Acadian	
	Georgian	Quartzite and slate
Archaean		gneisses and Granites

ARCHAEAN

This name was proposed by Prof. J. D. Dana to include those ancient crystalline rocks, which in nearly all countries are seen to underlie the oldest fossiliferous strata.

Although various subdivisions and classifications have been proposed at times, in the light of present knowledge their accuracy is uncertain and they will not be mentioned here.

The Laurentian rocks of Canada may be regarded as types of the Archaean.

In New York, as elsewhere, this system is represented by a series of crystalline rocks including gneiss, granite, diorite and norite. Crystalline limestone is often associated with them, but we do not know whether it should be regarded as truly Archaean. These rocks are exposed where uplifts from below in early time raised them up to form islands in the Palaeozoic seas, or in later time have caused them to break through the overlying strata. An instance of the latter occurs at Littlefalls, where the hard, red and gray granite has been forced up in a dome and appears

PLATE V.—To face page 138.

J. N. Nevius, Photo.

PRECAMBRIAN GNEISS. MOHAWK VALLEY, LITTLEFALLS, HERKIMER CO.

in the gorge of the Mohawk protruding through the Hudson river shale and Trenton limestone.

Beneath the metamorphic rocks of the Archaean and intersecting them, are found what are known as Plutonic[a] rocks, the peculiarity of which is, that they are not found in layers or strata, but in solid masses, and appear to have been forced up from below in a plastic condition. They form the central mass of the Adirondacks, and large areas of them are found in the Highlands and in many parts of New England. They were once generally called 'primary' or 'primitive', as it was believed that they were the original crust of the earth, first formed in the cooling of its melted mass, but it is now doubted whether, if such a crust exists, it can be identified, and many geologists think that most of the granites and other plutonic rocks are only re-melted and altered forms of older ones. That many such masses are so, is certain; and whether we can find any which are portions of an original crust of the globe, is at least very doubtful.

Containing no fossils, these rocks have their chief interest in their value for economic uses in building and other purposes, and in the cabinet specimens of the minerals which they so often contain.

The Archaean rocks cover two separate tracts of country in this state, one in its southeastern part known as the Highlands; the other lying in the central portion of the great Adirondack wilderness.

Various kinds of rocks are mingled over most of these areas, seeming often to change or gradually pass into each other. The metamorphic masses of gneiss, etc. are more fully exposed (as a general rule) around the edges of the tracts, where they pass under the lower strata of fossiliferous rocks; while the granite, hypersthene and other plutonic masses are more fully developed near the centers of these areas and among the highest of the mountains.

Throughout the Archaean districts there are many dykes, or veins of trap or other igneous rock penetrating masses of a different character. Not infrequently, a mountain or hill shows

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[a] Plutonic, from Pluto, king of the infernal regions in Pagan mythology.

such dykes cutting across or through it for a long distance, and to an unknown depth. These represent cracks or clefts by which the country has been riven and which have been filled by the rise of melted matter from below. They are all sizes, from half an inch to 100 feet or more in thickness.

Plutonic dykes are not confined to Archaean regions. Dykes of granite are seen in many places on New York island, penetrating in every direction the Lower Silurian mica-schist which forms the masses of its territory.

These are examples of a phenomenon frequently observed, viz.: a plutonic rock penetrating strata of Paleozoic or later age. They are similar in their origin to the out-flows of lava from volcanoes.

A prominent example of a late plutonic intrusion is seen in the 'palisades' of the Hudson, which is described under the Triassic rocks.

The plutonic and metamorphic rocks generally decompose slowly and produce a poor or barren soil. The districts formed of these rocks are the least fertile in our state, except where overlying deposits of glacial drift and alluvium furnish a soil which is adapted to tillage and the support of vegetation.

Typical Localities of the Archaean

The most southern locality of Archaean rock in New York state is on New York island, between 7th and 8th avenues south of 155th street. This is a good exposure and is typical of the Archaean gneiss of southeastern New York. This gneiss is well shown throughout Westchester county along the shore of the Hudson, though at a few points Lower Silurian limestone and mica-schist occur. A little north of Peekskill may be seen the granite mountains of the Highlands, which traverse Orange and Putnam counties. These are chiefly massive, though on their flanks are some gneissoid rocks and in many of the valleys are Palaeozoic limestones and schists. Other localities are seen in Dover mountain and in Stissing mountain in Dutchess county. North of this southeastern area, the Archaean rocks are chiefly confined to the region known as the Adirondack wilderness.

PLATE VI.—To face page 140.

J. F. Kemp, photo.

FOLDS IN FORDHAM GNEISS, NORTH SIDE OF 138TH ST., EAST OF 7TH AVE., NEW YORK CITY. PRECAMBRIAN.

PLATE VII.—To face page 140.

H. Ries, photo.

HIGHLANDS OF THE HUDSON. PRECAMBRIAN. VIEW FROM PEEKSKILL.

PLATE VIII.—To face page 140.

Anthony's Nose.

Manitou Mountain.

H. Ries, photo.

HIGHLANDS OF THE HUDSON. PRECAMBRIAN. ANTHONY'S NOSE AND MANITOU MOUNTAIN.

PLATE IX.—To face page 140.

Crow Nest. Storm King.

H. Ries, photo.

HIGHLANDS OF THE HUDSON. PRECAMBRIAN. CROW NEST AND STORM KING.

PLATE X.—To face page 140.

F. J. H. Merrill, photo.

View of the Highlands of the Hudson and Sugar Loaf Mountain, from Ft. Montgomery, Orange Co. Precambrian.

PLATE XI.—To face page 140.

H. Ries, photo.

BREAKNECK MOUNTAIN. SEEN FROM THE SHORE OPPOSITE COLD SPRING, PUTNAM CO. PRECAMBRIAN GRANITE.

PLATE XII.—To face page 140.

H. Ries, photo.

FISHKILL MOUNTAIN, SEEN FROM CORNWALL, ORANGE CO. PRECAMBRIAN AND LOWER SILURIAN.

PLATE XIII.—To face page 140.

S. R. Stoddard, photo.

Gorge of the Hudson River, Luzerne, Warren Co., and Hadley, Saratoga Co. Precambrian Gneiss.

PLATE XIV.—To face page 140.

PRECAMBRIAN ROCKS, ADIRONDACK MOUNTAINS. AVALANCHE LAKE, ESSEX CO.

PLATE XV.—To face page 140.

S. R. Stoddard, photo.

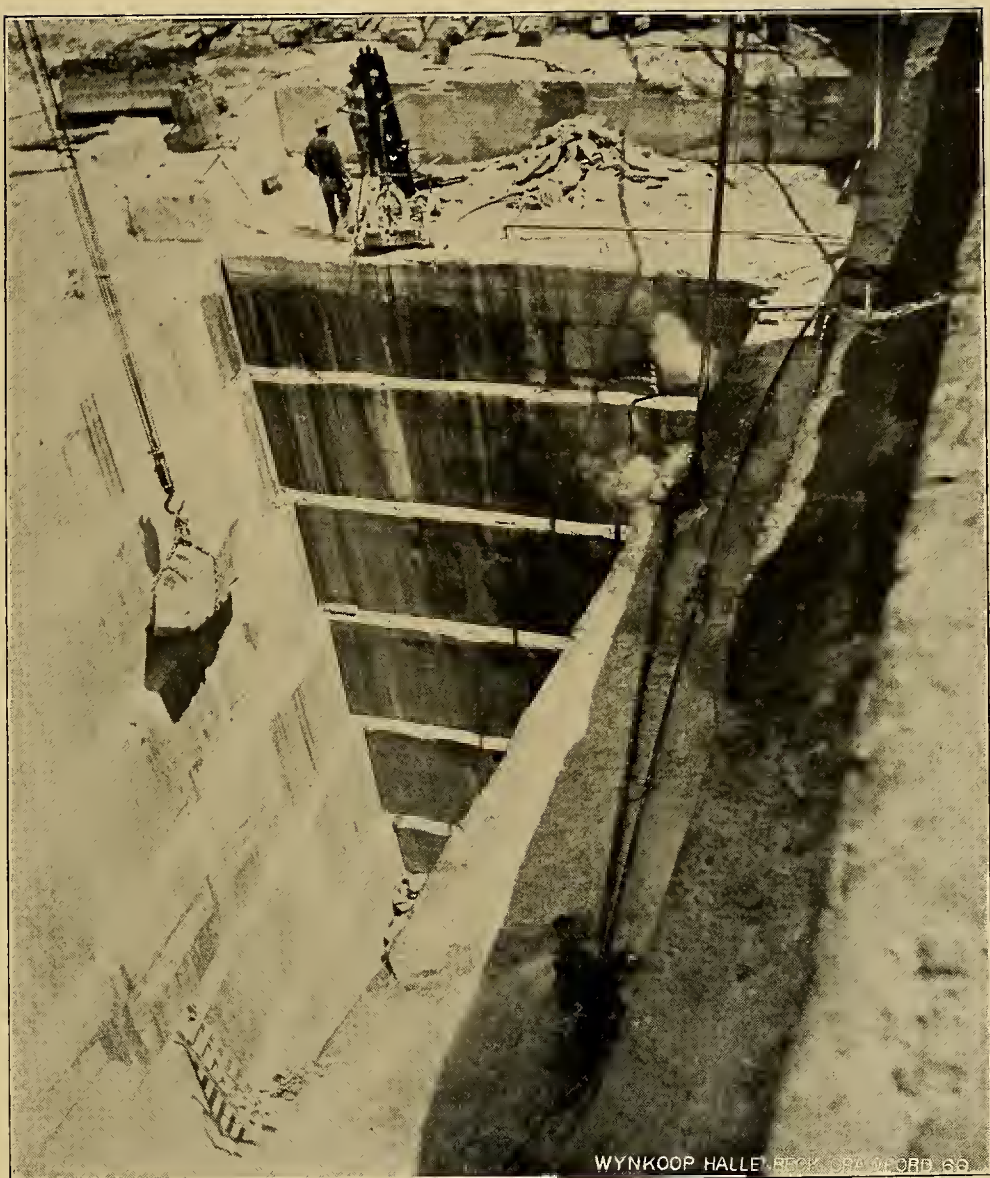
PRECAMBRIAN ROCKS, NORTH END OF WILLSBORO TUNNEL, SHORE OF LAKE CHAMPLAIN, ESSEX CO.

PLATE XVI.—To face page 140.

J. N. Nevius, photo.

Precambrian Marble, E. E. Stevens' Quarry, 3 Miles South of Canton, St. Lawrence Co.

PLATE XVII.—To face page 140.



J. N. Nevius, photo.

EMPIRE MARBLE CO.'S QUARRY NEAR GOUVERNEUR, ST. LAWRENCE CO.
PRECAMBRIAN.

The principal group of mountains, which includes Mt Marcy, is of massive rocks known as norite and anorthosite. The prevailing rocks of the wilderness are, however, gneisses of different kinds. In these are many local intrusions of granite and other eruptives. Trap, serpentine and many other rocks of igneous origin are found in all parts of the district. The great route of travel through Lakes George and Champlain is bordered by mountains and cliffs, in which these rocks are seen in great variety.

In the Mohawk valley are small exposures of pre-Cambrian, at Littlefalls and near Spraker's. These are important localities and show the relations of the over-lying Palaeozoic rocks.

Proterozoic or Agnotozoic

Rocks of this age are not definitely known in New York. They are well represented in the Lake Superior region by those formations known as Huronian and the copper bearing deposits of the Keeweenaw peninsula. West of the Rocky mountains, they are developed extensively. All rocks between the Archaean and the Cambrian are included.

Palaeozoic

Upon the plutonic and metamorphic rocks of the Archaean in New York rest directly the Palaeozoic strata which are all fossil-bearing rocks. The Palaeozoic series includes all strata from the base of the Cambrian to the summit of the Carboniferous.

These stratified fossil-bearing rocks form the greater part of the state of New York.

At the beginning of the Palaeozoic, all life was marine, probably because the land surfaces were at first too small to materially influence the evolution of living forms. In the Cambrian, crustaceans prevailed, in the Lower Silurian the Cephalopods or cuttle fishes, in the Devonian the soft boned fishes were the dominant type, while in the Carboniferous, fishes and amphibians divided the honors of the sea and the land.

In like manner plant life, beginning with marine forms of low type, gradually developed to the large tree ferns, sigillaria, lycopods and equisetae of the coal measures.

CAMBRIAN[a]

Subdivisions or periods

Potsdam	Sandstone around the Adirondacks Limestone in Dutchess, Washington and Saratoga counties
Acadian	Limestone in Dutchess county
Georgian	Roofing slates of Washington county Quartzite in Dutchess county

The first and lowest Palaeozoic system known in New York is the Cambrian, so called from *Cambria*, the latin name of Wales, where rocks of this age abound and were first studied by the British geologist, Adam Sedgwick. Our knowledge of the Cambrian of New York is largely due to the labors of C. D. Walcott, William B. Dwight, and S. W. Ford.

The base of the Cambrian system in New York and New England rests directly upon the Archaean rocks and its limit can be recognized by this fact, as well as by its containing the earliest known fauna. But the termination of the uppermost division is not so apparent, as it grades, both in sediment and fauna, into formations of the Lower Silurian system, thus showing that there was no great physical change to influence the transition. North of the Adirondacks the delimitation is more clearly defined.

The strata of the Cambrian system are classified as follows:

Upper Cambrian, or Potsdam.

The type rock is the sandstone of the northern and eastern borders of the Adirondack mountains, and correlated with it are certain limestones on the south side of the Adirondacks, near Whitehall and Saratoga Springs, and in Dutchess county near Poughkeepsie. The characteristic fossils are the Dikelocephalus trilobites.

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[a] The descriptions of the Georgian and Acadian groups are chiefly from the work of C. D. Walcott, Bulletin No. 81, U. S. Geological Survey.

Middle Cambrian, or Acadian.

The type rocks are the shales and slates of New Brunswick, Newfoundland and Braintree, Mass., and correlated with them are some limestones in Dutchess county. The characteristic fossils are the Paradoxides trilobites.

Lower Cambrian, or Georgian.

The type rocks are slates, limestones and the 'red sandrock' of western Vermont; and correlated with them the shales and interbedded limestones and roofing slates of Washington and Rensselaer counties. The characteristic fossils are the Olenellus trilobites.

Georgian

The lowest rock is a bedded quartzite, resting upon the Archaean. This is seen on the flank of Stissing mountain, and between Fishkill and Poughquag, in Dutchess county. From here its outcrops extend northeasterly through Massachusetts and Vermont, where it attains a great thickness.

At Stissing mountain it passes above into a limestone containing Lower Cambrian fossils. Above this lies a considerable thickness of arenaceous limestone, frequently passing into calcareous shale, and containing Middle Cambrian fossils.

Near Poughkeepsie an extensive limestone formation contains Upper Cambrian fossils.

Northward, in Washington county, the quartzite is represented by a great thickness of shales, slates, sandstones and limestones, well shown along a line between Greenwich and Salem, and the superjacent limestones of Dutchess county are entirely replaced in both Rensselaer and Washington counties by slates, shales and sandstones. Mingled fossils of Lower and Middle Cambrian are found at Berlin, Rensselaer county. These formations continue northeastward into Canada.

The great belt of *roofing slate* in western Vermont and Washington county, belongs to this (Georgian) group. The greatest development of this formation is at Georgia, Vt., from which place it extends southward into Washington county, where it is quarried at Middle Granville and vicinity, and broadening out southward, extends nearly across the southern part of Rensselaer county.

Acadian

The Middle Cambrian, or Acadian, group is not so well developed in New York.

Marble and limestone of this age are found resting conformably upon the Lower Cambrian rocks about Stissing mountain, shown in the cut for the N. Y. & Mass. R. R. near Stissing, and extending into Massachusetts, where the development is greater. A portion of the Stockbridge limestone may belong to this group, though most of it is Lower Silurian.

Potsdam

The Upper Cambrian, or Potsdam, group is exposed over a larger area in New York than the two lower divisions and is typically represented by the Potsdam sandstone, which is seen in many places to rest directly upon the Archaean. It is a hard silicious sandstone and an excellent building material, often thinly bedded and usually reddish-brown in color, though sometimes gray or buff. On many of its layers, are waved surfaces, precisely resembling the ripple-marks seen on sandy bottoms over which waters are agitated by waves or currents. They were formed in the same way, by movements of the waters in which were deposited the sands which were finally hardened into the Potsdam sandstone. Similar markings are frequent on almost all sandstones. The edge of this formation can be traced nearly all around the region of the Adirondacks, except between Canajoharie and Carthage, and is especially well seen near Keeseville in Clinton county, where the deep chasm of the Ausable river is cut through it, showing 333 ft. of horizontal strata, at Chateaugay chasm, where the section exposes a thickness of 250 ft., and at Potsdam, St Lawrence county, from which place it received its name, and where, in the valley of the Raquette river a thickness of 70 ft. is shown.

PLATE XVIII.—To face page 144.

J. N. Nevius, photo.

POTSDAM SANDSTONE, QUARRY OF MERRITT & TAPPAN, 3 MILES SOUTH OF POTSDAM, ST. LAWRENCE CO.

PLATE XIX.—To face page 144.

J. N. Nevius, photo.

POTSDAM SANDSTONE RESTING UNCONFORMABLY UPON PRECAMBRIAN GNEISS. DODGE FARM, MACOMB, ST. LAWRENCE CO.

PLATE XX.—To face page 144.

N. H. Darton, photo.

Potsdam Sandstone Resting Unconformably on Precambrian Gneiss. Hudson River Near Jessups Landing, Saratoga Co.

PLATE XXI.—To face page 144.

S. R. Stoddard, photo.

HELL GATE, AUSABLE CHASM, CLINTON CO. POTSDAM SANDSTONE.

PLATE XXII.—To face page 144.

S. R. Stoddard, photo.

Potsdam Sandstone, Grand Flume, Ausable Chasm, Clinton Co.

PLATE XXIII.—To face page 144.

N. H. Darton, photo.

GLACIATED SURFACE OF POTSDAM CONGLOMERATE, MOSHERVILLE, SARATOGA CO.

PLATE XXIV.—To face page 144.

N. H. Darton, photo.

POTSDAM CONGLOMERATE ON PRECAMBIAN CRYSTALLINE ROCKS, MOSHERVILLE, SARATOGA CO.

In the northern part of Lewis county the Potsdam sandstone, in a few small exposures, rests unconformably upon the Archaean terrane, and passes above into the Calciferous formation. It extends almost continuously through Jefferson, St Lawrence, Franklin and Clinton counties, and appears southward in the Champlain valley in irregular outcrops.

The Potsdam, though not seen distinctly in the Mohawk valley (where its place between the Archaean and the Calciferous sand rock appears to be vacant) is a thick mass in Pennsylvania, and is known northeastward and northwestward over a great area.

The base of the Potsdam at a few places in New York is a coarse conglomerate which gradually passes upward into the typical sandstone.

Near Whitehall, Saratoga and Poughkeepsie, the Potsdam horizon is represented by a limestone and at the two former localities it passes upward into the Calciferous formation without marked change except in fauna.

The characteristics of the Cambrian strata lead to the conclusion that the sediments were accumulated in shallow seas near the shore of a slowly sinking land. As the water slowly encroached upon the land in late Middle or early Upper Cambrian time, deeper water gradually covered the earlier longshore deposits, and finer sediments were deposited upon them. Toward the close of Cambrian time (Potsdam) only the higher parts of the continent were above the sea. At this time the Potsdam sandstone was deposited along the shores, while in the deeper water the conditions were becoming favorable for the formation of the great beds of Silurian limestone. The conglomerate at the base of the Potsdam, grading upwards into the finer sediments of the sandstone, indicates the deepening of the water along the shore line of the Cambrian ocean.

At their greatest development in Washington county, the Cambrian formations have a total thickness of 10,000 or 12,000 feet.

Life of the Cambrian

So far as we know, the life of the Cambrian was wholly marine. No vertebrates are known to have existed. The Brachiopods were small. The Lamellibranchs, so far as known, were also very small. There were representatives of the groups of Pteropods and Gastropods. Cephalopods appeared in the Upper Cambrian. There were also sponges, and corals. The trilobites, however, were the only forms which had attained large size or high development. Besides these were some other articulates, the Ostracoids and Phyllopods, and probably some worms. The plants were sea weeds.

LOWER SILURIAN OR ORDOVICIAN

This system is a subdivision of the original Silurian system which received its name from that of the *Silures*, an ancient race inhabiting the eastern part of Wales, where Sir Roderick Murchison studied these rocks in detail. The second name was derived by the British geologist Lapworth from that of the *Ordovices*, also an ancient British tribe.

In New York this system is well developed and includes the following subdivisions:

System	Group	Stage
Lower Silurian	Hudson river	Hudson river shale and sandstone
		Utica slate
	Trenton	Trenton
		Black river
		Birdseye
		Chazy
	Calciferous	

Calciferous Group

Overlying the Upper Cambrian or Potsdam sandstone at many points is another, which contains a considerable proportion of lime mingled with it, and from this fact has received the name of the Calciferous sandrock.

It may be described as a silicious or gritty limestone, generally of a brownish color, lying in straight, thin layers, and attaining

PLATE XXV.—To face page 146.

N. H. Darton, photo.

CALCIFEROUS SANDROCK RESTING ON PRECAMBRIAN CRYSTALLINE SCHISTS, WEST SHORE R. R. CUTTING, 1 MILE WEST OF DOWNING STATION, MONTGOMERY CO.

PLATE XXVI.—To face page 146.

N. H. Darton, photo.

CALCIFEROUS SANDROCK, EAST CANADA CREEK, HERKIMER CO., 1 MILE ABOVE ITS MOUTH.

PLATE XXVII.—To face page 146.

N. H. Darton, photo.

CALCIFEROUS SANDROCK. EAST CANADA CREEK, HERKIMER CO., TWO MILES ABOVE ITS MOUTH.

PLATE XXVIII.—To face page 146.

H. Ries, photo.

VIEW OF INWOOD, MANHATTAN ISLAND. Plain of Calciferous-Trenton Limestone. Hills Right and Left of Hudson River Schist. Palisades (Triassic) in the Background.

PLATE XXIX.—To face page 146.

H. Ries, photo.

MARBLE QUARRY, SING SING, WESTCHESTER CO. METAMORPHOSED CALCIFEROUS-TRENTON LIMESTONE.

a total thickness of 200 or 300 feet. It is well seen at the 'Noses' about Fonda on the Mohawk, and also at Littlefalls; in each of which places it has been raised to the surface by an uplift which has brought it from its original position below the Hudson river shales which are common in this region. It may also be seen near Middleville on West Canada creek (where it contains in its cavities many beautiful quartz crystals), and in many places in the vicinity of Lake Champlain and the St Lawrence river, in which latter region it has some layers so purely calcareous as to be profitably burnt for lime.

Outside of the Mohawk valley the Calciferous is a true limestone and in parts of Columbia, Dutchess, Putnam, Westchester, Orange and Rockland counties cannot be separated from the Trenton.

Trenton Group

Above the rocks of the Calciferous group between the Mohawk valley and the Canadian border succeeds a thick series of bedded limestones known as the Trenton group. This group has four principal divisions, Chazy, Birdseye, Black river and Trenton. These four divisions are nowhere all found together.

Chazy Limestone

Overlying the Calciferous sandrock in northern New York is a dark, irregular, thick-bedded limestone, which derives its name from the village in Clinton county where it was first studied.

Its thickness is about 730 feet on Lake Champlain: but, in striking contrast with the wide extent of many other rocks, it is known only in the Champlain valley, and does not appear to extend in any considerable thickness into those parts of the state west or south of the Adirondack region. It is not seen as a distinct or separate mass in the Mohawk valley, though the rocks above and below it are of well known occurrence outside of New York.

Birdseye Limestone

The rock which succeeds the Chazy limestone is one well known in the Mohawk valley, as well known along the Black river and

Lake Champlain: it is a fine grained, gray, brittle, limestone, 30 feet in its greatest thickness: and the most conspicuous of its fossils is one of which the nature is somewhat obscure, but which was regarded as the stem of some marine plant.

Standing in an upright position, perpendicular to the strata the ends of the stems are seen on the surface of the layers, to which they give a peculiar dotted appearance, from which the rock has derived its name, and by which, as well as by its characteristic color and fracture, it is easily recognized. It is a valuable rock for economical uses, as it is a good building stone, and dresses well under the chisel; it is quarried to a considerable extent at various points in the Mohawk valley.

Black River Limestone

To the Birdseye limestone succeeds a thin mass, amounting in all to only 10 or 12 feet, but classed as a distinct rock from having a somewhat peculiar mineral character and containing a peculiar set of fossils. It is a dark, thick-bedded, compact, hard limestone, fine grained and taking a high polish, and is worked as a black marble at Glens Falls on the Hudson river, and at Isle La Motte on Lake Champlain. It is also well seen at Watertown, Jefferson county, in the banks of the Black river from which locality it has been named.

In the last place it is lumpy and irregular in texture, and not fit for good masonry or marble; and is known among quarrymen as ‘the seven foot tier.’ In the Mohawk valley it seems to have been deposited in only a few places, the Birdseye being generally covered directly by the Trenton.

Trenton Limestone

Above the Black river limestone (or where this is absent, lying upon the Birdseye), is one of the most interesting repositories of organic remains in the state; a thick group of limestone strata, usually black and fine grained with seams of slate toward the lower part, but gray and crystalline near the top.

PLATE XXX.—To face page 148.

N. H. Darton, photo.

Glens Falls on the Hudson River, Saratoga and Warren Counties. Trenton Limestone.

PLATE XXXI.—To face page 148.

N. H. Darton, photo.

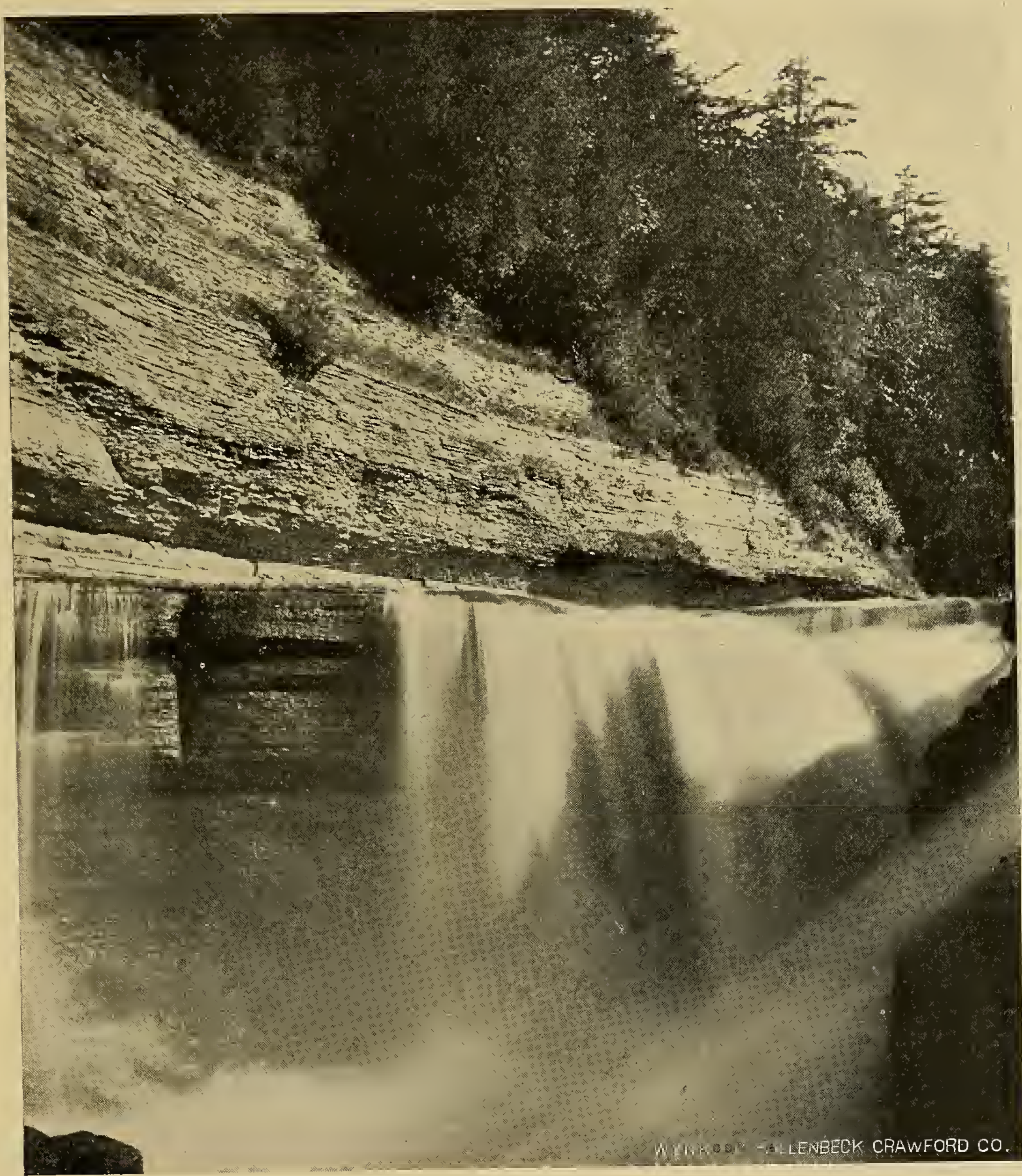
UPPER GORGE, TRENTON FALLS, ONEIDA CO. TRENTON LIMESTONE.

PLATE XXXII.—To face page 148.

N. H. Darton, photo

Principal Cascade, Trenton Falls, Oneida Co. Trenton Limestone.

PLATE XXXIII.—To face page 148.



N. H. Darton, photo.

TRENTON LIMESTONE, SPENCER FALL, TRENTON FALLS, ONEIDA CO.

PLATE XXXIV.—To face page 148.

N. H. Darton. photo.

UTICA SHALE, TRENTON LIMESTONE AND CALCIFEROUS SANDROCK, CANAJOHARIE, MONTGOMERY CO.

It attains an entire thickness of more than 300 feet, and, succeeding the lower rocks as already described, its edges surround the great Adirondack region in an almost unbroken circuit. Seen at Glens Falls on the Hudson, along the Mohawk at Fort Plain and elsewhere, on the west shore of Lake Champlain, and at many points on the shores of the St Lawrence, it also outcrops along the valley of the Black river and is crossed by West Canada creek at Trenton Falls, from which place it takes its name.

In many places it furnishes building stone of excellent quality.

Hudson River Group

This formation, which is next in upward succession, is an enormous deposit of sandstone, slate and shale. The lower part of the Hudson river group is a fissile black slate about 75 feet thick, known as the Utica slate.

The higher strata, to which the name of the Hudson river group is more usually restricted, are gray slaty masses, with coarse sandstones, especially toward the top, and in some places near the summit of the group, a coarse sparry limestone.

In the eastern part of the state these rocks are 3,500 feet thick, as shown by a boring near Altamont in Albany county. They are well seen in the north of Oswego county, near Pulaski, the south of Lewis county and the middle of Oneida county; also through the Mohawk valley, and from Glens Falls southward along the Hudson river, from which these strata take their name. West of Schenectady they are generally level and undisturbed; but near the Hudson river these strata are upheaved, broken, folded and faulted in every conceivable manner, as may well be seen in many places near Cohoes and Albany and along the Hudson river railroad. In much of this disturbed region the rock has been changed in texture by the forces to which it has been subjected and fossils are very rare.

That part of New York lying east of the Hudson, and along the western border of New England is formed of an enormous mass of upheaved and contorted strata of slate, schist sandstone and limestone, which were at one time supposed to be older than the Potsdam sandstone, and were called Taconic. This range of rocks contains very few fossils or none in most localities, and geologists have been obliged to study it without the aid which fossils would have given in explaining the relation and true position of its confused and contorted strata. The general conclusion has been that this series of strata is not a separate and distinct one, but merely the eastward extension of the rocks older than the Medina and Clinton groups, changed in character or 'metamorphosed' by the effect of heat and pressure. The work of Walcott and others has proved that most of the schistose rocks are of Hudson river age, though a portion of them contain Lower and Middle Cambrian fossils and are therefore distinct.

In Westchester and New York counties, rocks of Hudson river age cover large areas. They are, however, metamorphosed into mica schist and contain no fossils.

Life of the Lower Silurian

The animal life of this system was also marine and chiefly represented by sponges, corals, brachiopods, mollusks and crustaceans. Cephalopods were the dominant forms and were of great size. Fishes have recently been announced by C. D. Walcott. No land animals are known to have existed except some insects reported from Europe. Vegetable life was represented by sea weeds, though a land plant has been found in Great Britain.

UPPER SILURIAN SYSTEM

The Upper Silurian system, which is the upper division of the original Silurian system, consists in New York state of the following divisions:

System	Group	
Upper Silurian	Lower Helderberg	
	Onondaga Salt Group	Waterlime Salina
	Niagara	
	Clinton	
	Medina	
	Oneida	

PLATE XXXV.—To face page 150.

N. H. Darton, photo.

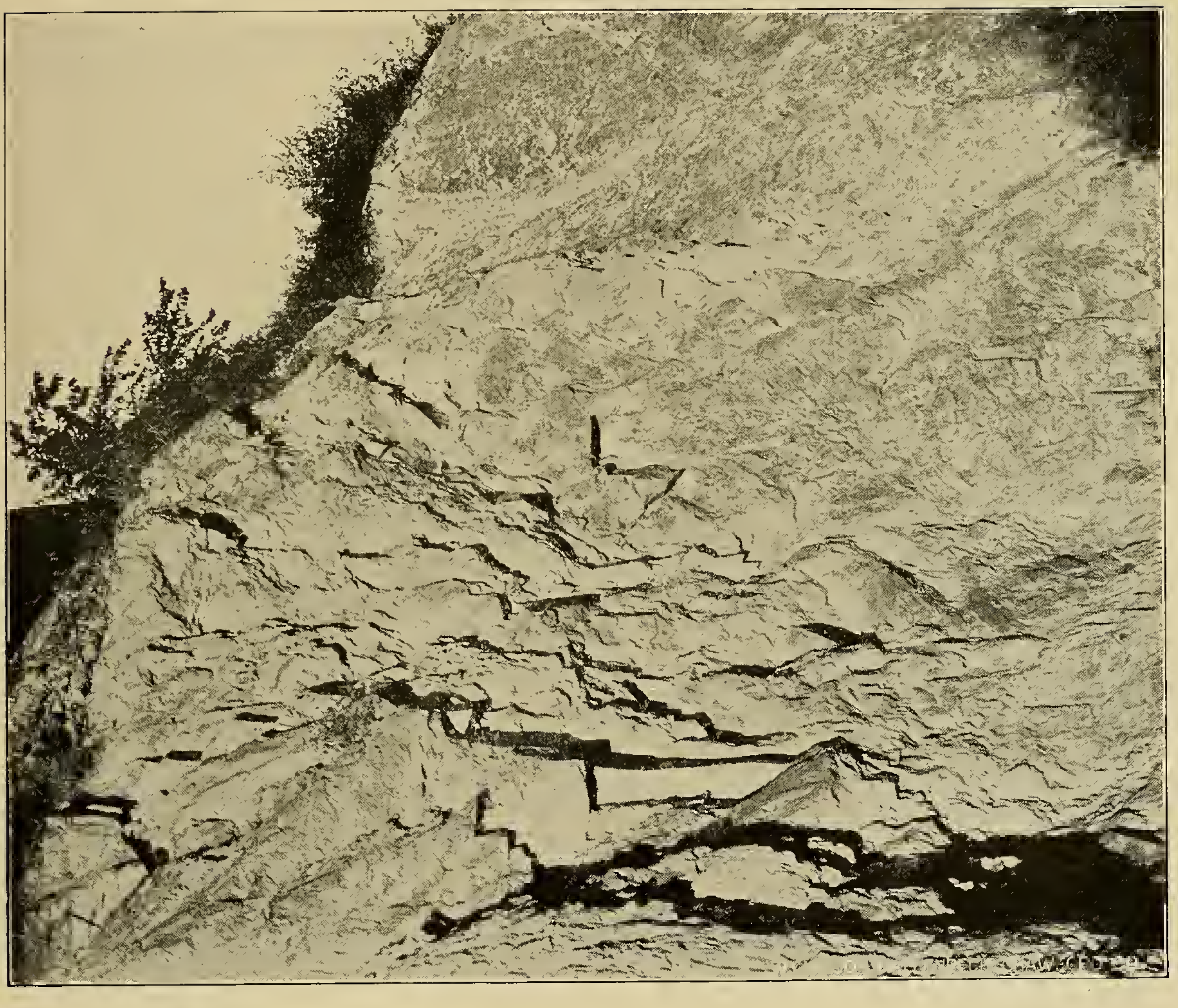
GORGE IN THE UTICA SHALE SOUTH OF CANAJOHARIE, MONTGOMERY CO.

PLATE XXXVI.—To face page 150.

H. Ries, photo.

FOLD IN SANDSTONES OF THE HUDSON RIVER GROUP, CATSKILL CREEK, GREENE CO.

PLATE XXXVII.—To face page 150.



J. N. Nevius, photo.

HUDSON RIVER SHALE IN RAILROAD CUTTING. KENWOOD, ALBANY CO. DIP VERTICAL.

PLATE XXXVIII.—To face page 150.

J. F. Kemp, photo.

Crumpled Hudson River Schist, with Pegmatite Veins, Opposite 130th St., on West Side of St. Nicholas Ave., New York City.

PLATE XXXIX.—To face page 150.

H. Ries, photo.

METAMORPHOSED HUDSON RIVER MICA SCHIST OVERLYING SEMICRYSTALLINE CALCIFEROUS-TRENTON LIMESTONE.
VERPLANCK'S POINT, WESTCHESTER CO.

Generally speaking, the lowest of these groups lies conformably upon the strata of the Hudson river group,—the uppermost of the Lower Silurian,—though in eastern Albany county the Hudson river shales are much disturbed.

In regard to this relation it has been said by Dana[a]: 'Cases of intervening erosion may be found, for every period loses by erosion a large part of its deposition in the supply of material for the beds of the following period.'

Oneida Conglomerate

The Hudson river group is covered in many places by a bed of conglomerate consisting chiefly of coarse sand and rounded pebbles of quartz, cemented together into a firm mass. Being well developed in Oneida county south of Utica, it has received its name from that of the county.

It is the base of the Lower Silurian system. In central New York it is but a few feet in thickness, and indeed seems to be entirely wanting in many places; but in the lower Hudson valley it swells to a thickness of several hundred feet and southwest of Rondout forms the Shawangunk mountain from which it receives the name of Shawangunk grit. From this place its upheaved edges may be traced in the range of hills southeast of the Delaware and Hudson canal and parallel to it, and the same rock forms most of the mountain range of the Kittatinny or Blue Ridge, along which the Delaware flows from Port Jervis, where it leaves New York, to the famous Delaware Water Gap where it cuts through the barrier. From this point, its edge ranges southward to Virginia. No fossils have yet been discovered in it: indeed the rolled and worn condition of its materials would indicate that it was formed under agitated waters, which did not allow the growth or preservation of organic forms.

The well known summer resort of Lake Mohonk is on the Shawangunk grit.

The 'Rensselaer plateau,' in Rensselaer county, is an extensive outcrop of greenish conglomerate, resting conformably

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a Man. Geol. pp. xxx

upon the Hudson river schists. This is probably equivalent to the Oneida conglomerate, or possibly the base of the Medina group.

The source from which such enormous quantities of rolled pebbles of quartz could have been derived and the mode by which they could have been spread so widely over a sea bottom is a very obscure question in geology. Several other such formations of conglomerate are known, two of which occur at the lower and middle parts of the Carboniferous system.

Medina Sandstone

The next succeeding group is that named from a village in Orleans county where it is well exposed.

It is a huge mass of sandy and shaly rock, of very variable hardness from soft marl to hard sandstone, and varying in color from deep red to olive and light gray. It is not known in the far west, seeming to thin out and disappear before reaching Wisconsin, but is well seen on the Niagara river, where it forms most of the precipice near Lewiston. At this point the lower part is a soft red shale, with harder and lighter colored layers above, to one heavy bed of which the cables of the Lewiston suspension bridge are fastened. This sandstone may also be seen in the lower part of the river cliffs, extending as far as the upper Suspension Bridge. The same rock is quarried near the lower part of Lockport for building and flagstone, and it forms the lower falls of the Genesee at Rochester, at the top of which the hard uppermost layer, called the 'Gray band,' is very conspicuous from its light color. Further east, the same rock forms the falls of the Oswego river at Fulton; but in the Mohawk valley it thins out, and disappears. In southeastern New York, however, near Rondout, it re-appears and is very thick at the Delaware water gap in New Jersey and Pennsylvania, reaching, in the latter state, the thickness of 1,000 feet; and it may be recognized as far south as Alabama.

PLATE XL.—To face page 152.

N. H. Darton, photo.

EASTERN FACE OF SHAWANGUNK MOUNTAIN, 2 MILES SOUTH OF LAKE MOHONK, ULSTER CO. ONEIDA CONGLOMERATE RESTING ON HUDSON RIVER SHALE.

N. H. Darton, photo.

CLIFFS OF SHAWANGUNK GRIT ON THE WEST SHORE OF LAKE MOHONK, ULSTER CO.

PLATE XLII.—To face page 152.

N. H. Darton, photo.

Awosting Falls over Shawangunk Grit, Peterkill, near Lake Minnewaska, Ulster Co. Oneida Conglomerate.

PLATE XLIII.—To face page 152.

Medina shales and sandstone

I. P. Bishop, photo

NIAGARA GORGE NEAR LEWISTON. MEDINA GROUP.

PLATE XLIV.—To face page 152.

Clinton limestone.

Clinton shale.

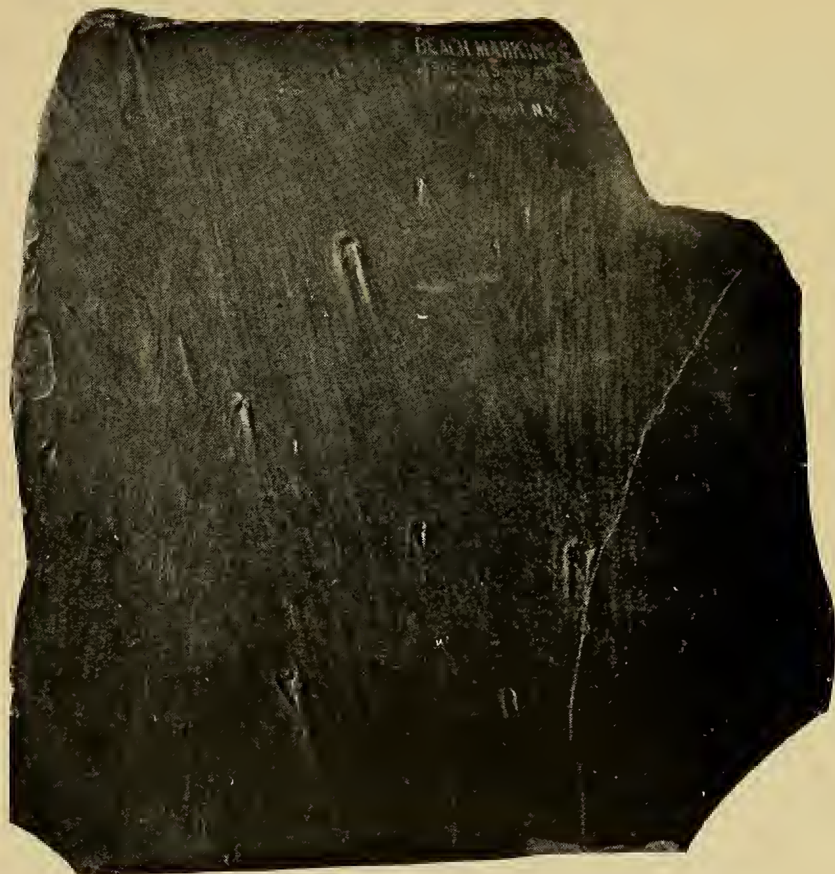
Medina grey sandstone.

Medina red shales and sandstones.

I. P. Bishop, photo.

NIAGARA RIVER GORGE, SOUTH OF LEWISTON, NIAGARA CO.

PLATE XLV.—To face page 152.

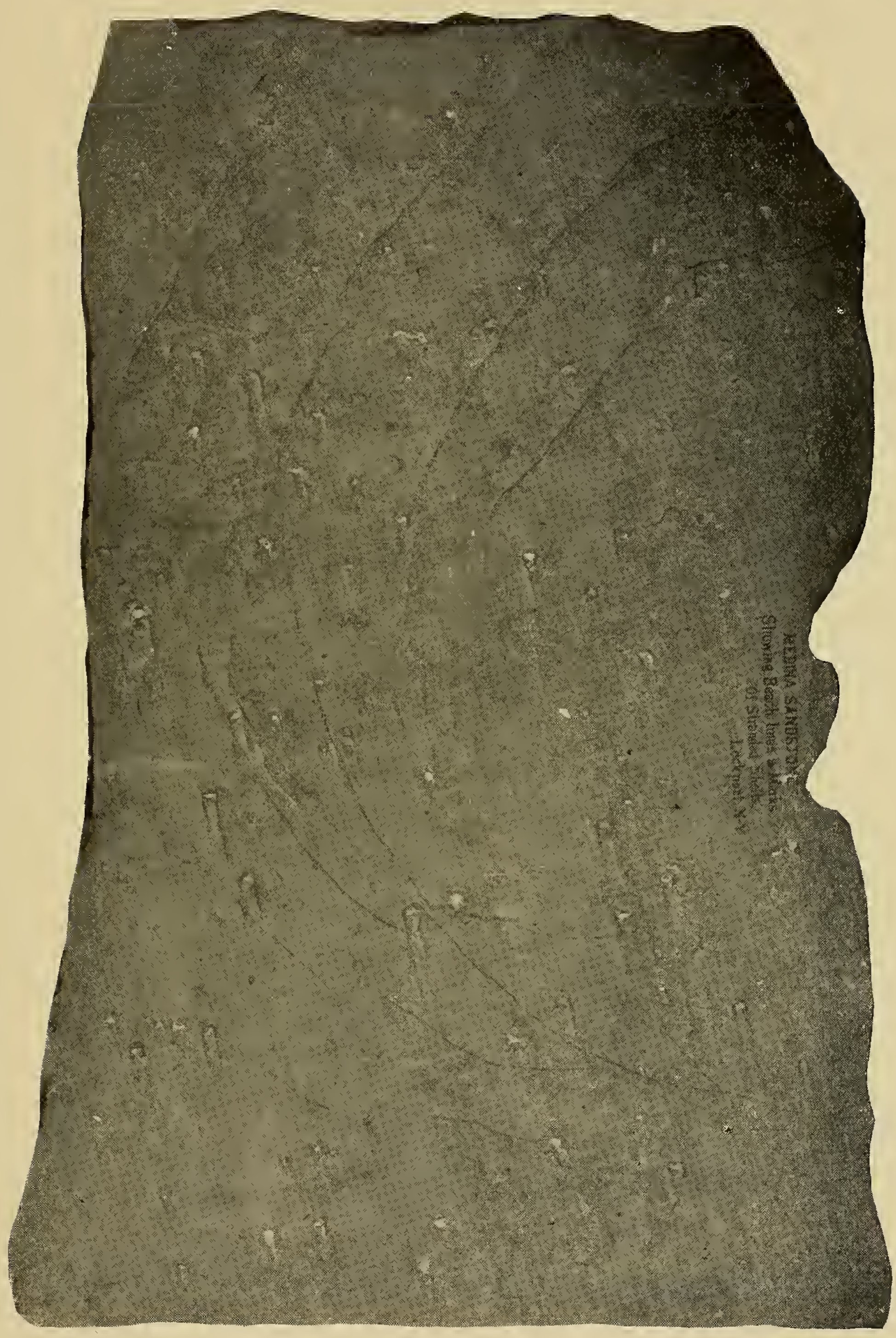


J. N. Nevius, photo.

BEACH MARKINGS ON MEDINA SANDSTONE.

SEAWEED, ARTHROPHYCUS HARLANI, ON MEDINA SANDSTONE.

PLATE XLVI.—To face page 152.



J. N. Nevius, photo.

BEACH MARKINGS ON MEDINA SANDSTONE, LOCKPORT, NIAGARA CO.
ORIGINAL SLAB 53 INCHES BY 32 INCHES.

PLATE XLVII.—To face page 152.

I. P. Bishop, photo.

FALLS OVER MEDINA GREY SANDSTONE, NEAR LOCKPORT, NIAGARA CO.

PLATE XLVIII.—To face page 152.

I. P. Bishop, photo.

MEDINA GREY SANDSTONE, NEAR LOCKPORT, NIAGARA CO. QUARRY OF R. KEENEY.

PLATE XLIX.—To face page 152.

Webster & Albee, photo.

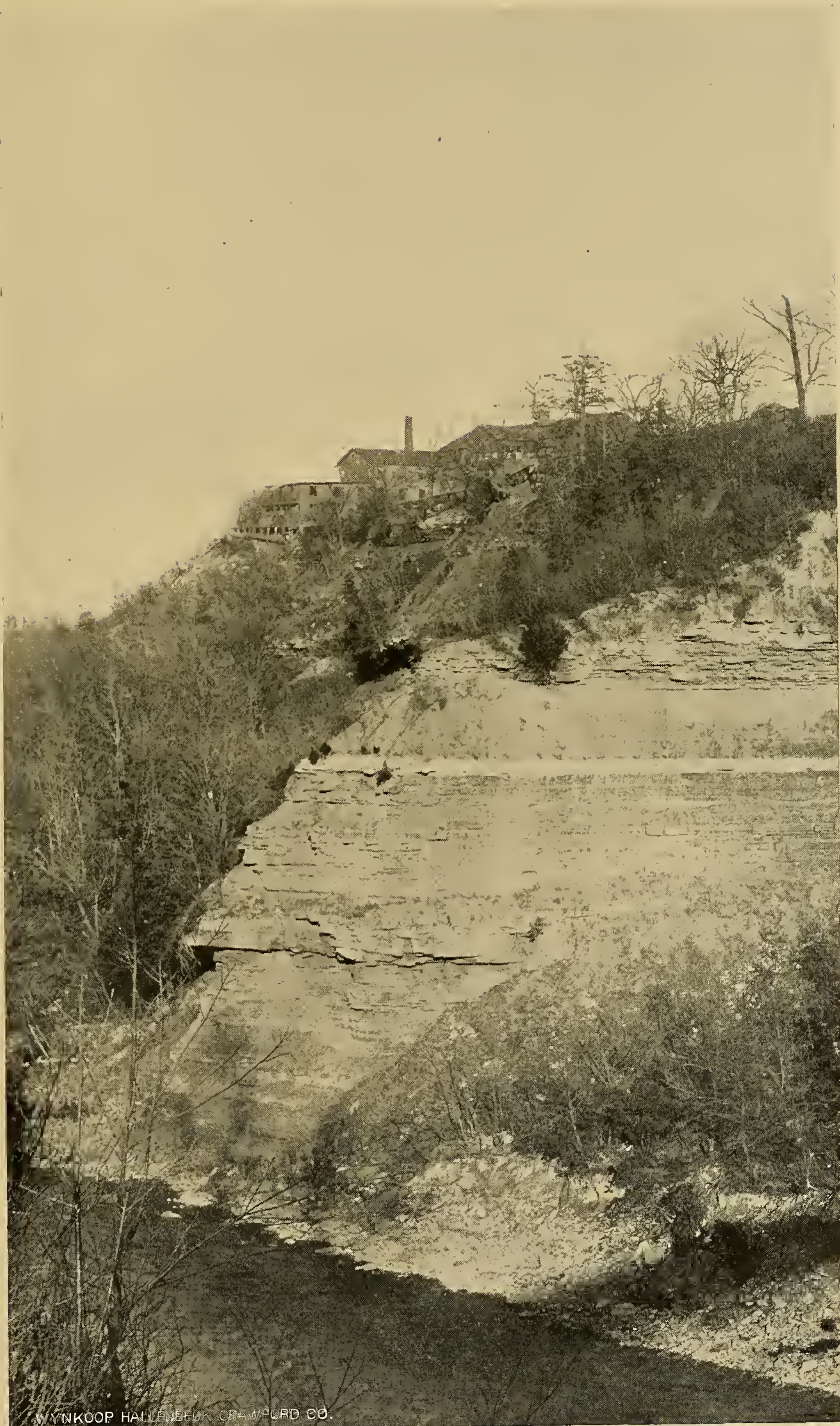
LOWER FALLS OF THE GENESEE RIVER, OVER THE GREY MEDINA SANDSTONE. MONROE CO. MEDINA AND CLINTON GROUPS.

PLATE L.—To face page 152.

Webster & Albee, photo.

GORGE OF THE GENESEE RIVER, MONROE CO., BELOW THE LOWER FALLS. MEDINA, CLINTON AND NIAGARA GROUPS.

PLATE LI.—To face page 152.



Webster & Albee, photo.

Gorge of the Genesee River, Monroe Co., below the Lower Falls. Medina and Clinton Groups.

Clinton Group

Above the Medina sandstone lies a series of sandstones, limestones and shales, which receives its name from one of the localities where it is well seen, the vicinity of Clinton, Oneida county. This group of strata is hardly distinguishable east of Fulton county, appearing to thin out in the eastern part of the state, where it is all sandstone and greenish shale. In the western part of the state, however, it contains two distinct layers of limestone and two of greenish shale, which can be well examined above the lower falls of the Genesee river near Rochester. Two thin strata of iron ore are found in this group, and are extensively mined in the vicinity of Clinton; the ore is of a peculiar granular appearance like an aggregate of small shot, and contains many fossils of small size.

On the Niagara river, the upper limestone of this group is about 20 feet thick, and a very solid, massive rock. At the falls, this layer is near the level of the water below the cataract.

This group of rocks extends westward through Canada, but does not appear beyond Wisconsin as a distinct mass. It re-appears in Pennsylvania in enormously increased thickness, amounting to nearly 2,000 feet, and extends southward along the Appalachian chain even to eastern Tennessee. It seems everywhere to contain beds of iron ore of the same character as those in New York.

Niagara Group

This group consists in the region from Wayne county westward of two distinct members, a shale and limestone, which, are recognized as the products of one period, during which, there was an important change in the materials deposited and a lesser one in the animal life. The shale is a very uniform deposit throughout the whole extent of the fourth district; while the limestone, from a thin, dark colored, concretionary mass at the east becomes an extensive and conspicuous rock, constantly increasing in thickness in a westerly direction, even far beyond the limits of the state.

The cataract of Niagara is produced by the passage of the river over this limestone and shale; and from being a well known and extremely interesting locality, as well as exhibiting the greatest natural development of these rocks within the limits of the state, this name has been adopted for its designation.

Standing on the upper suspension bridge at Niagara Falls, one sees in the precipice, above the Clinton limestone, a sloping bank of soft gray shale about 80 feet thick, above which succeeds a thick series of layers of limestone forming the brink of the rocky wall: these are the Niagara shale and the Niagara limestone. The great cataract pours over their edges; and its vertical descent is owing to the fact that the soft shale below wears away more rapidly than the hard limestone which forms the top of the fall, thus maintaining a recess behind the descending sheet of water. These rocks are perfectly exhibited in the gorge of the Niagara river, especially along the Niagara Falls and Lewiston railroad.

The limestone at Niagara is about 160 feet thick (of which only the lower part is seen at the falls); at Rochester it is about 70 feet thick. The shale decomposes rapidly where exposed to the air, until it resembles a deposit of gray clay. It contains thin layers of limestone in many places, the surfaces of which are often covered with beautiful small corals of several species, and the shale itself contains them in great numbers. The 'deep cut' of the canal above Lockport is through the Niagara limestone, some layers of which there form a massive and beautiful building stone. The same limestone and shale form the upper falls of the Genesee at Rochester.

Salina Group, or Onondaga Salt Group

The next series of strata in upward succession is a group of shales and thin limestones, the whole of which in central and western New York attains a thickness of nearly 1,000 feet. Its lower part in central New York is composed for several hundred feet of a soft red shale or hardened clay, especially conspicuous along the Erie canal in Madison county. Its upper

PLATE LII.—To face page 154.

Niagara shale.

Clinton limestone.

I. P. Bishop, photo.

NIAGARA RIVER GORGE, BELOW DEVIL'S HOLE, NIAGARA CO. NEW YORK CENTRAL RAILROAD CUT.

PLATE LIII.—To face page 154.

Niagara shale.

Clinton limestone.

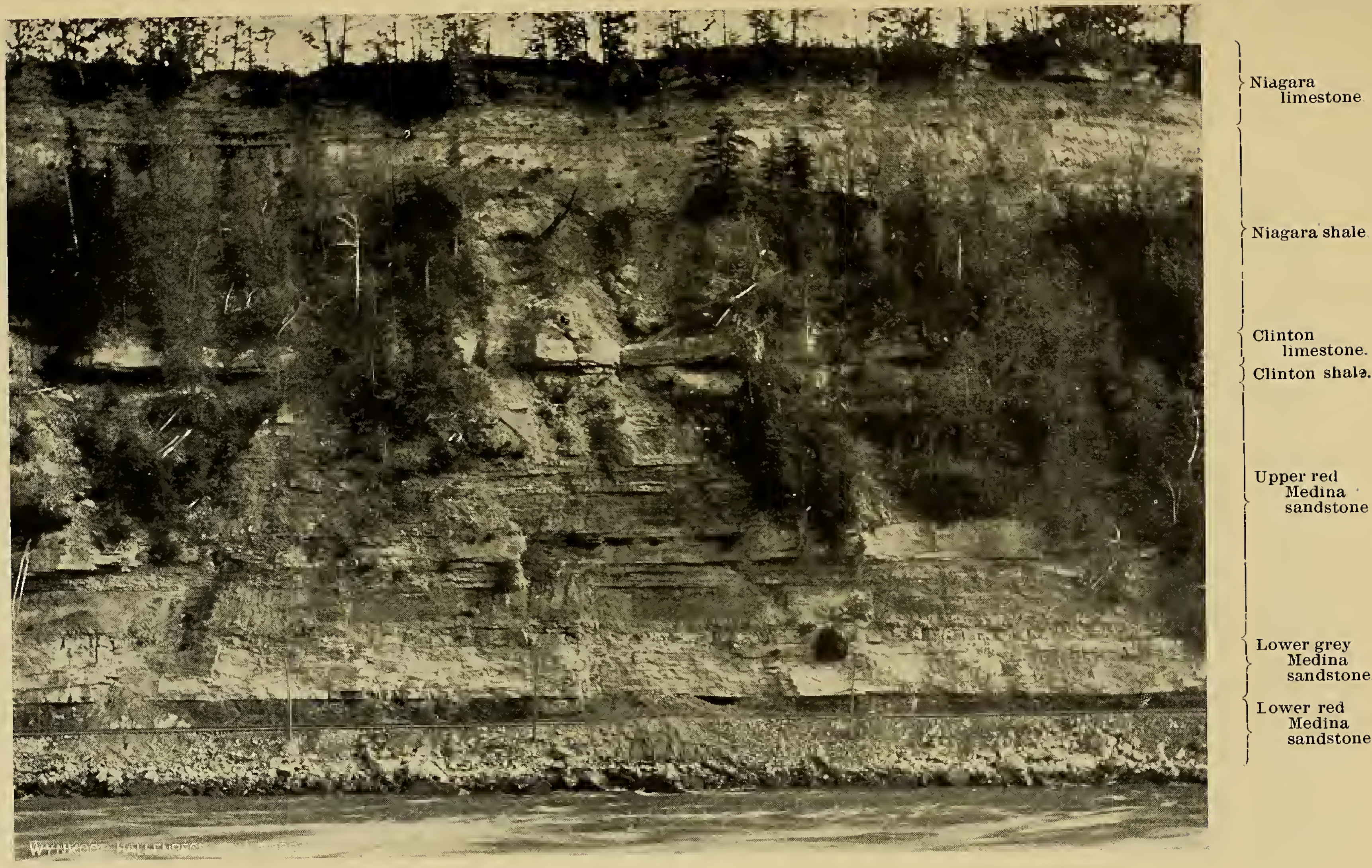
Clinton shale.

Medina grey sandstone.

I. P. Bishop, photo.

NIAGARA RIVER GORGE, SOUTH OF LEWISTON, NIAGARA CO. NEW YORK CENTRAL R. R. CUT.

PLATE LIV.—To face page 154.



I. P. Bishop, photo.

Wall of the Niagara River Gorge, American Side. View from Foster's Flats, 1½ Miles North of Suspension Bridge.

PLATE LV.—To face page 154

Niagara limestone.

Niagara shale.

Clinton limestone.

Clinton shale.

Upper grey Medina.

Medina red shales and sand-stones.

I. P. Bishop, photo.

Niagara Gorge Below the Suspension Bridge, Niagara Co. View from the Canadian Side.

PLATE LVI.—To face page 154.

I. P. Bishop, photo.

NIAGARA RIVER GORGE, FROM THE SUSPENSION BRIDGE, LOOKING NORTH. MEDINA, CLINTON AND NIAGARA GROUPS.

I. P. Bishop, photo.

OUTLET OF THE WHIRLPOOL, NIAGARA RIVER, NIAGARA CO. VIEW NORTHWARD FROM THE CANADIAN SHORE.

Webster & Albee, photo.

UPPER FALLS OF THE GENESEE RIVER, ROCHESTER, MONROE CO. NIAGARA GROUP.

PLATE LIX.—To face page 154.

Webster & Albee, photo.

GORGE OF THE GENESEE RIVER. BELOW THE UPPER FALLS, ROCHESTER, MONROE CO. NIAGARA GROUP.

PLATE LX.—To face page 154.

I. P. Bishop, photo.

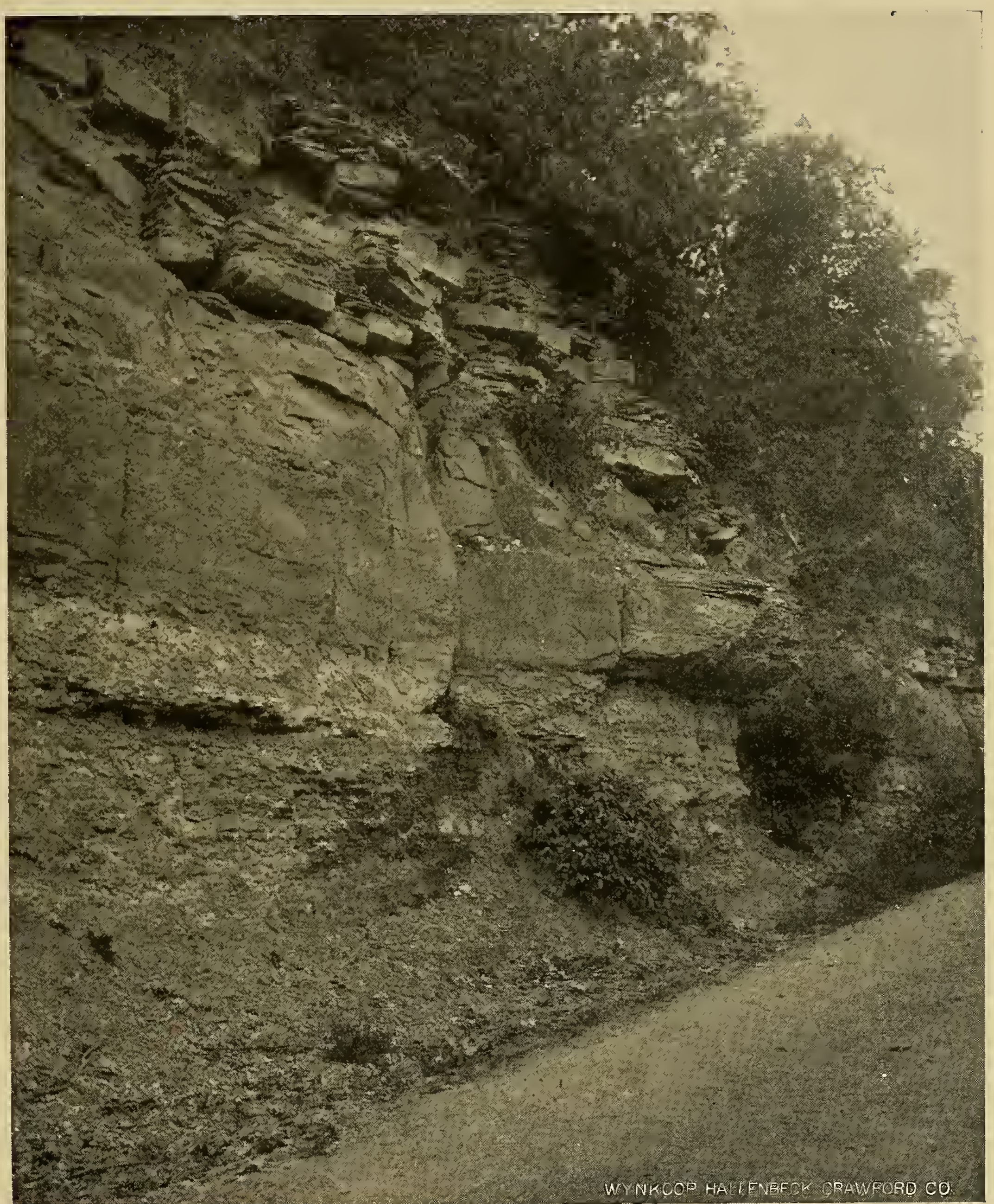
Niagara River, Niagara Co. View from Bluff near Lewiston, Looking North.

PLATE LXI.—To face page 154.

Salina shales.

Niagara limestone.

Clinton shales.



N. H. Darton, photo.

UPPER SILURIAN ROCKS IN ROAD CUT NEAR HOWE'S CAVE, SCHOHARIE CO.

PLATE LXII.—To face page 154.

N. H. Darton, photo.

Clinton and Salina Groups in West Bank of Rondout Creek, High Falls, Ulster Co., N. Y.

PLATE LXIII.—To face page 154.

N. H. Darton, photo.

ARCH IN SALINA AND CLINTON BEDS AT HIGH FALLS, ULSTER CO.

portion is generally a dark gray slaty rock, with layers of impure limestone, well seen along the Auburn and Syracuse railroad. The important salt springs of Syracuse being derived from these rocks, they received originally the name of Onondaga salt group.

In the days of the original Natural History Survey, the salt was not found in solid masses, though the gray part of the rock in some places showed impressions of the peculiar 'hopper shaped' crystals of halite or rock salt, proving that it once existed there in small quantities. It is now known to be diffused in beds and lenses through large extents of these strata, through which in places the surface water percolates and bears the salt in solution to the deep basin at Salina. This was found, by boring, to be several hundred feet in depth, filled with gravel and sand, in which the salt water seemed to lie as in a reservoir, and from which it is raised by the pumps for the supply of the evaporating works. The Onondaga lake, which is a comparatively shallow body of fresh water, lies over this deep mass of gravel, but has a water tight bottom of marl which keeps its fresh waters separate from the salt waters below.

During the past 18 years a large industry has been developed from the boring of salt wells in New York state at points distant from Syracuse, at Warsaw and in the Genesee valley. These wells show that rock salt in beds and lenticular masses varying in thickness from a few inches to 150 feet is abundantly intercalated between the layers of shale and limestone of the Salina group. This salt being easily soluble in water does not appear at the surface of the ground nor within reach of surface waters.

The upper drab or gray shales of this group contain great quantities of gypsum, which is quarried extensively from Madison county westward. The rock over the masses of gypsum often seems arched, as if this mineral, in forming, through some chemical change, had exerted an upward pressure, lifting the overlying masses.

The whole group is remarkably destitute of organic remains; not a single fossil having been found in the lower part or red shale, and but a small number in the upper portion at a few localities.

The Onondaga-salt group is hardly seen in New York east of Herkimer county. The succeeding formation, however, which is grouped with the Salina is fairly persistent.

Waterlime

Overlying the salt-bearing rocks and forming with them the Onondaga group is the Waterlime, a succession of dark-colored, fine-grained and straight-bedded layers of limestone, attaining in Madison county a thickness of over 100 feet. It lies immediately over the gray and drab limestones of the upper part of the salt group, and is not divided from them by any very distinct or sudden change in the appearance of the strata. The name is given from the waterlime or hydraulic cement which is extensively manufactured from two of the layers toward their upper part: these are generally of a drab color, and separated from each other by a thin mass of blue limestone. They are quarried, burnt and ground on a very large scale near Manlius in Onondaga county, and the hydraulic cement of Rosendale and Rondout is made from the same beds. That manufactured at Williamsville, Erie county, and at Buffalo, is from the upper limestones of the Salina group below; and in Niagara and Orleans counties, a similar cement is made from some layers of the Niagara group.

HELDERBERG ROCKS

Above the formations already described succeeds a thick series of strata, chiefly limestone, separated by sandstone and grit rocks, first described under the general name of the Helderberg rocks, as they formed the great escarpment of the Helderberg mountains in Albany county. From this place their edges may be followed southward in the hills lying west of the Hudson river, past the base of the Catskill mountains, and through Ulster county as far as Kingston and Rondout; whence their outcrops bend southwestward and extend along the hills west of the valley of the Delaware and Hudson canal, passing out of the state near the northwest corner of New Jersey. They run still farther southwestward, are seen above the Delaware Water Gap, and their

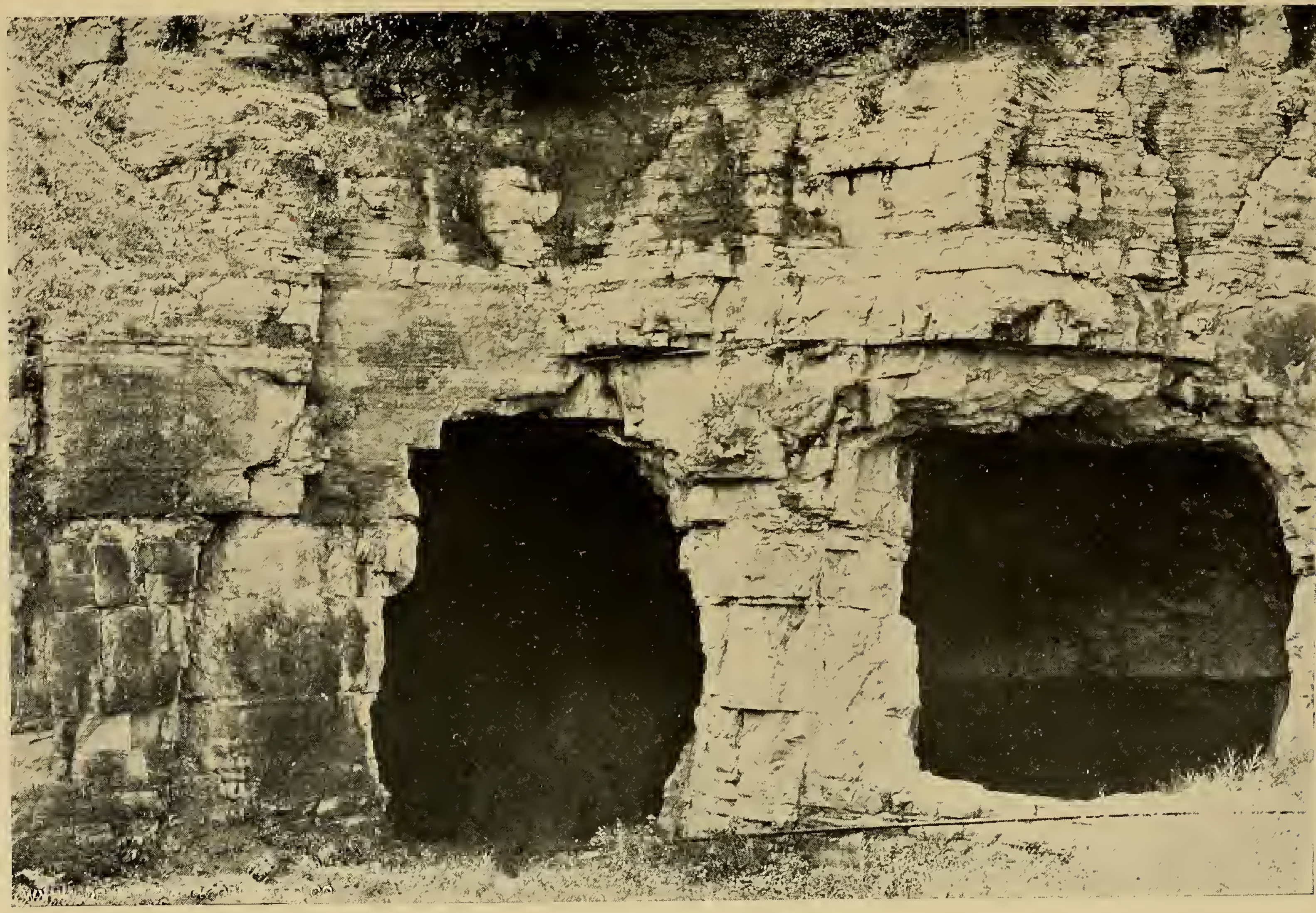
PLATE LXIV.—To face page 156.

I. P. Bishop, photo.

MINE OR QUARRY OF THE CUMMINGS CEMENT CO., AKRON, ERIE CO.

N. B.—The term "bull-head" is used by the quarrymen to denote the impure limestone which overlies the cement rock and is unfit for use.

PLATE LXV.—To face page 156.



H. Ries, photo.

OLD MINE OF THE NEWARK CEMENT CO., RONDOUT, ULSTER CO. WATERLIME GROUP.

PLATE LXVI.—To face page 156.

N. H. Darton, photo.

HIGH FALLS OF RONDOUT CREEK OVER CEMENT BEDS OF THE WATERLIME GROUP, ULSTER CO.

lower strata are traceable in the Appalachians as far as Tennessee, though their upper limestones do not extend beyond the Susquehanna. In following them westward from Albany county, we find the lower limestones and sandstones thin out rapidly, not extending beyond the Niagara in any considerable thickness, while the upper limestones are found spreading into the far west.

This series of rocks which may be considered collectively in its effect on topography, belongs partly to the Upper Silurian system and partly to the Devonian and may be divided into two parts; the Lower Helderberg limestones which are of Upper Silurian age, and the Oriskany sandstone and Upper Helderberg limestones which are included in the Devonian.

Lower Helderberg Group

The subdivisions of this group are as follows:

	Thickness
Scutella limestone Upper Pentamerus	15 ft. in Albany county
Delthyris, or Catskill shaly limestone	100 ft.
Lower Pentamerus limestone	65 ft. in Albany county
Tentaculite limestone	30 ft. "

The Scutella limestone, named from a fossil crinoid which it contains, is the uppermost member of the group where it occurs, but it has not been found associated with the Upper Pentamerus.

The Lower Pentamerus limestone is coarse-grained, thick-bedded and often a concretionary limestone; while the Catskill limestone is in thin layers, with much shaly or slaty matter interstratified with it.

The Lower Helderberg group has its greatest development in Albany and Schoharie counties; the subdivisions above given may be differentiated in Greene, Albany and Schoharie counties, but west of the last county they are not distinct and the group itself is indistinguishable from the Salina formation, at the surface, west of Seneca lake. In the Livonia salt shaft, however, about 35 feet of limestone was found containing Tentaculite fossils. It may, with the waterlime, be traced through Pennsylvania and Virginia, but is very thin and not found everywhere, having been deposited locally in areas of no great extent.

Life of the Upper Silurian

There is no radical difference between the general character of the fossil remains of this system, and those of the Lower Silurian, but of several thousand species found in the Upper Silurian, only a few occur also in the Lower Silurian, and the animal forms are nearly all marine. Sea weeds were very abundant and a few land plants, similar to equisetae, occur.

DEVONIAN SYSTEM

This system takes its name from Devonshire in England where its rocks were studied by Sir Roderick Murchison.

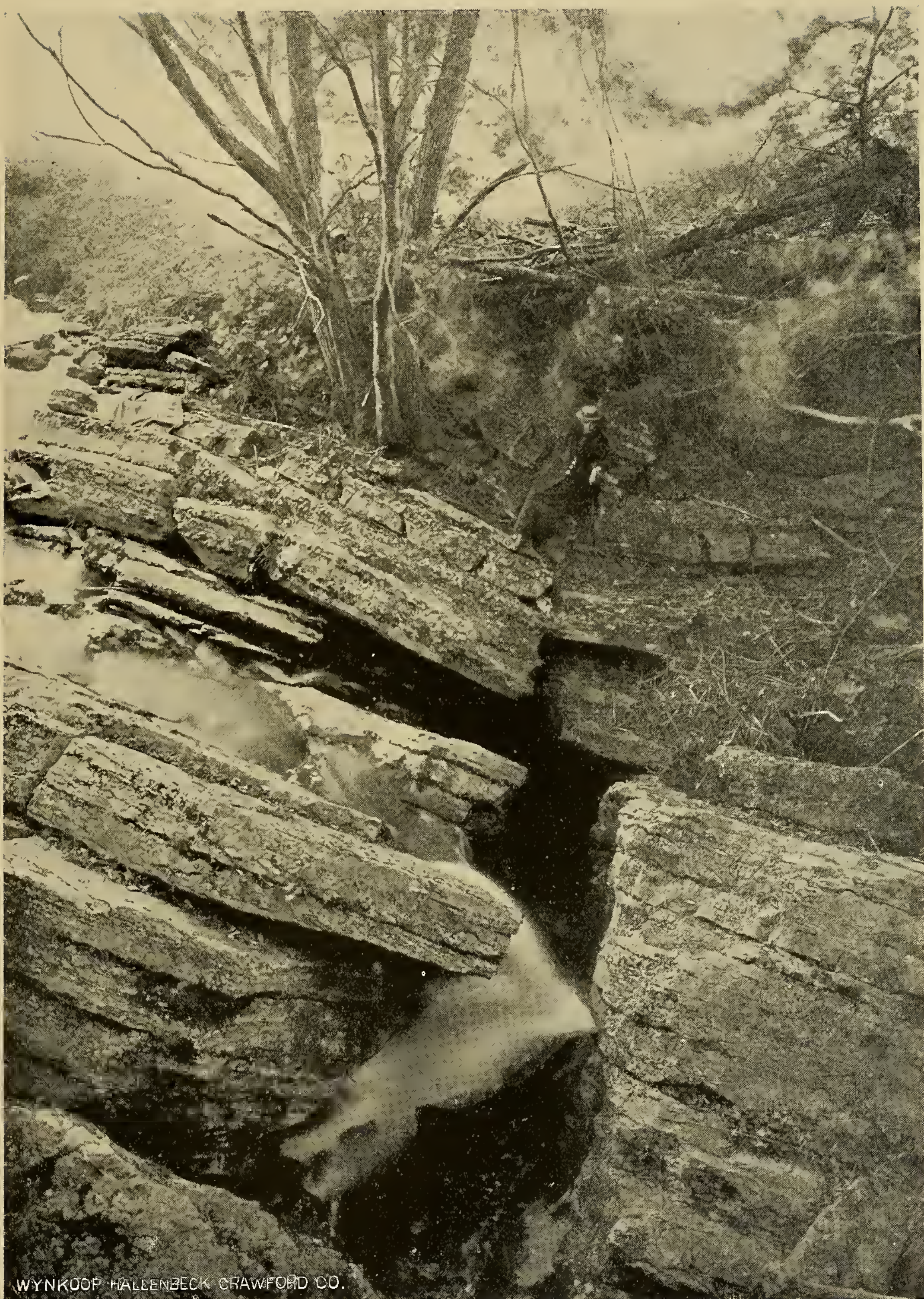
The Devonian was the age of fishes, since fishes were the prevailing type. America has probably the most complete series known of the Devonian rocks but they have a comparatively limited extent. The Devonian rocks contain much carbon in the form of bituminous shales and it has been suggested that there may be more carbon in the Devonian than the Carboniferous. These rocks are well developed in New York but the vertebrate life of the system is better shown in other states.

System	Group	Stage
Devonian	Chemung	
	Portage	Gardeau shales
		Cashaqua "
	Hamilton	Genesee "
		Tully limestone
		Moscow shale
		Encrinal limestone
		Ludlowville shale
		Marcellus "
	Corniferous	Corniferous limestone
		Onondaga "
		Schoharie grit
	Oriskany	Cauda Galli grit
		Oriskany sandstone

PLATE LXVII.—To face page 158.

HELDERBERG ESCARPMENT, WEST MOUNTAIN, SCHOHARIE, FROM A PHOTOGRAPH BY N. H. DARTON.

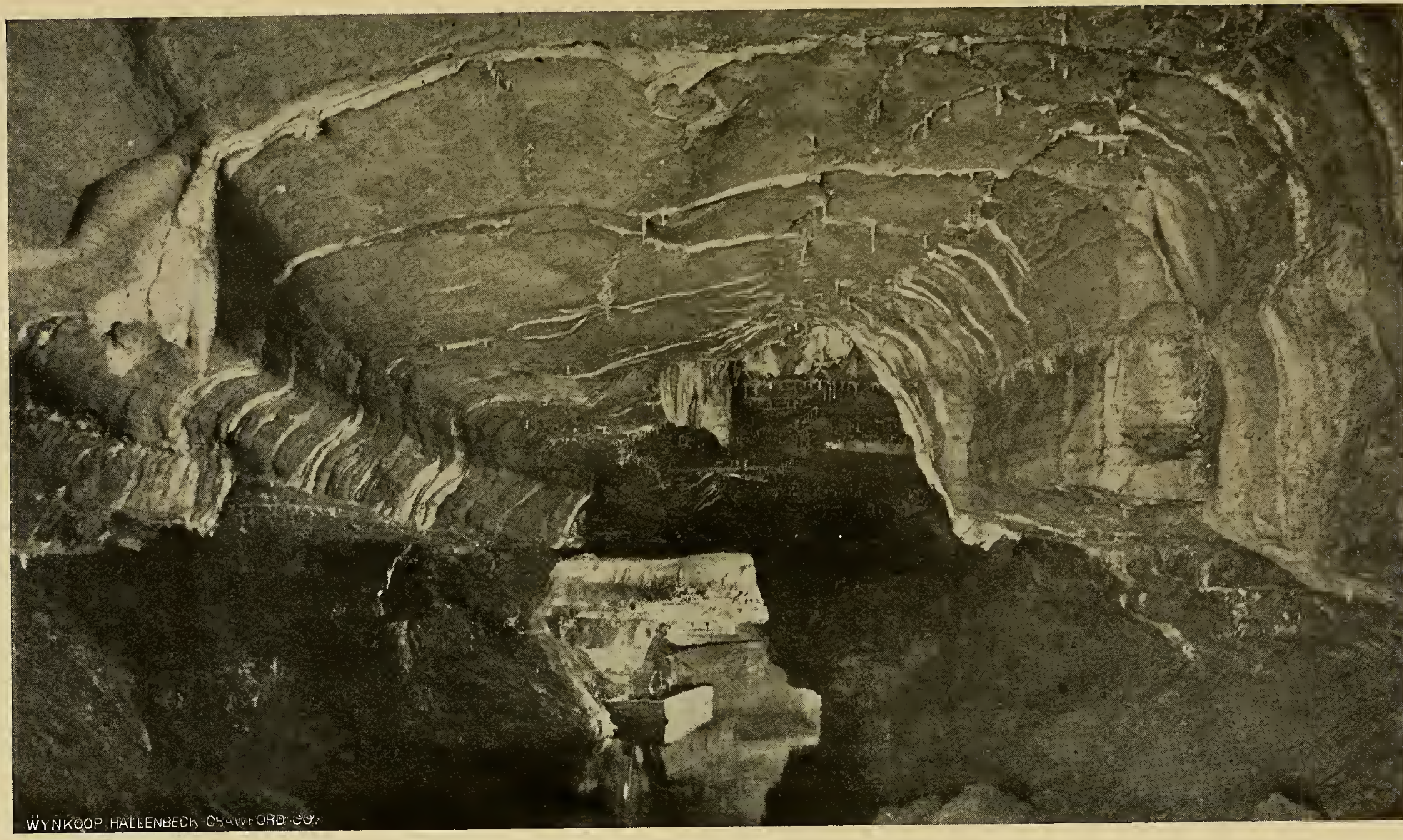
PLATE LXVIII.—To face page 158.



N. H. Darton, photo.

Sink in the Lower Helderberg Limestone West of Coxsackie, Greene Co.

PLATE LXIX.—To face page 158.



S. R. Stoddard, photo.

INTERIOR OF HOWE'S CAVE, SCHOHARIE CO., SHOWING SUBTERRANEAN STREAM, STALACTITES, ETC LOWER HELDERBERG LIMESTONE.

PLATE LXX.—To face page 158.

N. H. Darton, photo.

CLIFF OF LOWER PENTAMERUS LIMESTONE, NEAR INDIAN LADDER, ALBANY CO.

Oriskany sandstone

This rock which overlies the Lower Helderberg group, is, at Oriskany Falls, whence it derives its name, a coarse light colored sandstone about 20 feet thick. In localities further west it is sometimes, as at the falls of the Chittenango creek and at Split Rock near Syracuse, either wanting or represented only by a few inches of dark sandy rock; sometimes, as between Elbridge and Skaneateles, 30 feet thick; and in other localities, of various intermediate thicknesses. Near Schoharie, it contains some lime with its sand, and is light colored; in some parts of the Helderberg region, as near Clarksville, and Knox, it is only a foot or two thick, a hard, dark colored stratum full of fossils and having[a] on its upper surface myriads of impressions of the Spirophyton cauda galli. In Pennsylvania, it is from 150 feet to 300 feet in thickness, and contains the same organic remains which are found in it in New York.

Cauda Galli Grit

Above the Oriskany sandstone, in the Helderberg region, is a mass of sandy slate or shale, often more than fifty feet thick; but it is not known west of Herkimer county. In Pennsylvania, it is seen from the state line to the Water Gap. It is valuable as a road metal though not very durable and forms, by decomposing, a poor soil. It is equally barren in fossils, the only form known being what is called the Cocktail fucoid, Spirophyton cauda galli, supposed to be the remains of a marine plant, the form of which resembles the peculiar plumage from which it is named. The abundance of this fossil has given the rock in which it lies the name of 'Cauda galli grit.[b]

Schoharie Grit

Upon it lies the Schoharie grit, a thin mass, usually only four or five feet of hard calcareous sandstone, which, when freshly quarried, looks like a gray limestone, but when long weathered,

a This important fact is not noted by either Mather or Lincklaen though it must have been observed by them. F. J. H. M.

b As I have noted under Oriskany, this fossil is not confined to the Cauda galli and occurs on the Oriskany sandstone. F J. H. M.

loses its carbonate of lime and becomes a gritty yellowish sandstone. It is found only from Cherry Valley eastward, extending round the front of the Helderbergs and along the hills west of the Hudson, but does not appear to be known in Pennsylvania.

Upper Helderberg or Corniferous Limestone

This which lies above the Schoharie grit, Cauda galli grit and Oriskany sandstone, and where these are wanting, together with the Lower Helderberg, as in western New York, rests immediately on the waterlime group, is one of the most widely known and useful limestones of the state. The lower portion, from 10 to 20 feet in thickness, is generally a coarse-grained crystalline gray rock, and, when free from chert, working well under the hammer and chisel, and often taking a good polish as a marble. It is called, from being very extensively quarried in Onondaga county, the Onondaga Limestone. It is easily traced from near Rondout on the Hudson to the Helderbergs in Albany county, where its outcropping edge turns westward, and extends past Schoharie, Cherry Valley, Bridgewater, Oriskany falls, the falls of the Chittenango below Cazenovia, Split Rock, Auburn, Phelps, Le Roy, and Williamsville to Black Rock. Through nearly all this distance it preserves its well marked character, and is extensively used in building.

The upper portion of the group is what was originally called the Corniferous limestone, from its containing beds and nodules of hornstone or chert: it is usually from 30 to 50 feet thick, a bluish or grayish rock, often having some shale interstratified with it. Though these two portions of the Upper Helderberg limestone are in most places very distinct, yet in others, especially in the west, they seem to run together or blend in one mass; so that they are now regarded only as local varieties of a single rock.

Upper Devonian Rocks

In the Upper Helderberg group, we have the last or highest formation of limestone of any considerable extent or thickness in the state. All the southern counties, lying above or south of

PLATE LXXI.—To face page 160.

I. P. Bishop, photo.

Corniferous Limestone, Cayuga Creek, Bellevue, Erie Co. The Surface Shows the Dissolving Action of Water.

the line of outcrop of the Onondaga and Corniferous limestones as before described, are nearly destitute of this useful rock; being formed of vast deposits of slaty, shaly, and sandy strata, several thousand feet in thickness, the exposures of which extend southward from a few miles south of the Erie canal to beyond the Pennsylvania line.

These rocks give rise to peculiarities in the topographic features of the country which they underlie, and in its soil and vegetable productions. Containing little lime, the culture of wheat does not generally succeed well upon them; nor does the central wheat growing district extend over them for more than a few miles south of the limestone range, except in a few alluvial valleys, or places where calcareous materials from the limestone belts have been strewed over the southern shales by glacial action, of which we shall speak hereafter. Grazing and dairying are almost exclusively the pursuits of the farmer.

The most marked physical features of this great extent of country are its deep valleys and long hills, usually extending in a north and south direction, as an inspection of any map will show. Some of these long north and south valleys dammed by drift deposits are the basins of that remarkable series of lakes beginning with Otsego, and comprising Canaseraga, Cazenovia, Otisco, Skaneateles, Owasco, Cayuga, Seneca, Crooked, Canandaigua, Honeoye, Canadice, Hemlock, and Conesus; all so similar in general form and direction, and in the shape and geological formation of their enclosing hills. Over the whole extent of these rocks, the country is 'rolling,' or broken into ridges generally running north and south, and rising from one to eight hundred feet above the main valleys; and it is rarely that we find among them a plain half a mile wide, except in a few of the 'bottom-flats' or alluvial lands along the larger rivers, such as the Genesee.

These rocks are generally quite uniform in their character, especially in the eastern part of the state near the Hudson valley, and might be grouped into one enormous formation 5,000 feet or more in thickness, except for a few variations in texture, and some more marked differences in the fossils of their lower, middle, and higher portions, on account of which they have been separated and described under the successive divisions of the Marcellus, Hamilton, Genesee, Portage, Chemung and Catskill.

Hamilton group

The Hamilton group, named from its exposure at Hamilton, Madison county, consists of the following sub-divisions.

Group	Stage	
Hamilton	Genesee	
	Tully	
	Hamilton	Moscow shale Encrinal limestone Ludlowville shale
	Marcellus	

Marcellus Shale

The lowest division, resting immediately on the Upper Helderberg limestone, was named from the village of Marcellus, near which it is well exposed. It is a mass of dark, fissile, short-fractured shale, one or two hundred feet in thickness, in most places containing layers of impure limestone and rounded concretions of similar material in its lower part.

At the village of Stafford in Genesee county, a thin limestone is well exposed about 40 feet above the base of the Marcellus. It has been called by Prof. J. M. Clarke, the Stafford Limestone, and extends from central New York to Lake Erie.

In Onondaga county the Goniatite limestone replaces the Stafford limestone.

These shales closely resemble those of the coal formation and sometimes contain thin seams of coaly or bituminous matter, which have misled many persons to spend considerable sums in digging and boring in them, with the illfounded expectation of finding useful layers of coal. This is an idle hope, for they lie thousands of feet below the Carboniferous system, beneath which no valuable coal strata have ever been found.

I. P. Bishop, photo.

MARCELLUS AND HAMILTON SHALES, ATHOL SPRINGS, SHORE OF LAKE ERIE, ERIE CO.

PLATE LXXIII.—To face page 162.

I. P. Bishop, photo.

Cliff of Devonian Shales, Shore of Lake Erie, Near Bay View, Erie Co.

PLATE LXXIV.—To face page 162.

I. P. Bishop, photo.

EXPOSURE OF DEVONIAN SHALES, GORGE OF EIGHTEEN MILE CREEK, ERIE CO.

PLATE LXXV.—To face page 162.

I. P. Bishop, photo.

Upper Devonian Rocks, Gorge of Eighteen Mile Creek, Near Lake View, Erie Co., ¼ Mile Below the L. S. & M. S. R. R. Bridge.

Encrinal limestone.

I. P. Bishop, photo.

HAMILTON SHALES, SHORE OF LAKE ERIE, AT THE MOUTH OF EIGHTEEN MILE CREEK, ERIE CO.

I. P. Bishop, photo.

Devonian Rocks. Wanakah. Shore of Lake Erie, Erie Co.

PLATE LXXVIII.—To face page 162.

N. H. Darton, photo.

DEVONIAN STRATA, HONK FALLS, NEAR NAPANOCK, ULSTER CO.

Hamilton Shale

The Marcellus shales change gradually at their higher part into the Hamilton shale which is a harder, lighter colored mass, often containing sandstones, and, in central New York and as far east as the Catskill range, is 1,000 feet or more in thickness. Like the Marcellus shale, many parts of it show few marks of stratification; but it is divided vertically by joints, which, where it is excavated, are often as upright and smooth as the walls of a plastered building. In the more eastern part of the state, it is generally coarse-grained and sandy; in western New York, it is fine-grained, soft and more calcareous, forming by its decomposition a rich soil.

In the survey of the fourth district Hall divided the Hamilton into three parts; at the base the *Ludlowville shale*, overlaid by the *Encrinal limestone* and at the summit the *Moscow shale*. The Ludlowville and Moscow horizons take their name from localities in western New York. The Encrinal limestone is named from its prevailing fossil.

Tully limestone

The Hamilton group terminates in central New York with a very impure dark limestone, about 10 feet thick, which received its name from the village of Tully in Onondaga county. In the eastern and western parts of the state this rock does not exist, as it extends only from Ontario county to Madison, and beyond these limits the Genesee slate lies directly on the Hamilton group. The Tully limestone contains some fossils which are common to it and the lower shales.

Genesee

The next rock in upward order is the Genesee, a series of layers of thin-bedded, fissile, black slate, in some places 150 feet thick, but diminishing westward so that it is only about 25 feet on Lake Erie. It is, however, distinctly recognized in Pennsylvania, where it is some 300 feet thick. It derives its name from one of its best localities in this state, the gorge of the Genesee river below Portage. It is generally recognized by its black, soft, slaty texture, but its fossils are very rare.

Portage group

This name has been given to the next higher portion of the great slaty and shaly masses, which form the walls of deep gorge of the Genesee at Portage and cover everywhere on the south the Hamilton group and Genesee slates. This enormous pile of sandy, slaty and shaly strata is in some parts of the state 1,000 feet in thickness: it was divided by Prof. Hall into a lower mass called the Cashaqua shale, a middle mass called the Gardeau shale and flagstones, and a terminal mass of sandstones seen at Portage; but in middle and eastern New York, these divisions are not distinct.

Much of this group is a soft olive-colored shale; but its most useful portions are its layers of flagstone, which are largely quarried near Norwich and Ithaca, on the hills back of the Helderbergs, on those west of the Hudson river as far down as Rondout; and in Sullivan county near the Delaware river.

From Chenango and Broome counties eastward to Greene county the Portage is represented by the Oneonta formation which forms the lower 1,000 feet of the Catskill mountain strata.

The soft shales of the Portage group contain many of the concretions known as *Septaria*, which also occur in the Marcellus shales.

Chemung group

To the Portage succeeds the Chemung, so called from being well exhibited at the 'Narrows' of the Chemung river, near Waverly, in Tioga county. Its thickness of 1,000 or 1,500 feet is made up of a series of thin-bedded sandstones with intervening shales and occasional beds of impure limestone mainly formed by the materials of fossil shells. In many places it abounds with fossils. While well developed in central and western New York the Chemung, as a group of fine sediments, disappears to the eastward and is represented by the Catskill formation.

PLATE LXXIX.—To face page 164.

I. P. Bishop, photo.

ERODED DEVONIAN SHALES, SHORE OF LAKE ERIE, MOUTH OF PIKE CREEK, NEAR DERBY, ERIE CO.

PLATE LXXX.—To face page 164.

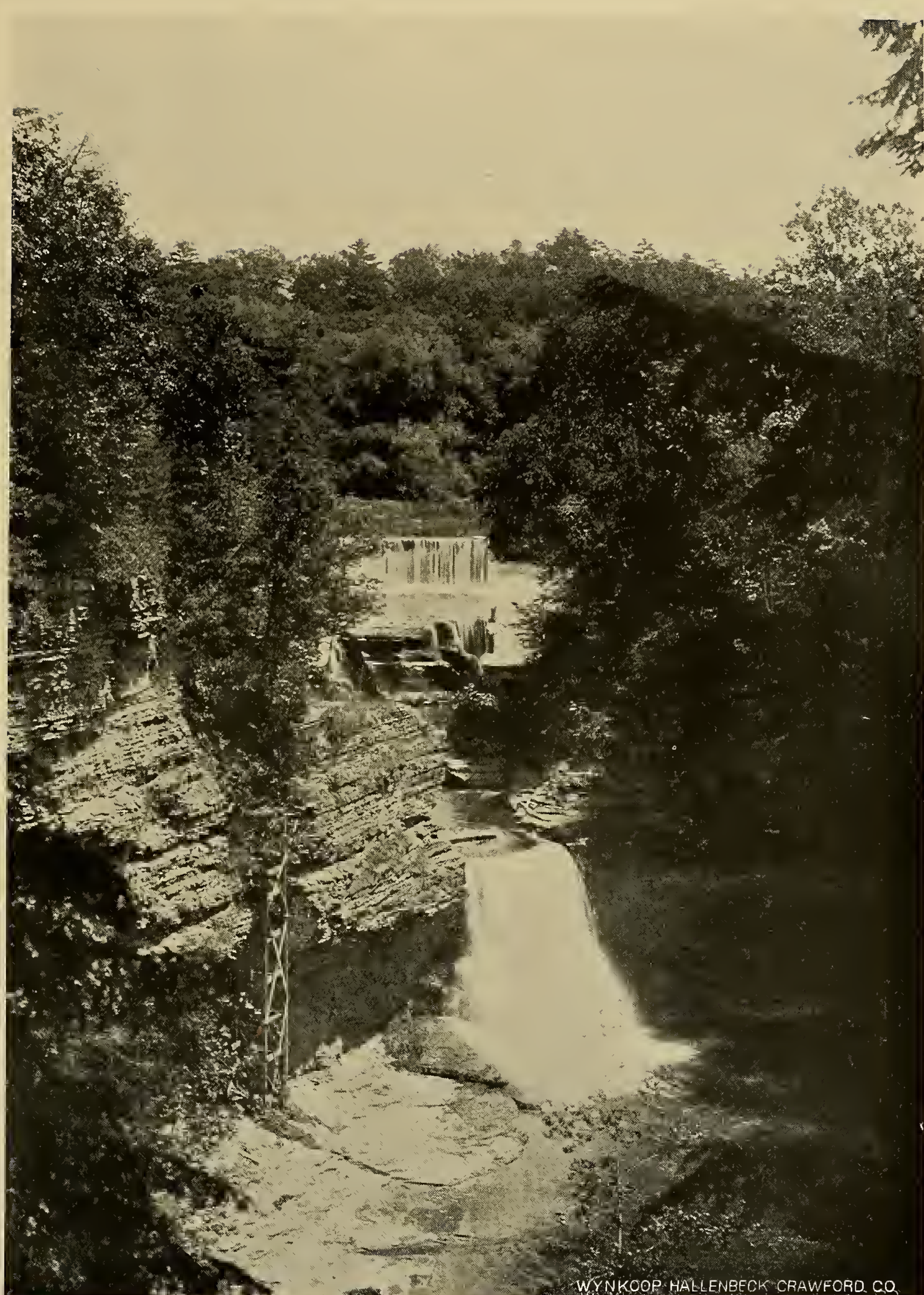
Cashaqua shale.

Genesee shale.

I. P. Bishop, photo.

HAMILTON AND PORTAGE SHALES, SHORE OF LAKE ERIE, MOUTH OF PIKE CREEK, NEAR DERBY, ERIE CO.

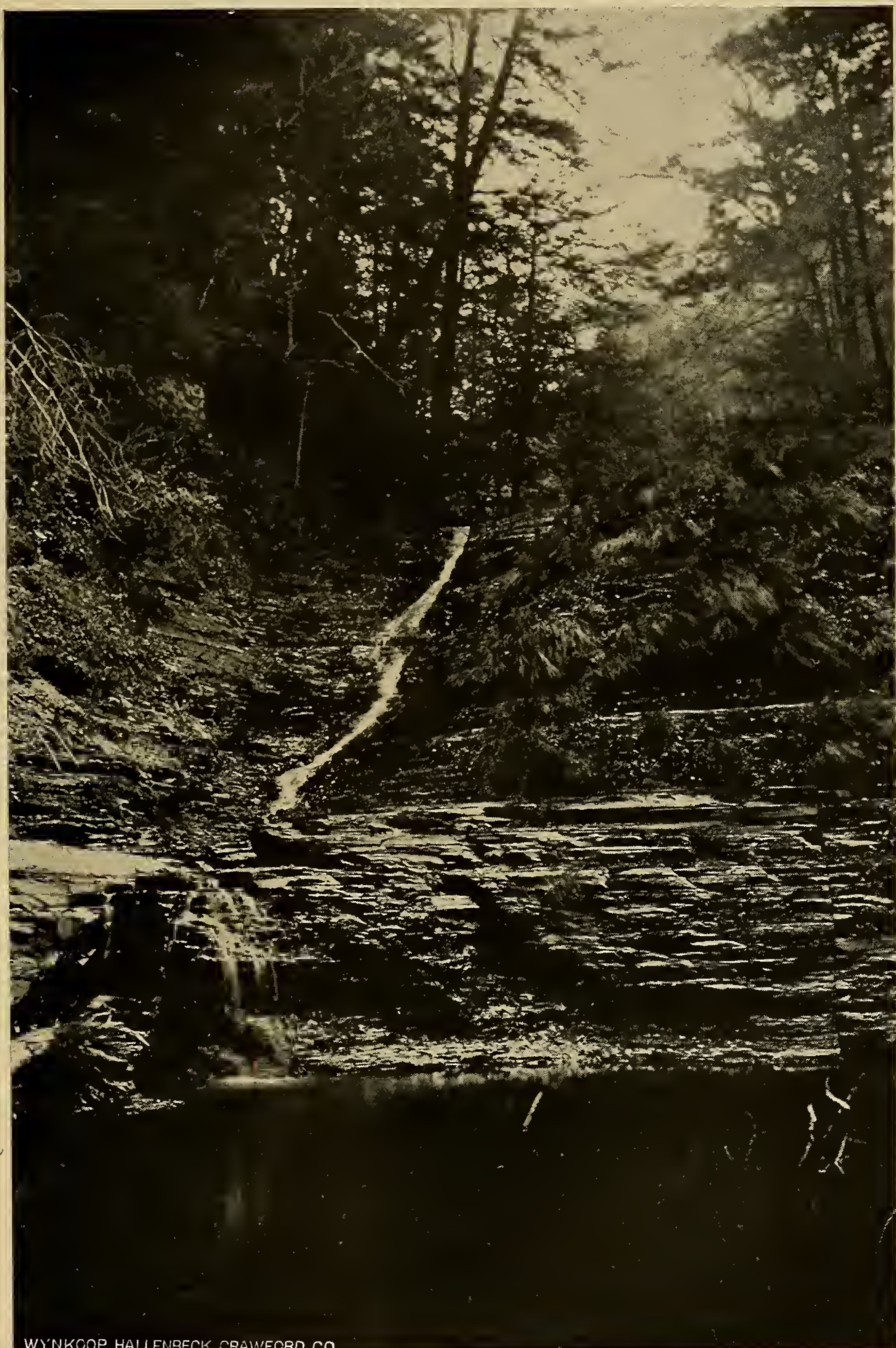
PLATE LXXXI.—To face page 164.



R. S. Tarr, photo.

LOWER PORTAGE SHALES, TRIPHAMMER FALLS, ITHACA, TOMPKINS CO.

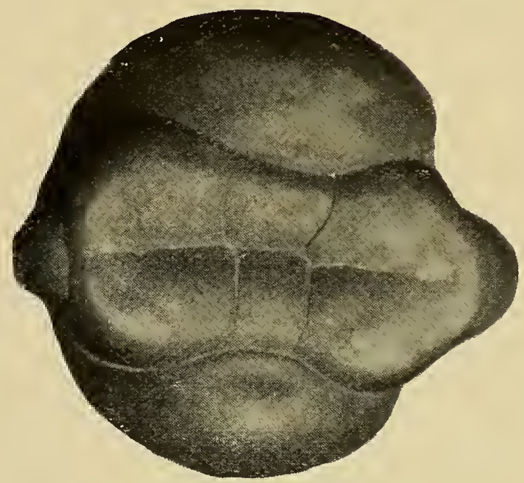
PLATE LXXXII.—To face page 164.



I. P. Bishop, photo.

BLACK SHALES, PORTAGE GROUP, PIKE CREEK, NEAR WEST FALLS, ERIE CO.

PLATE LXXXIII.—To face page 164.



14″ x 13″

18″ x 16″

Clay Iron Stone Concretions, Pcrtage Group, Shore of Lake Erie.

PLATE LXXXIV.—To face page 164.

N. H. Darton, photo.

View of the Wittemberg Range, Southern Catskills, from a Point Half a Mile East of Shokan Station, Ulster Co., Looking West.

Relief Map of the Eastern Catskill Mountains and the Hudson River Valley.

Catskill group

The Chemung passes or changes eastward into the Catskill, an enormous series of shaly and sandy strata, which covers all the upper range of the Catskill mountains, and many of the higher tracts of the southern counties as far west as Steuben. In the latter county it is only a thin mass of calcareous sandstone, and farther west it thins out and disappears entirely; but in the Catskill region it is probably 2,500 feet thick, and twice as much in Pennsylvania; whence it is found southward along the mountain ridges, but in thinner volume.

The beds of this series are varied in color, being greenish gray sandstones, fine-grained reddish sandstones, slates, shales, grindstone grits and an accretionary mass appearing like fragments of hard slate cemented in calcareous rock. The hard sandstone often weathers in a peculiar way, dividing into thin layers almost like piles of boards.

The fossils of this rock are very few. Recent studies of this group suggest that it is not entitled to distinct recognition but is equivalent to the Chemung and perhaps to the Portage. Remains of plants are numerous, forming occasionally tiny seams of coal; and in some localities are teeth, bones and scales of fishes. The latter are often conspicuous objects, as they are usually white or bluish in color, and contrast strongly with the red rock.

Life of the Devonian

In the Devonian is observed a marked general advance in the character of life on the globe.

Sponges were few. Brachiopods were varied and numerous. Mollusks were abundant. Corals were highly developed and very numerous.

Fishes were the dominant type and appear to have supplanted the immense cephalopods which ruled in the Lower Silurian seas.

Plant life was well represented on land, especially by ferns. Conifers also existed.

The abundant flora which gave rise to the coal formations of the Carboniferous first became prominent in the Devonian.

CARBONIFEROUS SYSTEM

This system took its name from the fact of its being the chief coal bearing formation of Europe.

The Carboniferous is not well represented in New York; some of the uppermost sandstones, shales and conglomerates near the Pennsylvania boundary are undoubtedly of this age, but they contain no fossils.

In the endeavor to identify the Carboniferous strata of New York, it has been necessary to take up the known strata of this age in Pennsylvania and trace them, so far as possible, into New York.

The gradation from the rocks of the Devonian to those of the Carboniferous is not abrupt. On either side of the assumed boundary plane are greenish gray shales and sandstones without distinctive characters. For the present purpose it is necessary to describe the succession of the Pennsylvania rocks and indicate their occurrence in New York.

Sub-Carboniferous, Pocono group

Above the uppermost Devonian sandstones lie the rocks which are considered to be the base of the Carboniferous system. They are mainly sandstones with occasional beds of conglomerate. This conglomerate is said to occur on some of the peaks of the Catskills, but it has not yet been recognized in southwestern New York.

Sandstones of Pocono age doubtless occur in New York near the Pennsylvania boundary but they have no fossils.

The Pocono formation attains a thickness of more than 2,500 feet in Pennsylvania on the Susquehanna river. Some thin seams of coal occur in it. It contains no fossils except fragments of plants.

Mauch Chunk group

The Pocono is succeeded by a formation called the Mauch Chunk group, which, in Pennsylvania, is about 3,000 feet in its greatest thickness, though far less in some districts. It is almost entirely composed of soft, red shales and argillaceous red sandstones seen in the northern counties and generally around the edges of the different coal fields. In southern Pennsylvania it includes limestones. This formation has not been recognized in New York.

Pottsville conglomerate

The Mauch Chunk red shale is covered by a thick series of strata, known as the Pottsville conglomerate. It is a gray and whitish conglomerate, in massive beds alternating with gray sandstones, and consists mainly of rolled and rounded quartz pebbles cemented with ferruginous sand into a solid mass. Some of its finer or more sandy layers often show lamination in a diagonal or slanting direction. It is 1,700 feet thick at its maximum and often contains one or more thin seams of coal; being the lowest horizon in which any considerable quantity of that mineral has yet been found. It is remarkably massive in its general appearance, the ledges often separating into huge blocks with wide fissures between, which have been fancifully compared to ruined cities. Such localities are to be seen in New York six miles south of Olean, seven miles south of Ellicottville and near Wellsville, where they are popularly called 'rock-cities.' This is locally known as the Olean conglomerate.

The 'rock cities' lie on high points not far from the Pennsylvania line and are simply remnants of the conglomerate left far north of the main body of the rock by the wear and tear of the elements, which, going on through ages, has worn away this massive stratum over a great extent of country. They are impressive monuments to the vastness of that erosion, which has left them in this isolated position and which will in the course of future centuries demolish them entirely.

This conglomerate is the highest and latest formed of all Palaeozoic rocks known within the limits of New York. In Pennsylvania it is the base of the 'Productive Coal-measures,' as the strata containing workable layers of coal are called. They are made up of thick beds of sandstones and black shale, with which the coal layers are interstratified. The coal strata are of all thicknesses, from a few inches up to 20 or even

100 feet, and are separated from each other by masses of rock from 10 or 20 to 200 or 300 feet thick, and are mined in various ways according to their situation.

Geologic investigation in all coal regions has led to the conclusion that the strata of coal are composed of vegetable matter, which during the Carboniferous epoch appears to have reached an enormous and luxuriant growth, and formed vast accumulations, which after being buried under the marine sediments of clay and sand which now form the shales and sandstones over them, underwent chemical changes which transformed them to their present condition. The proofs of this are found in the fact that the rocks above and below the coal seams are filled with vegetable remains, leaves, stems, roots, etc.; the trunks of the trees being in some places found still erect and standing upon their roots, but converted into coal; and that even the coal itself, though in most cases it is solidified into one mass so as to show no organic structure, displays in other instances, under the microscope, all the structure of wood; the cells, the ducts through which the sap once circulated, and even minute markings by which it can be determined whether the wood belonged to one or another general class of trees.

The vegetable origin of all coal is well established; but the mode in which great accumulations of it were made, over such vast areas, is yet an obscure question. A single bed of coal, that called the Pittsburgh seam, is known to extend over no less than 14,000 square miles, with a usual thickness of from four to ten feet. Other layers, though less in extent, are much greater in thickness, reaching even 100 feet. The prevailing opinion is that it grew in enormous morasses or swampy tracts, resembling on a larger scale the Great Dismal swamp, or the Okefinokee swamp of Georgia, in which the annual fall of leaves, branches, and trunks through a long period of time formed thick peaty masses, which, being submerged under the sea and covered with sediments, became the vast deposits of fossil fuel which are now of so great importance.

The fossils of the coal measures are almost entirely vegetable. In the slates above the coal seams, most perfect and beautiful impressions of leaves occur in profusion; and large trunks or stems are found, almost always compressed to a thickness of only an inch or two, though two feet or more in width. The greater part of these trees seem to have been allied to the tree-ferns of tropical climates, though there are remains of coniferous trees and several other vegetable families. The character of this fossil vegetation would seem to indicate that at the time it grew, a far warmer climate than that now known prevailed over the temperate and arctic zones.

The fact that coal is of vegetable origin, seems to explain why the lower rocks which form the state of New York contain no coal. *They appear to have been formed before terrestrial vegetation flourished to an extent sufficient to form accumulations of this substance.*

The first relics of land plants are found in the Upper Silurian; above this they become more numerous and in the Catskill group of the Devonian are quite abundant, forming occasionally miniature coal seams an inch thick.

In the Carboniferous rocks they increase suddenly to an enormous quantity, and in later formations are found in considerable, but generally in less abundance. Coal is also found in newer rocks, such as the Jurassic, Cretaceous and Tertiary. The coal or lignite beds of the central part of the continent near the Rocky mountains, belong to the Cretaceous and Tertiary rocks. The coal of Vancouver island on the Pacific coast is Cretaceous. The coal beds near Richmond, Virginia, are of Triassic age. The conclusions to be drawn from our present knowledge are that good coal is found *above* the Carboniferous system, but *never below it.*

Permian

This formation which is well developed in Europe, taking its name from the Province of Perm, in Russia, is not known to exist in New York state. It occurs in Texas and its vicinity. It has been suggested that some of the uppermost deposits commonly known as Carboniferous in Pennsylvania, should be referred to this horizon.

Life of the Carboniferous

Animals

Foraminifera were abundant. Sponges were well represented. Reef building corals were scarce. Crinoids were abundant.

Brachiopods were large and numerous.

Mollusks were prominently represented by cephalopods.

The fishes of the Carboniferous were very numerous and were principally sharks and ganoids.

The presence of amphibians was the prominent feature in the life of the Carboniferous; their bones occur in the coal measures. The largest were about the size of alligators.

Before the close of the Carboniferous, reptiles appeared.

Plants

Vegetable life was well represented by ferns, lycopods, equisetae, conifers and cycads. These were the plants which supplied the vegetable tissue which forms the coal beds.

Mesozoic Time

The Mesozoic presents a marked contrast to the Palaeozoic. The sea was peopled with fishes. Cephalopods were most prominent among the mollusks. True reptiles which appeared in the Permian were large and numerous and reached their highest development. Mammals appeared as a new element but held a subordinate position. They were at first quite small.

There was a complete change in the vegetation. Sigillaria and calamites disappeared and the age of gymnosperms succeeded that of acrogens or pteridophyta.

Arborescent conifers were very large and abundant. The cycads occupied the place of the palms of the present day.

The Mesozoic series includes the *Triassic*, *Jurassic* and *Cretaceous* systems.

TRIASSIC SYSTEM

This system received its name in Germany where it consists of three distinct members. In England it is known as the New Red Sandstone and contains the salt deposits of that country. West of the Mississippi river the Triassic is well represented in the United States, but in the east it is found only in narrow troughs on the east side of the Appalachian chain and approximately parallel to it. It is well developed in the Connecticut valley and is again found near Stony Point, New York, from which locality it extends southwest across Rockland county into New Jersey, thence through Pennsylvania and Virginia. In the latter state it includes the Deep and Dan river coal basins which are of considerable importance.

The Triassic deposits of New York and New England were apparently formed in estuaries and consist of shales and sandstones. These bear ripple marks, sun cracks, rain prints and the foot prints of enormous biped reptiles with three toes. These were at first supposed to be bird tracks. Fishes are also abundant in the sandstones of New York and New Jersey.

The eastern Triassic rocks are important as having furnished the greater part of the brown sandstone, which is used so extensively for building houses in our eastern cities. The Triassic period was also characterized by eruptions of igneous rock, which formed the well known trap dykes of Connecticut and New Jersey. In the latter state the most prominent is that known as the 'Palisades of the Hudson,' which extend along the west shore of the Hudson river from Staten Island to a point northwest of Nyack. At the level of the river the rock is a nearly horizontally stratified red sandstone; but between the bedding planes a vast volume of melted rock has been injected, and in cooling has assumed the rudely crystalline or columnar structure so common in basaltic or trap rocks. The broken edge of this enormous sheet of trap, fronting on the river, forms the precipice so well known as 'the Palisades.' The Orange mountains are also of the same formation.

Life of the Triassic period

In the Triassic was the reign of the amphibians, some of which were very large. The most highly developed was the labyrinthodon, which had the form of a frog and was as large as an ox. Reptiles were very large and numerous but their remains are more abundant in Europe than America. The mammalian fauna was insignificant; fishes were numerous; mollusks were abundant, but were not a prevailing type.

JURASSIC SYSTEM

The connection between the Triassic and Jurassic is very close and the passage is very gradual. The Jurassic takes its name from the Jura mountains of France and Switzerland, which are chiefly composed of the rocks of this age. In eastern North America the Jurassic is moderately developed, and it is considered that a part of the Triassic sandstone, already described, may have been deposited during this age.

West of the Mississippi the Jurassic is well developed.

Life of the Jurassic period

The Jurassic was especially characterized by the prominence of reptilian life which appeared in a great variety of forms and occupied every place in nature. Reptiles were large and numerous, in the ocean and on land. Even in the air immense lizards with wings like those of a bat were abundant. In this age the first of the birds appears. This was the *archaeopteryx*, found in the slates of Solenhofen, Germany, a bird which was rudimentary in its development. The wings were short and also the wing feathers which were radiated. The tail was vertebrated and the vertebrae bore feathers. It had no teeth. The sharks and ganoid fishes were large and abundant. The mammals were numerous, but subordinate in rank, not being larger than rats and opossums.

In this system also was the culmination of the ammonite family, a group of coiled cephalopods named from their resemblance to the horns on the statues of Jupiter Ammon. As the cephalo-

PLATE LXXXVI.—To face page 172.

H. Ries, photo.

TRIASSIC CONGLOMERATE, STONY POINT, ROCKLAND CO.

PLATE LXXXVII.—To face page 172.

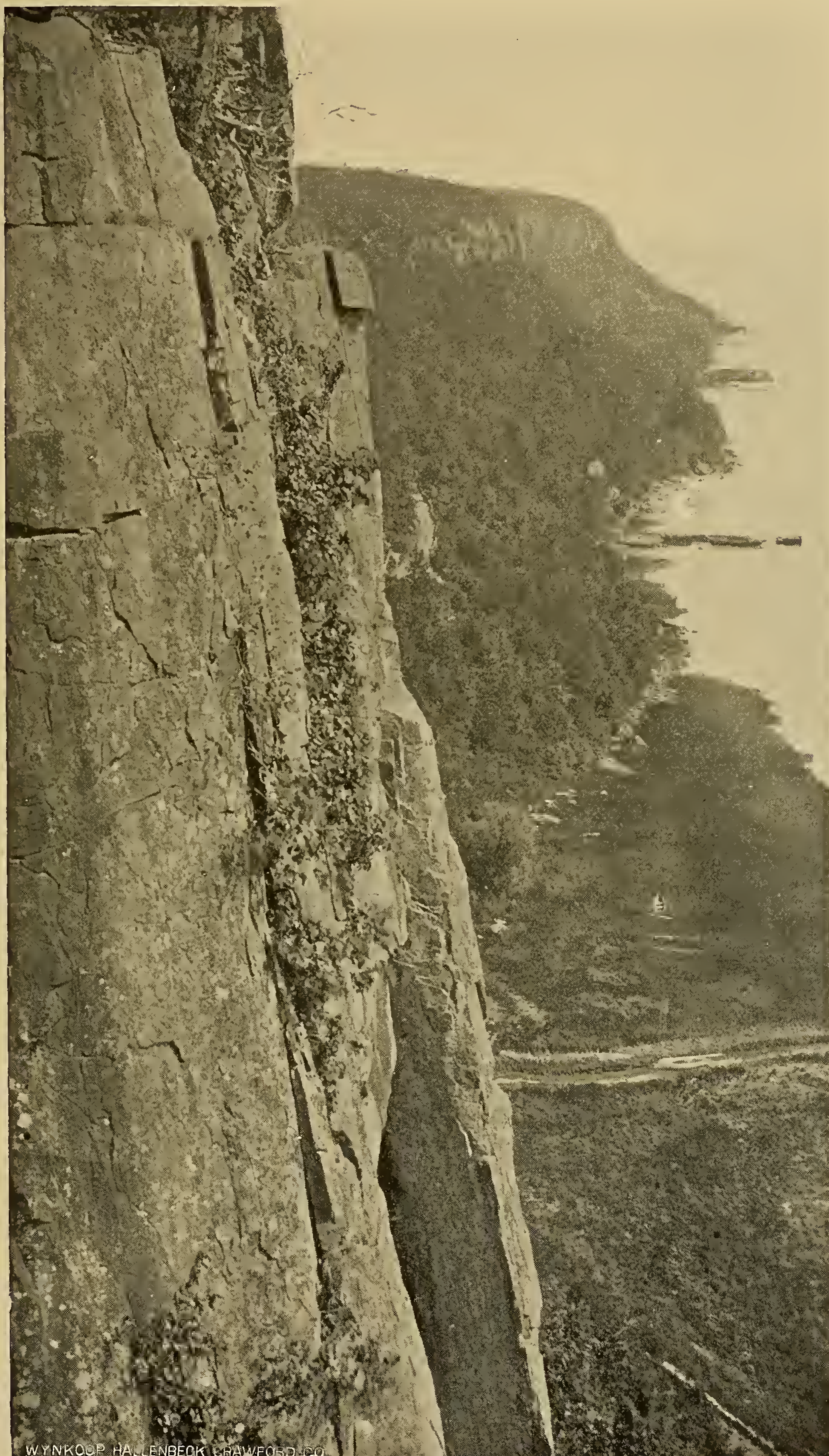
Triassic Diabase

H. Ries, photo.

VIEW NORTHWARD ALONG THE PALISADES OF THE HUDSON RIVER, FROM FORT LEE, N. J.

PLATE LXXXVIII.—To face page 172.

Triassic
Diabase.



S. R. Stoddard, photo.

THE PALISADES OF THE HUDSON. VIEW NORTHWARD FROM ENGLEWOOD CLIFFS, N. J.

PLATE LXXXIX.—To face page 172.

J. N. Nevius, photo.

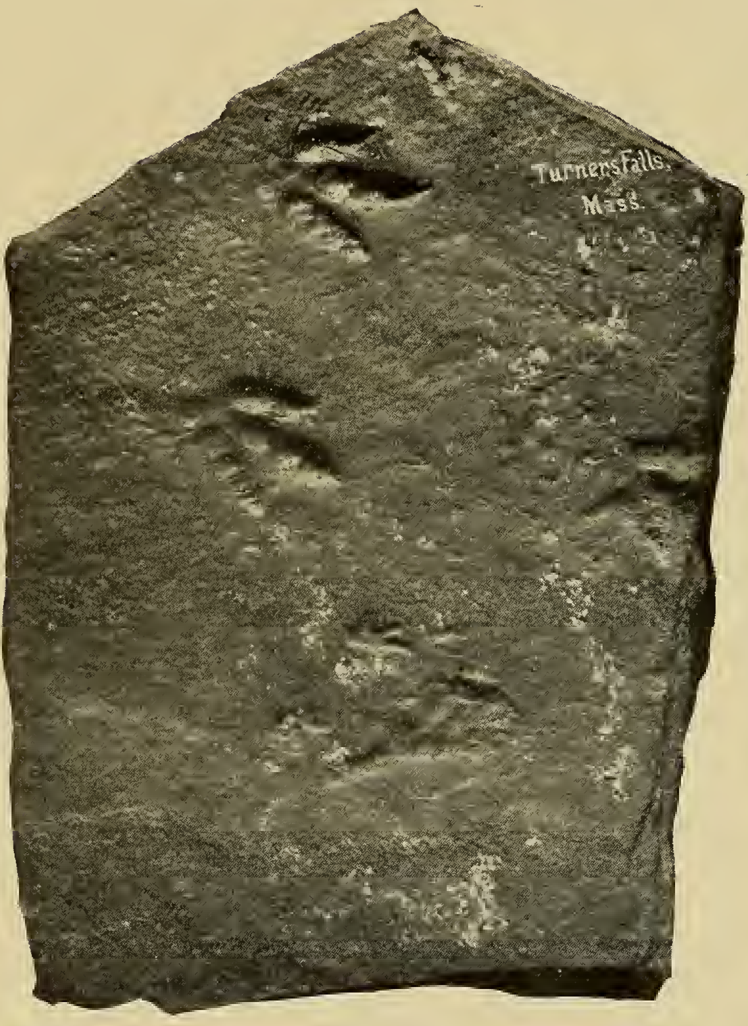
TRIASSIC DIABASE EXPOSED IN A CUT FOR THE ORANGE MOUNTAIN CABLE-ROAD, ORANGE, N. J.

PLATE XC.—To face page 172.

H. Ries, photo.

Contact of Trap and Underlying Triassic Sandstone, South End of Lane's Quarry, Fort Lee, Bergen Co., New Jersey.

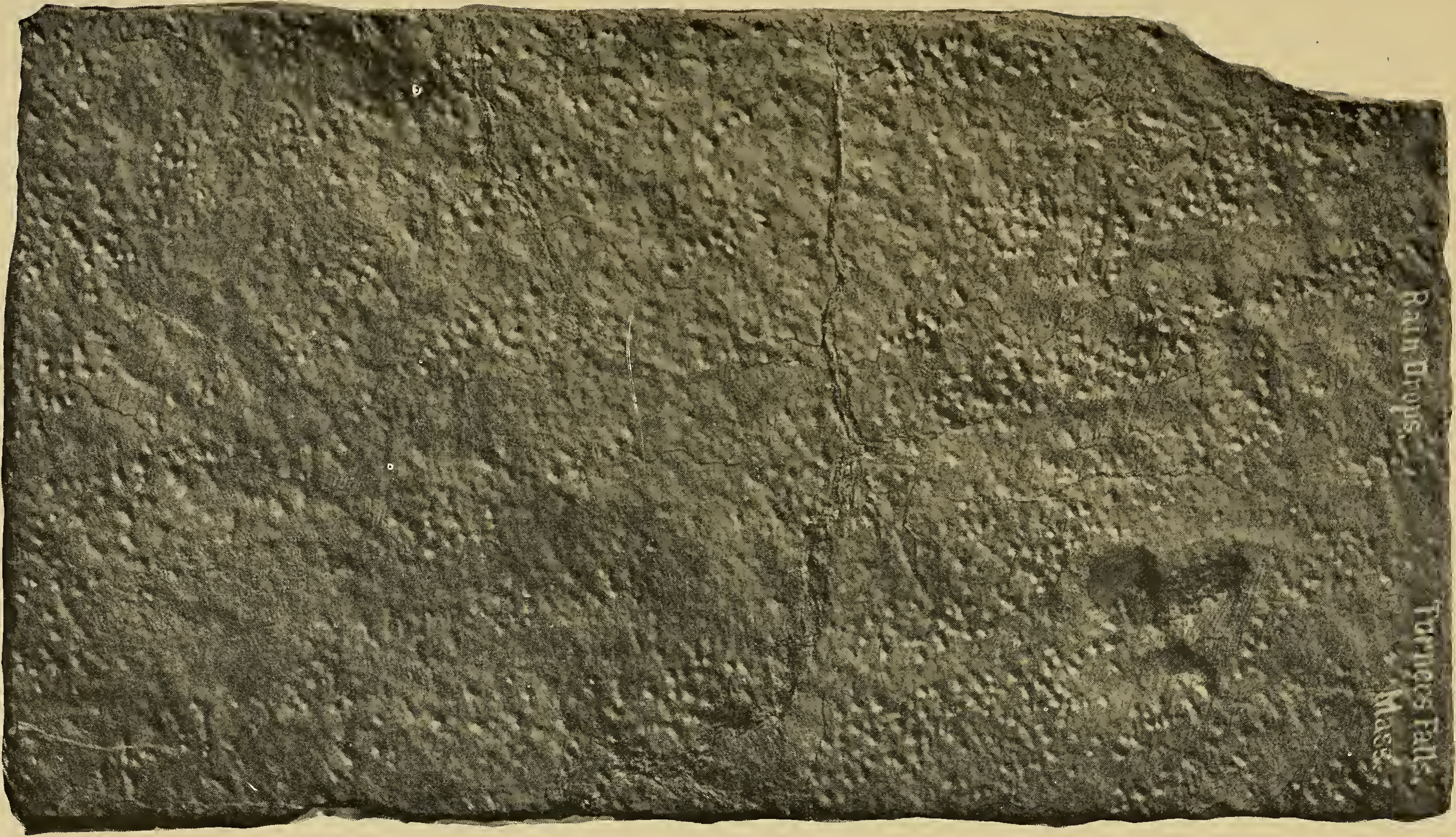
PLATE XCI.—To face page 172.



J. N. Nevius, photo.

REPTILIAN FOOTPRINTS ON TRIASSIC SANDSTONE, TURNER'S FALLS, MASS. ORIGINAL SLAB 19 INCHES BY 27 INCHES.

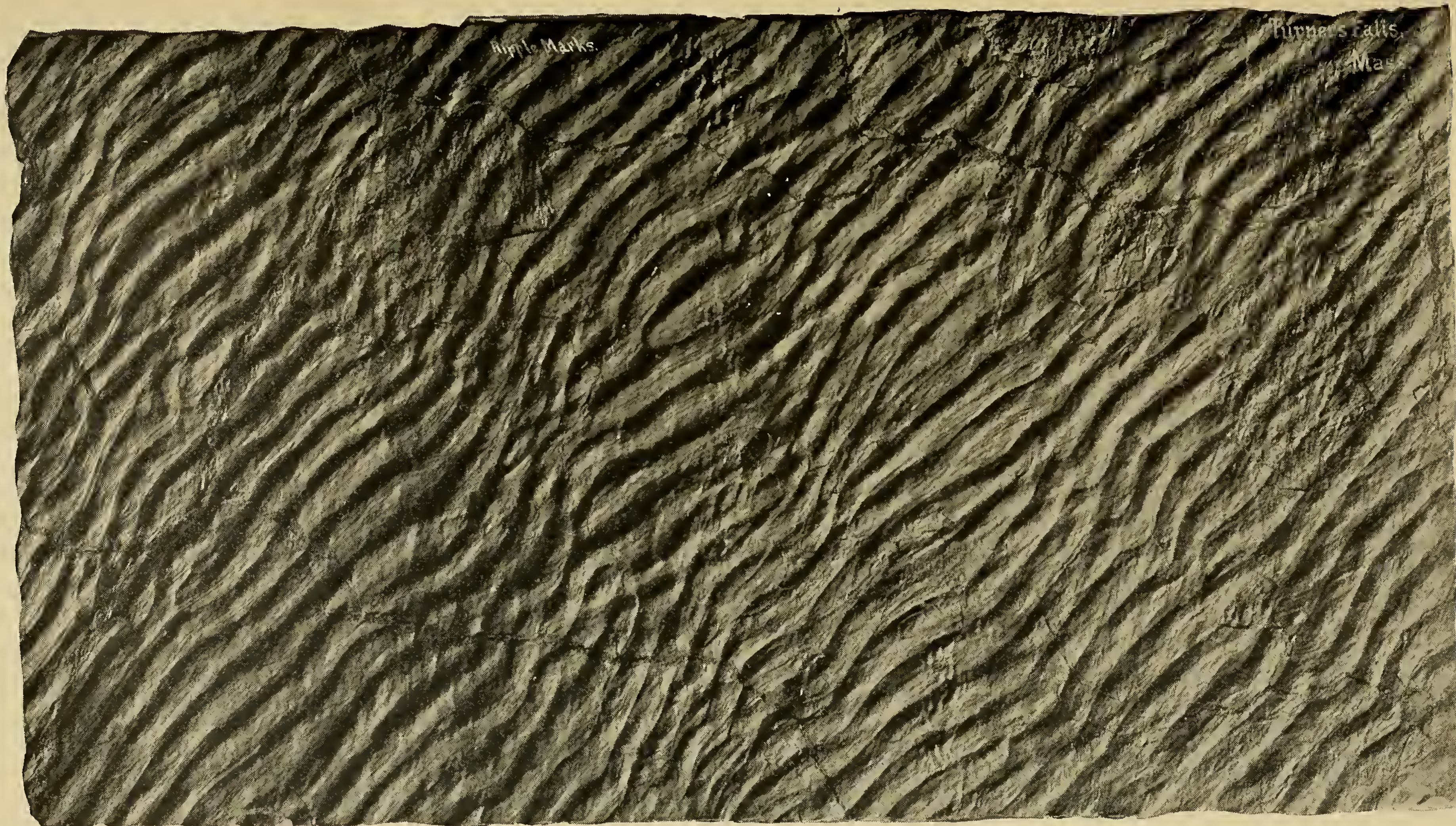
PLATE XCII.—To face page 172.



J. N. Nevius, photo.

Rain Prints and Reptilian Footprints on Triassic Sandstone, Turner's Falls, Mass. Original Slab 33 Inches by 18 Inches.

PLATE XCIII.—To face page 172.



J. N. Nevius, photo.

Ripple Marks on Triassic Sandstone, Turner's Falls, Mass. Original Slab 43 Inches by 24 Inches.

pods were represented in great development by the orthoceras in the Lower Silurian seas, so were they represented by the ammonite in the Jurassic. The orthoceras disappeared after the Triassic age.

The smaller mollusks were also abundant and began to assume more nearly the features of those which occur at the present day. At this time the oyster made its appearance.

CRETACEOUS SYSTEM

The Jurassic system was succeeded by the Cretaceous. This received its name in Europe from the chalk formation, which in England and France is very prominent, being several hundred feet thick. The chalk is a limestone which has not been consolidated. If it had been exposed to the same agencies as the Palaeozoic limestones it would probably like them have been consolidated to form a hard rock. A large part of the chalk consists of skeletons and shells of foraminifera, some of the species being found in the ocean at the present day. With these foraminifera, which are mostly calcareous, are the remains of other minute animals called polycystines which are silicious and also the spicules of sponges. These, by some chemical action, have been gathered together and consolidated into nodules of flint which is a variety of quartz similar in composition to the hornstone of the Corniferous and other limestones. Hornstone is also called chert and has furnished the material for most of the North American Indian arrow-heads which are commonly called flint arrow-heads. As a matter of fact the true flint does not occur in America and technically American flint arrow-heads are made of chert or hornstone. It is not impossible, however, that early traders from England may have supplied our Indians with flint from Europe.

In America there is but little chalk, although the Cretaceous system is largely developed. It extends from the Gulf of Mexico to the Arctic ocean in a belt 200 miles wide. On the Atlantic coast Cretaceous deposits are found beneath the Tertiary and consist chiefly of sand and clay. The clays which occur on Long

Island and are well represented from Staten Island to the vicinity of Camden, New Jersey, are important in the manufacture of pottery. Some of the clay beds contain plant remains and about 50 species of land plants have been recognized here. Among these are many genera which exist at the present day, such as the cinnamon, sassafras, oak, gum etc. The character of this vegetation suggests that a temperate climate prevailed in this region during cretaceous time. A little later, in the Tertiary, a sub-tropical climate prevailed in what are now the Arctic regions. West of the Mississippi the Cretaceous deposits of our country are divided into three principal groups; the *Dakota*, which consists of sandstone and conglomerate with beds of clay; the *Colorado*, a group of limestone and bituminous shales; and the *Laramie*, which is a bed of passage into the Tertiary and contains important deposits of lignite, a variety of coal.

Life of the Cretaceous period

In the Cretaceous, mammals were still insignificant. The members of the ammonite group of the cephalopoda, were numerous and varied in form. The other mollusks were closely allied to those of the present day. Many bony fishes appeared and supplanted the ganoid fishes which had previously prevailed. The reptilian fauna was prominent, but became greatly diminished before the tertiary. With the close of this period occurred a great change in the life of the globe.

Cenozoic Time

Following the close of the Mesozoic age begins the Cenozoic, which includes the Tertiary and Quaternary systems and is characterized by a marked resemblance of its life, to that of the present day.

TERTIARY SYSTEM

Sir Charles Lyell divided the European Tertiary into three parts; the Eocene, Miocene and Pliocene. The Eocene was estimated to contain about 10% of living species, the Miocene about 50% and the Pliocene about 90%, but these percentages are not of world wide application.

The Tertiary of our Atlantic slope consists chiefly of sands and clays, which in the southern states are well developed. A much larger development occurs west of the Mississippi river on the sites of extinct Tertiary lakes. Marine Tertiary is also found on the Pacific coast.

In New York state the Tertiary is not accurately identified and is indivisible, but is probably represented by sands and gravel on Staten Island and Long Island. There is comparatively little marine Tertiary in North America, as the northern part of the continent was out of water at that time. The Tertiary beds west of the Mississippi are chiefly fresh water deposits formed in lake basins. The Tertiary was a period of mountain making. In southern Europe the great chains of mountains known locally as the Pyrenees, Alps, Apennines and Carpathians, consist to a large extent of Tertiary rocks. This is also true of the Himalaya mountains of India. It is known that extensive disturbances in our Appalachian system occurred during the Tertiary.

Life of the Tertiary period

Birds and mammals succeeded the reptiles of the cretaceous. Of the mammals all the orders now existing were represented. Reptiles were not more numerous than at present and were similar to existing genera. Fishes were very abundant. Insects were many and varied. Mollusks were abundant; oysters occurred in great variety and of enormous size. Corals were not plentiful. Land plants were very abundant and very similar to those of the present day; the cypress grew in the Arctic regions.

QUATERNARY SYSTEM

At the close of the Tertiary a cold temperate climate reigned in the United States and a great ice age began, during which the northern part of our continent was covered with a sheet of ice many hundred feet thick. The chief evidences of this are the inscriptions of the continental glaciers on the rocks in the shape of grooves and polished surfaces and the material transported by it.

The glacial phenomena are well marked. Ice worked blocks of stone have a peculiar angular form, which does not occur on water worn boulders.

The theory of continental glaciation was first worked out in Europe from studies of the glaciers of the Alps. These are the result of a copious precipitation of moisture on the mountains in the form of snow and the formation of snow ice. Large masses of this consolidate and form ice rivers or glaciers, which slowly move toward the valleys grooving and polishing the rocks over which they pass and tearing off rock fragments, which in turn are polished and scratched as they are dragged along in the base of the ice.

Glaciers now exist in Iceland, Greenland and Alaska and in other Arctic countries, also on some of the mountains of Washington, South America, Asia and Africa. They also abound within the Antarctic Circle.

Evidences of former continental glaciation occur in both hemispheres.

In New York state the continental glacier extended as far south as Long Island and Staten Island and formed at its front a great ridge of transported rock debris, sand, gravel, boulders and clay, at some points over 360 feet in height, which is called the 'terminal moraine' and is known locally as the back bone of Long Island.

After reaching its point of maximum extension and resting there, perhaps for a long time, the ice sheet with a recurrence of a warmer climate began to retreat. This retreat was not at an even rate. There were periods of arrested motion and probably of temporary advance as shown by the moraines of recession. These are masses of earth, gravel and boulders which form small hills and ridges.

As the ice melted, great volumes of water were poured over the land and the valleys were flooded. The streams thus formed were loaded with sand and gravel which they carried for a dis-

PLATE XCIV.—To face page 176.

I. P. Bishop, photo.

Glacial Scratches on the Corniferous Limestone, Cheektowaga, Erie Co.

PLATE XCV.—To face page 176.

H. Ries, photo.

Quaternary Delta Deposit of Croton River, 1 Mile South of Croton Landing, Westchester Co.

PLATE XCVI.—To face page 176.

J. N. Nevius, photo.

VIEW OF QUATERNARY KAME DEPOSIT, NORTH ALBANY, ALBANY CO.

PLATE XCVII.—To face page 176.

J. N. Nevius, photo.

Section of Quaternary Sand and Gravel Beds, North Albany, Albany Co., Shown in Last Illustration.

PLATE XCVIII.—To face page 176.

J. N. Nevius, photo.

VALLEY OF EROSION, IN THE QUATERNARY SAND PLAIN, NEAR DELMAR, ALBANY CO.

PLATE XCIX.—To face page 176.

N. H. Darton, photo.

Lake in Quaternary Drift Hills Southwest of Glens Falls, Warren Co. French Mountain in the Distance.

PLATE C.—To face page 176.

H. Ries, photo.

QUATERNARY PLAIN AT THE FOOT OF THE HELDERBERG ESCARPMENT, BETWEEN RAVENA AND SOUTH BETHLEHEM, ALBANY CO.

PLATE CI.—To face page 176.

J. N. Nevius, photo.

VALLEY OF THE NORMANSKILL, NEAR ALBANY, ALBANY CO., CARVED BY THE STREAM THROUGH A PLAIN OF QUATERNARY SANDS. CRESENT SHAPED LAKE WAS FORMED BY NATURAL DIVERSION OF THE STREAM INTO A NEW CHANNEL.

PLATE CII.—To face page 176.

I. P. Bishop, photo.

SAND BARS, LAKE ERIE, MOUTH OF EIGHTEEN MILE CREEK, ERIE CO.

I. P. Bishop, photo.

Glacial Boulders Washed from Moraine, Stony Point, Near West Seneca, Erie Co. Shore of Lake Erie.

PLATE CIV.—To face page 176.

S. R. Stoddard, photo.

Foot of the Selkirk Glacier, British Columbia, Showing the Formation of a Moraine Deposit.

tance and dropped to form the flood plains and terraces which border our river valleys and the hills of sand and gravel in the valleys which are called kames and eskers. Where there were bodies of still water the finer materials were dropped to form clay.

At this time the country was deeply submerged and tide water filled the valley of the Hudson river and Lake Champlain so that the Gulf of St Lawrence and New York harbor were united. This is evidenced by the fact that near the St Lawrence and Lake Champlain, above the gravel beds, are some beds of clay 200 feet thick or more, which contain marine shells of species now existing on the coasts of New England and Canada. These show that, since such shells were living, those valleys have been depressed below the sea-level, long enough for these deposits of clay to be formed. They are known as pleistocene clays. The Hudson river valley clays are their southern extension, but contain no fossils.

The Quaternary deposits of New York are, therefore, chiefly those made in the presence of the ice and those resulting from the working over of the glacial deposits by running water. In this latter process the angularity of the glacial boulders and pebbles has been worn off. The evidences of glacial action are well seen in almost all parts of this state. Almost every gravel-bank consists of waterworn fragments of the old rocky strata; pebbles of limestone, sandstone and slate, with some of gneiss and granite, which universally appear to have been transported from north to south. From a bushel of pebbles taken from any gravel bank south of the Erie canal, the geologist can pick out specimens of almost every stratum which is exposed north of the bed whence they were taken. South of the line of outcrop of the Helderberg limestones, the gravels are full of fragments of their different layers; and among them lie worn pieces of the red Medina sandstone, others of the Hudson river group, and others of still more northern strata; while some are granite pebbles, which must in many instances have come from Canada. They have evidently been transported from north to south in vast quantities; they are smooth-worn, and are smaller the farther they are found from their original strata; they are generally found in irregular layers with sand and clay, as if left so by the action of rapid currents of water. One of the most interesting facts connected with them is, that they have been in many cases transported from lower to higher levels, even up steep acclivities and over high hills. There are spread with them also (but generally lying on the surface of the ground) many large and heavy masses of loose rock, called boulders. Some of these are limestones or sandstones, the origin of which can easily be traced to thin native strata within the state; others are granitic masses, which must have come from beyond Lake Ontario, in the same manner that the peculiar crystalline rocks of the Adirondack mountains are found to have been carried south beyond the Mohawk valley. The surfaces of the rocky strata in all the country, over which these 'drift beds' have passed, are in many places found to be worn smooth, and scratched or furrowed in a general north and south, or northwest and southeast direction, as if heavy materials had been dragged or driven over them.

Quaternary fossils

Among the most recent of the fossil remains, which link together the vanished forms of the past with the living animals of to-day, are the bones of the mastodon and fossil elephant, which are occasionally disinterred in various parts of the state, found buried only in recent accumulations of muck, peat, or other earthy materials. They are relics of a very modern period of geologic history, and these immense animals seem to have lived during the existence in this region of many of our still-remaining wild animals; possibly even since it was inhabited by man. Specimens of the mastodon have been found at Cohoes, at Batavia and in Orange county. In addition to these may be mentioned the *Castoroides ohioensis*, a gigantic extinct species of beaver, which was probably of the same period with the mastodon. A skull of this species was found near the village of Clyde, in earth, during the excavation of a canal. Remains of a reindeer have been found at Sing Sing.

The petrified wood, leaves, moss, etc., which are common in our limestone districts, are of modern date, and are forming at the present time. The rain-water which percolates through the crevices of the limestone rocks, by means of the carbonic acid which it gathers from the air, dissolves the carbonate of lime; and on coming again to the air in springs, re-deposits it in the form of tufa, a drab-colored mass which is nearly pure carbonate of lime. This, as it gradually forms, incrusts the leaves, sticks, etc., with which it comes in contact; and often, as they decay, replaces them in such a manner as to present the same form and structure; pieces of wood being thus replaced by a stony mass closely resembling the original substance.

Age of man

Man is the most highly specialized member of the animal kingdom. His remains are not found in deposits earlier than the post glacial, which appear to have an age of not many thousand years. There is, so far, no clue to his origin. The first relics of man are rude implements of stone or bone such as knives, arrow-heads, etc., and are found in the gravels of streams and in caves.

The first period of man is known as the stone age, but though it ceased long ago in Europe, in North America it has existed to within the present century. The bronze age succeeded the stone age. Last of all came the age of iron which is the present.

PRESENT SURFACE OF NEW YORK

Under this head it is important to consider briefly the causes which have reduced so large a portion of the rock strata of New York, from the original condition of the wide and uninterrupted extent in which they were formed to that of an undulating and broken aggregate of hills and valleys which we now see. It is probable that during the slow process of emergence from their native sea, the action of waves and currents wore them deeply and extensively; and since they were uplifted to their present elevation, the elements have unremittingly acted upon them.

As the rocks, newer than the Carboniferous, occur in but small areas within our state, it may be concluded that the greater part of this region has been above water since the Carboniferous period, during the countless ages while the Triassic, Jurassic, Cretaceous and Tertiary rocks were formed and during the deposition of which the animated population of the earth has been changed many times. All of these formations were made of sediments worn from pre-existing land. It is to be expected, therefore, that this ancient land should show the marks of vast erosion and wear. Some marks of this are found in the long and deep valleys which traverse the state, all of which have been worn out of the solid strata, the remaining portions of which form the adjacent hills. These valleys are being worn deeper where the rivers are strong and their cutting action continues, and everywhere they are being widened and the mountains and hills reduced in height by rains and frost. Some valleys have been excavated much below the level of their present outlets, so that they retain the drainage and form the remarkable series of finger lakes previously mentioned.

Vast as the work may seem, the fact is plain that not only have these valleys been formed by erosion, but hundreds of feet of rocky strata have been removed from the summits of the hills themselves and from large tracts of plain country. The whole vast basin of Lake Ontario is an excavation in rocks which still lie nearly as level as when first deposited; and there seems no reason to doubt that the northern edges of the enormous thickness of formations above the Helderberg limestones once overspread the present lowlands of the counties bordering that great body of water.

Such long lines of bluffs as the Niagara 'mountain ridge,' and the steep escarpments of the Helderberg limestones, are evidences of the great work of erosion. The existence of old beaches, such as the Lake Ridge near Rochester, proves that the waters of the lake once stood far higher than now.

PART 3.

ECONOMIC GEOLOGY

BUILDING STONE [a]

GRANITIC ROCKS

Granite, Gneiss, Syenite, Trap and Norite

Granite. Typical granite is a crystalline, granular mixture of a feldspar, quartz and hornblende. In addition to these essential constituents, one or more accessory minerals may be present. The more common are the micas, muscovite and biotite, garnet, tourmaline, magnetite and pyrite. The character of the rock is often determined by the presence of these accessory constituents in quantity, as in some cases the hornblende is entirely replaced by mica.

The chemical composition also varies from that of the average or typical kind. The mineralogical differences mark the varieties, thus there are: hornblende granite, biotite granite, tourmaline granite, etc.

The texture of granites is determined by the aggregated minerals entering into their composition. It varies from coarse-crystalline, in which the individual crystals may be an inch or more in length, to fine-crystalline and aphanitic, wherein the minerals are hardly visible to the eye. In consequence of the wide variation due to the mode of arrangement of the mineral constituents, there is an equally great variety noticeable in the texture.

The color also is dependent upon the minerals. As feldspar is the predominant constituent it gives character to the mass, and the red varieties owe their color to the red or pink feldspars in them, as in the case of the granite of Grindstone Island in the St Lawrence. The shades of gray are due to the varying

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a This chapter on building stone is abridged with alterations and additions from Bulletin No. 10 of the New York State Museum, by John C. Smock.

amount of the dark colored mica mixed with the feldspar and quartz; and the dark colored varieties owe their color, in most cases, to hornblende or tourmaline which may be present.

The beauty, ease of working, durability and value of the granites for use in construction is related closely to their mineralogical composition. Their arrangement in the mass and their relative proportions determine the color and give beauty. The presence or absence of certain species influence the hardness and homogeneous nature and the consequent ease with which the stone can be dressed and polished. For example the mica, if disposed in parallel surfaces, gives a foliated structure and tends to produce what is known as rift, and the granite is more readily split in the planes of the mica than across them. Again the mica flakes may be so large and irregularly massed that the surface is not susceptible of a uniform degree of polish. Hornblende, on account of its superior toughness, is less brittle than pyroxene under the polishing, and the hornblende granites are said to be preferred to those rocks which contain pyroxene in quantity.

The more nearly alike in hardness and the more intimately interwoven the texture of the minerals, the more capable they are of receiving a good polish. Hence it follows that the very coarse crystalline granites are not so well suited for ornamental work.

The enduring properties of granites vary with the nature of the minerals in their composition. Although popularly they are regarded as our most durable building stone, there are some notable exceptions, which are evident in the natural outcrops, where this rock is found decayed to the depth of 100 to 200 feet, and in the active disintegration which is in progress in structures of the present century. Foliated varieties placed on edge in buildings, tend necessarily to scale under the great changes of temperature in our northern cities and towns. The more rapid decomposition of the micas makes those varieties in which they occur in large flakes or aggregations more liable to decay. The condition of the feldspar also is often such as to influence the durability. When kaolinized in part, it is an element of weakness rather than of strength. The presence of the easily decom-

PLATE CV.—To face page 182.

H. Ries, photo.

Granite Quarry, Round Island, Near Peekskill. Westchester Co. Precambrian.

posable varieties of pyrite is not only prejudicial to strength and durability but also to the beauty of the stone as soon as it begins to decay.

The term 'granite' as used among builders and architects is not restricted to rock species of this name in geologic nomenclature, but includes what are known as gneisses (foliated and bedded granites), diorites, gabbro and other crystalline rocks whose uses are the same. In fact, the similar adaptability and use have brought the latter species into the class of granites. For example, the Au Sable granite of Essex county is a norite. The term is applied in some cases to the diabases or trap-rocks, as the 'granite quarries' of Staten Island.

Another massive crystalline rock which is used in building is norite, consisting of labradorite and hypersthene, with some brown mica. It is a common rock in the Adirondack region, and is known commercially as a granite.

The massive crystalline rocks are of common occurrence in New York, but not in outcrops over extensive areas, excepting in the Adirondack region and in the Highlands of the Hudson. The schistose crystalline rocks are developed extensively in the Highlands of the Hudson and on the borders of the Adirondack region. On New York island and within the city limits the gneiss rocks have been quarried at many points. In Westchester county there are belts of gneiss and mica schist, in which quarries have been opened near Hastings; near Hartsdale, east of Yonkers; at Kensico; at Tarrytown and at Ganung's, west of Croton Falls. In Putnam county there are quarries of granite near Peekskill, Garrison's and Cold Spring. West of the Hudson river there are quarries on Iona island; at West Point; on Storm King mountain, near Cornwall; near Suffern; at Ramapo; and on Mount Eve, near Florida. The outcrops of the gneissoid and granitoid rocks are so numerous in the belt of the Hudson Highlands that quarries can be opened at many points. The supply of stone is inexhaustible. On the Hudson river, between Peekskill and Fishkill, there is a fine section of these rocks exposed.

On the borders of the Adirondack region quarries have been opened in the towns of Wilton, Hadley and Greenfield, in Saratoga county; at Whitehall, in Washington county; at Littlefalls, in Herkimer county; Grindstone Island, Jefferson county; and near Canton in St Lawrence county. The inaccessibility of much of this region and the distance from the large city markets have prevented the opening of more quarries in the gneissic rocks on the borders of the Adirondacks.

TRAP

Trap-rock or trap is the common name given to a class of eruptive rocks because of a structural peculiarity, and has no distinctive significance in mineralogical composition. The rocks of the Palisade mountain range and of the Torn mountain, which extends from the New Jersey line, on the west shore of the Hudson river to Haverstraw, are known as trap-rocks. There is an outcrop on Staten Island, at Graniteville, near Port Richmond, where a large amount of stone has been quarried at the so-called 'granite quarries.'

The trap-rock of the Palisades range is a crystalline, granular mass of plagioclase feldspar (usually labradorite) augite and magnetite. It is generally finer crystalline than the granite. The colors vary from dark gray through dark green to almost black.

This trap-rock is hard and tough, but some of it is split readily into blocks for paving. It has been used extensively in New York and adjacent cities for street paving, but since the introduction of granite blocks this use has nearly ceased. On account of its toughness it makes an admirable material for macadamizing roadways. It is so hard that only rock-face blocks are used in constructive work. Several prominent buildings in Jersey City and Hoboken are built of it. There is a large quarry on the river at Rockland lake, near Haverstraw, the output of which is for street work and road material almost exclusively. There are also quarries at Piermont and at Graniteville, Staten Island.

SANDSTONE

Sandstone consists of grains of sand which are united by a cement.

The grains may be of varying sizes, from almost impalpable dust to small pebbles, and may be angular or more or less rounded in form. The cementing matter also may vary greatly in its nature. From this variation, both in the grains and in the cement, there is an almost endless gradation in the kinds of sandstone.

Quartz is the essential constituent, but with it there may be feldspar, mica, calcite, pyrite, glauconite, clay or other minerals, and rock fragments common to stone of sedimentary origin. These accessory materials often give character to the mass, and make a basis for a division into feldspathic, micaceous, calcareous sandstones, etc., as one or another of them predominates.

The texture of the mass also is subject to a wide range of variation, from fine-grained, almost aphanitic, to pebbly sandstone, or conglomerate, or a brecciated stone in which the component parts are more or less angular.

Some of the brown sandstones of the Triassic age, quarried near Haverstraw, are such conglomeratic and brecciated sandstones. Accordingly, as the grains are small or large, the stone is said to be fine-grained or coarse-grained.

The variety of the cementing material also affords a basis for classification. Silicious sandstones have the grains bound together by silica. They consist almost exclusively of quartz, and grade into quártzite. The ferruginous varieties have for their cement an oxide of iron, often coating the grains and making a considerable percentage of the whole. The iron is usually present as ferric oxide. Calcareous sandstones are marked by the presence of carbonate of lime. When it exceeds the quartz in amount, the sandstone becomes a silicious limestone. In the argillaceous varieties, the binding material is a clay, or an impure kaolin.

The cementing material determines in most cases the color. The various shades of red and yellow depend upon the iron oxides; some of the rich purple tints are said to be due to oxide of manganese.

The gray and blue tints are produced by iron in the form of ferrous silicate or carbonate. By an irregular association of masses of different colors a variegated surface is produced, or by an alternation of white and variously-colored laminæ a striped appearance is given to the mass.

Sandstones occur stratified and in beds of greater or less thickness, and they are said to be thick-bedded or thin-bedded. In some cases the beds are so thick, and the stone of such a uniform texture, that the stone can be worked equally well in all directions, and is known as *freestone*. A laminated structure is common, especially in the thin strata, or when the stone is micaceous. When the beds can be split into thin slabs along planes parallel to the bedding, it is called a *flagstone*. A less common structure is what is termed lenticular or wedge-shaped, in which the upper and under surfaces lack parallelism, and the beds wedge out. It makes the quarrying more difficult, and produces more waste material.

The variations in the nature of the component grains, and binding material, in their arrangement, and in the forms of bedding, produce a great variety of stone, and the gradations from one to another are slight. The hardness, strength, beauty and durability are determined by these varying elements of constitution. The stone best resisting the action of the atmospheric agencies is that in which the quartz grains are cemented by a silicious paste, or in which the close-grained mass approaches in texture a quartzite.

The presence of mineral liable to decomposition, as feldspar highly kaolinized, of mica, marcasite, and pyrite, of calcite in quantity, and clays, affects the durability and tends to its destruction.

Sandstones are classified according to their geologic age also. They are found occurring in all the series, from the oldest to the most recent formations. Those of a given age are generally marked by characteristic properties, which serve for their identification, aside from the fossil organic remains by which their exact position in the geologic series is fixed. This persistence in characters is exemplified in the Medina sandstones, in the Devonian bluestone, and in those of Triassic age.

Sandstones occur in workable quantity in nearly all the greater divisions of the state.

Quarries have not, however, been opened everywhere in the sandstone formations, because of the abundant supply of superior stone from favorably situated localities. There are, in consequence, large sandstone areas and districts in which there is an absence of local development, or abandoned enterprises mark a change in conditions, which has injuriously affected the quarry industry.

Following the geologic order of arrangement and beginning with the Potsdam sandstone, the several sandstone formations are here briefly reviewed.

Potsdam sandstone

This formation is the oldest in which, in this state, sandstone is quarried for building purposes.[a]

The bottom beds are of fine, silicious conglomerate; above are sandstones generally in thin beds. It is gray-white, yellow, brown and red in color. In texture it varies from a strong, compact quartzite rock to a loosely coherent, coarse-granular mass, which crumbles at the touch.

Outcrops of limited area occur in the Mohawk valley. In the Champlain valley the formation is well developed at Fort Ann, Whitehall, Port Henry and Keeseville, and quarries are opened at these localities. The stone is a hard, quartzose rock, and in thin beds. North of the Adirondacks the formation stretches westward from Lake Champlain to the St Lawrence; and there are quarries in the towns of Malone, Bangor and Moira in Franklin county; in Potsdam and Hammond in St Lawrence county;

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a Some of the sandstones east of the Hudson and in the Taghkanic range may belong to the Lower Cambrian. See *Amer. Jour. of Science,* series iii, vol. 35, pp. 399-401. But there are no quarries opened in these localities.

and in Clayton, Jefferson county. In parts of Clinton county the stone is too friable for building.

The most extensive openings are near Potsdam; the stone is hard, compact and even-grained, and pink to red in color. Some of it has a laminated structure and striped appearance. It is an excellent building stone and is widely known and esteemed for its beauty and durability.

The Hammond quarries produce a gray to red stone. Nearly all of the output is cut into paving blocks and street material.

Hudson river sandstone

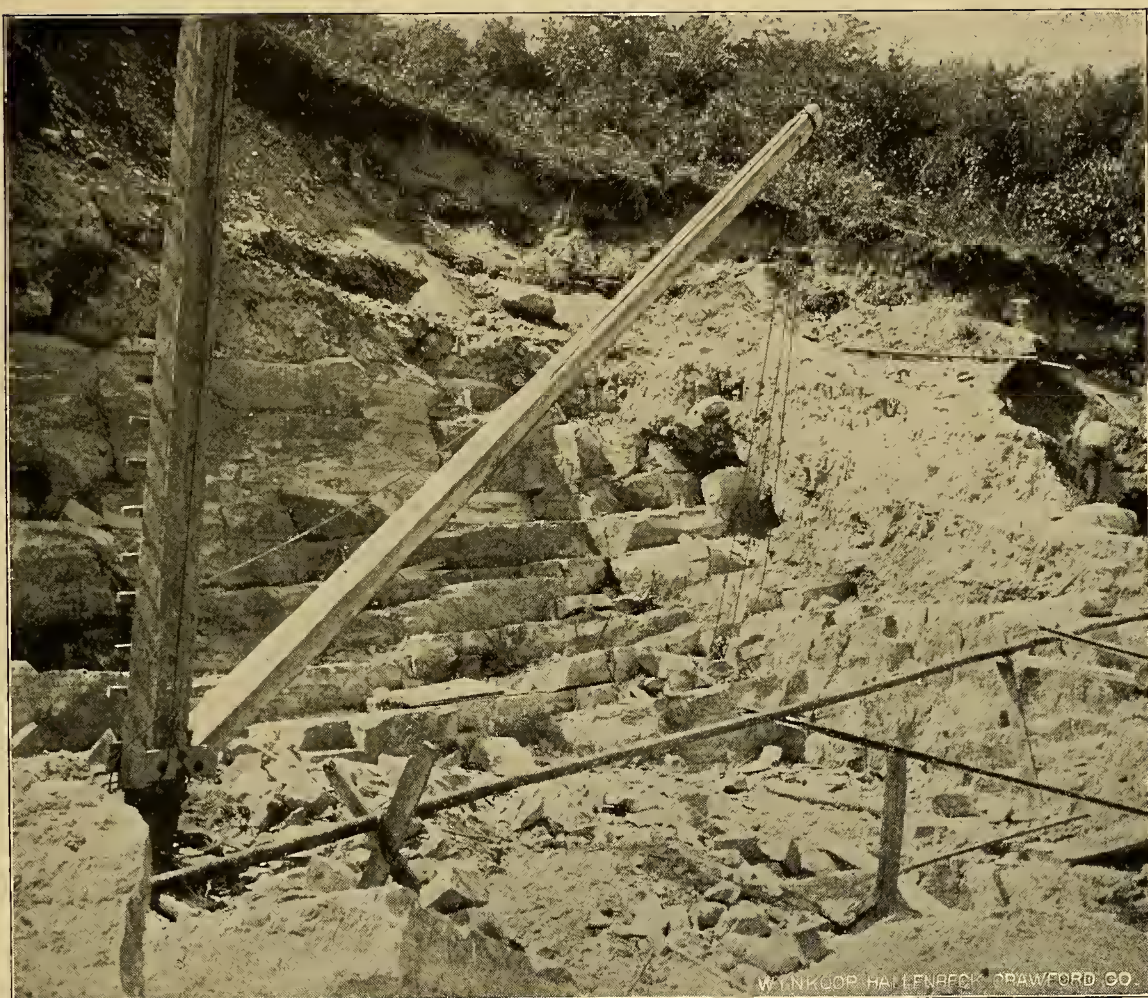
Rocks of this group outcrop in Orange county, northwest of the Highlands and in the valley of the Hudson river northward to the Champlain valley in Washington county. From the Hudson westward, the Mohawk valley is partly occupied by them. The belt increases thence in breadth, in a northwest course across Oneida, Oswego and Lewis counties, and continues to Lake Ontario.

The rocks consist of shales interbedded with sandstones and silicious conglomerates.

The sandstones are generally fine-grained and of light-gray or greenish-gray color. They are often argillaceous and not adapted for building purposes. But the even-bedded and well-marked jointed structure makes the quarrying comparatively easy, and the nearness to lines of transportation, and to the cities of the Hudson and Mohawk valleys have stimulated the opening of quarries at many points.

For common rubble work and for local use, the quarries in this formation have furnished a large amount of stone. The more important quarrying centers are now at Rhinecliff-on-the-Hudson, New Baltimore and Troy, in the Hudson valley; at Aqueduct, Schenectady and Duanesburg, Schenectady county; and Frankfort Hill, Oneida county. Flagstones are quarried from this formation in the gorge of the Bozenkill a few miles northwest of Altamont, Albany county.

PLATE CVI.—To face page 188.



J. N. Nevius, photo.

POTSDAM SANDSTONE, CLARKSON'S QUARRY, 3 MILES SOUTH OF POTSDAM, ST. LAWRENCE CO.

Oneida conglomerate

This formation is developed to its greatest thickness in the Shawangunk mountain in Orange and Ulster counties.

It is recognized in the Bellevale and Skunnemunk mountains, also, in Orange county. In the central part of the state it is traced westward in a narrow belt from Herkimer county into Oneida county. The prevailing rocks are gray and reddish-gray, silicious conglomerates and sandstones, which are noted for their hardness and durability. The cementing material is silicious. The jagged edges and angular blocks and the polished and grooved surfaces of the glaciated ledges, so common on the Shawangunk range, afford the best proof of the durable nature of these rocks. The bottom beds, near the slate, contain some pyrite. No attempt has been made to open quarries for stone, excepting at a few localities for occasional use in common wall work. The grit rock is quarried near Esopus creek for mill-stones, and at Ellenville is crushed for glass sand.

The accessibility of the outcrops to the New York, Lake Erie and Western railroad, the New York, Ontario and Western railroad, the West Shore railroad and the Delaware and Hudson canal lines is an advantage, as well as the comparative nearness to New York. No other formation in the state exhibits in its outcrops better evidence of ability to resist the weather.

Medina sandstone

The Medina sandstone is next above the Oneida conglomerate. It is recognized in the red and gray sandstones and the red and mottled (red and green) shales of the Shawangunk and Skunnemunk mountains in Orange county. A large amount of the red sandstone has been quarried on the north end of the Skunnemunk range, in the town of Cornwall, for bridge work on the railroads which cross the range near the quarry.

The red sandstone is seen exposed in the cuts of the Erie railway northeast of Port Jervis. This formation reappears in Oswego county, and thence west to the Niagara river in a belt bordering Lake Ontario.

Quartz is the principal mineral constituent associated with some kaolinized feldspar. The cementing material is mainly oxide of iron, with less carbonate of lime. The stone is even-bedded and the strata dip gently southward. The prevailing systems of vertical joints, generally at right angles to one another, divide the beds into blocks, facilitating the labor of quarrying.

Quarries have been opened at Fulton, Granby and Oswego, in Oswego county; at several points in Wayne county; at Rochester, on the Irondequoit creek, and at Brockport, Monroe county; at Holley, Hulburton, Hindsburg, Albion, Medina and Shelby Basin, in Orleans county; and at Lockport and Lewiston, in Niagara county. The Medina sandstone district proper is restricted to the group of quarries from Brockport west to Lockport.

The leading varieties of stone are known as the Medina red stone, the white or gray Medina and the variegated (red and white) or spotted. The quarries in this district are worked on an extensive scale, and their equipment is adequate to a large annual production. The aggregate output is larger and more valuable in dimension stone for dressing than that of any other quarry district in the state. Including the stone for street work, the total value is greater than that obtained from the stone of any other geological formation in the state. The stone has gained a well-deserved reputation for its value as a beautiful and durable building material; and its more general employment, both in construction and in paving, is much to be desired. The extent of the outcrops offers additional sites for quarrying operations, and the greater use of this stone, and the increase of the producing capacity of the district are here suggested.

Clinton group

The rocks of this group are shales, thin beds of limestone and shaly sandstones. They crop out in a narrow belt from Herkimer county west to the Niagara river and bordering the Medina sandstone on the south. Sandstone for building has been quarried in the southern part of Herkimer county; at Clinton, near Vernon and at Higginsville in Oneida county, from this formation. The nearness of the Medina sandstone, with its more accessible quarries and superior stone, has prevented the more extensive development of the quarrying industry in the sandstone of the Clinton group.

Oriskany sandstone

The Oriskany sandstone formation is best developed in Oneida and Otsego counties. The rock is hard, silicious and cherty in places, and generally too friable to make a good building stone. No quarry of more than a local importance is known in it.

Cauda galli grit and Schoharie grit

These rocks are limited to Schoharie and Albany counties and to a very narrow belt which stretches south and thence southwest to Ulster county. The Cauda galli sandstones are argillaceous and calcareous and are not durable. They are used in Albany county for road metal, but are not very good for this purpose. The Schoharie grit is generally a fine-grained, calcareous sandrock which also is unsuited for building. Quarries in these rocks have local use only.

Marcellus shale

As its name implies, this formation is characterized by shaly rocks, which are not adapted to building. The abundance of good building stone in the next geologic member below it—the Corniferous limestone—whose outcrop borders it on the north throughout the central and western parts of the state, also prevents any use which might be made of its stone. A single quarry was at one time opened in it at Chapinville, Ontario county.

Hamilton group

The rocks of the Hamilton group outcrop in a narrow belt, which runs from the Delaware river, in a northeast course, across Sullivan and Ulster counties to the Hudson valley near Kingston; thence north, in the foot-hills, bordering the Catskills, to Albany county; then, bending to the northwest and west across the Helderberg mountains into Schoharie county; thence increasing in width, through Otsego, Madison and Onondaga counties, forming the upper part of the Susquehanna and Chenango watersheds; thence west, across Cayuga, Seneca, Ontario, Livingston, Genesee and Erie counties to Lake Erie. In this distance there is some variation in composition and texture. In the western and central parts of the state there is an immense development of shales and the few quarries in the sandstone referable to this group are unimportant. In the Helderberg region in the Hudson valley and thence, southwest, to the Delaware river, the sandstones predominate, and all of the beds are more sandy than at the west.

Bluestone

There is a great development of the bluish-gray, hard, compact and even-bedded stone, which is known as 'Hudson river bluestone.'

This is a variety of sandstone, which, by reason of its even texture can be cut or sawed into any desired form and is therefore peculiarly available for house trimmings of various kinds. The sandstone is usually interbedded with shale and in general, the layers in the quarries vary from an inch to several feet in thickness; the thinner of these are used for flagstones and the thicker are cut into dimension stones for building purposes.

The geological horizon of the commercial bluestone is very near the dividing line between the Hamilton and Portage groups. It is, however, not usually possible to determine in which of these groups a given quarry belongs, owing to the great scarcity of fossils.

The bluestone industry is chiefly located in Ulster county and the quarries are almost innumerable but the business is controlled by a few large dealers who are located at points favorably situated for shipment and who, to a considerable extent, buy stone from the men who quarry it. Bluestone is also produced in the counties of Albany, Greene, Sullivan, Delaware and Chenango in Eastern New York and in Cattaraugus and Wyoming counties in Western New York.

The number of quarries is large and can be increased indefinitely, as nearly the whole area of the formation appears to be capable of producing stone for flagging or for building. The difficulty of indicating the division line between the Hamilton and the Oneonta and the Hamilton and the Portage groups of rocks makes it impossible to refer to localities more particularly. The quarries near Cooperstown, and in the lake region, particularly at Atwater, Trumansburg, Watkins and Penn Yan belong to the Hamilton group.

Portage group

In this is included the Oneonta sandstone, the limits of which at the east can not be indicated; the flagstone beds of the Hudson valley and of the eastern part of the State continue up into the Oneonta sandstone horizon. Many of the quarries are in the latter formation. The more western and northwestern and higher quarries are in it; and some of the Chenango county quarries also.

The Portage rocks in the western part of the State consist of shales at the base; then shales and flagstones; and the Portage sandstone at the top. In the last division, thick beds with little shale are marks of this horizon. The stone is generally fine-grained. The quarries near Portage and near Warsaw are in it; also the quarries at Laona and Westfield in Chautauqua county.

Although not of as great extent in its outcrop as the Hamilton group, the Portage rocks are developed to a thickness of several hundred feet along the Genesee river at Mount Morris and at Portage; and form a belt having a breadth of several miles through Tompkins, Schuyler, Yates, Ontario and Livingston counties, and thence west to Lake Erie. The formation is capable of supplying an immense amount of good building stone and flagstone throughout its undeveloped territory.

Chemung group

The rocks of the Chemung group crop out in the southern tier of counties, from Lake Erie eastward to the Susquehanna. The shales are in excess of the sandstones in many outcrops, and there is less good building stone than in the Portage horizon. The variation in color and texture is necessarily great in the extensive area occupied by the Chemung rocks, but the sandstones can be described as thin bedded, generally intercalated with shaly strata, and of a light-gray color, often with a tinge of green or olive-colored. The outcropping ledges weather to a brownish color. Owing to the shaly nature of much of the sandstone of the Chemung group, the selection of stone demands care, and the location of quarries where good stone may be found is attended with the outlay of time and money, and with great chances of possible failure. Quarries have been opened near the towns and where there is a market for ordinary grades of common wall stone, and also for cut stone, but the larger part of their product is put into retaining walls. At Elmira and Corning good stone has been obtained, which is expensive to dress, and does not compete for fine work with sandstones from districts outside of the State. The quarries at Waverly, Owego, Elmira and Corning, and nearly all of the quarries in Allegany, Cattaraugus and Chautauqua counties are in the Chemung sandstone.

Catskill group

As implied in the name, this formation is developed in the Catskill mountain plateau in the eastern part of the state. Sandstones and silicious conglomerates predominate over the shales. The thicker beds of sandstones are generally marked by oblique lamination and cross-bedding, which make it difficult and expensive to work into dimension blocks. Except for flagging and for local use but little is quarried. There are no large towns in the district, and consequently the demand is light. There are, however, some good quarries, which are worked for flagging, chiefly along the New York, Ontario and Western railroad and the Ulster and Delaware railroad lines in Ulster and Delaware counties; and in the Catskills, in Greene county, there are quarries in Lexington, Jewett, Windham, Hunter and Prattsville.

Triassic formation

This formation, which is known, locally, as the red sandstone, is limited in New York to a triangular area in Rockland county, between Stony Point on the Hudson and the New Jersey line, and to a small outcrop near the north shore of Staten Island, which is the southern end of the same belt.

The sandstones are both shaly and silicious, and the varieties grade into one another. Conglomerates of variegated shades of color also occur, interbedded with the shales and sandstones. Formerly these conglomerates were in favor for the construction of furnace hearths. They are not now quarried. The prevailing color of the sandstone is dark-red to brown, whence the name 'brownstone.' In texture there is a wide variation, from fine conglomerates, in which the rounded grains are somewhat loosely aggregated, to the fine, shaly rock and the 'liver rock' of the quarrymen. Oxide of iron and some carbonate of lime are the cementing materials in these sandstones.

The well-known Massachusetts Longmeadow sandstone and the Connecticut brownstone are obtained from quarries in the Connecticut valley region, and of the same geological horizon. The Littlefalls, Belleville and Newark freestones are from the same formation in its southwest extension into New Jersey.

Quarries were opened in this sandstone more than a century ago, and many of the old houses of Rockland county are built of it. Prof. Mather reported 31 quarries on the bank of the Hudson near Nyack. The principal market was New York city, and the stone was sold for flagging, house trimmings and common walls. The Nyack quarries have been abandoned, with one or two exceptions, as the ground has become valuable for villa sites and town lots. There are small quarries at Suffern, near Congers Station, near New City and at the foot of the Torn mountain west of Haverstraw. They are worked irregularly and for local supplies of stone. The stone is sometimes known as 'Nyack stone,' also as 'Haverstraw stone.'

SLATE

Argillite, clay-slate, or roofing slate, which is marked by the presence of cleavage planes, and can be split into thin plates of uniform thickness, is a characteristic rock in the Hudson river group and the Lower Cambrian or Georgian group.

Slate suitable for roofing has been found in many localities, and quarries have been opened in Orange, Dutchess, Columbia, Rensselaer and Washington counties. The openings in Orange county have not resulted in productive quarries. In Columbia county quarries were worked many years ago, east of New Lebanon. The Hoosick quarries, in Rensselaer county, were once more extensively worked, and produced a good, black slate. Outcrops of red slate are noted east of the Hudson, from Fishkill and Matteawan northward, but no attempts have been made to open quarries in them.

The productive slate quarries of the state are in a narrow belt, which runs a north-northeast course through the towns of Salem, Hebron, Granville, Hampton and Whitehall in Washington county.

This slate belt is divided by the quarrymen into four parallel ranges or 'veins,' which are: East Whitehall red slates; the Mettowee, or North Bend red slate; the purple, green and variegated slates of Middle Granville; and the Granville red slates. The latter are close to the Vermont line. Further to the east, but over the state line, in Vermont, is the range of the sea-green slates.

The quarry localities are at Shushan, Salem, and Black Creek valley, in the town of Salem, Slateville, in Hebron, Granville, the Penrhyn Slate Company's quarries, Middle Granville, Mettowee or North Bend quarries, and the Hatch Hill quarries in East Whitehall.

LIMESTONE AND MARBLE

Limestones consist essentially of calcium carbonate. They are, however, often quite impure; and the more common accessory constituents are silica, clay, oxides of iron, magnesia, and bituminous matter. These foreign materials may enter into their composition to such an extent as to give character to the mass, and hence they are said to be silicious, argillaceous, ferruginous, magnesian, dolomitic, and bituminous.

The chemical composition is subject to great variation, and there is an almost endless series of gradation between these various kinds. Thus, the magnesium carbonate may vary in quantity from a trace, to the full percentage of a typical dolomite. Or, the silica may range from a fractional percentage to the extreme limit where the stone becomes a calcareous sandstone. Crystallized minerals, as mica, quartz, talc, serpentine and others, also occur, particularly in the more crystalline limestone.

In color there is a wide variation—from the white of the more nearly pure carbonate of lime through gray, blue, yellow, red, brown, and to black. The color is dependent upon the impurities.

The texture also varies greatly. All limestones exhibit a crystalline structure under the microscope, but to the unaided eye there are crystalline and massive varieties. There are coarse crystalline, fine crystalline, and sub-crystalline varieties, according as the crystals are larger, smaller, or recognized by the aid of a magnifying glass only. The terms coarse-grained and fine-grained may apply when there is a resemblance to sandstone in the granular state of aggregation. Other terms, as saccharoidal (like sugar), oolitic, when the mass resembles the roe of a fish; crinoidal, made up of the stems of fossil crinoids, also are in use, and are descriptive of texture. The state of aggregation of the constituent particles varies greatly, and the stone is hard and compact, almost like chert, or is loosely held together and crumbles on slight pressure, or again it is dull and earthy as in chalk.

The crystalline, granular limestones, which are susceptible of a fine polish, and which are adapted to decorative work, are classed as *marbles*. Inasmuch as the distinction is in part based upon the use, it is not sharply defined and scientific. Generally the term is restricted to those limestones in which the sediments have been altered and so metamorphosed as to have a more or less crystalline texture. There is however some confusion in the use of the terms, and the same stone is occasionally known as marble and limestone, e. g., the Lockport limestone or marble; the limestone and coral shell marble of Becraft's mountain, near Hudson; the Lepanto marble or limestone near Plattsburg, and others.

The fossiliferous limestones are made up of the remains of organisms which have grown in situ, as for example, the coralline beds in the Helderberg and Niagara limestones, or have been deposited as marine sediments. In the case of the latter the fossils are more or less comminuted and held in a calcareous matrix. Generally the fossil portions of the mass are crystalline. The Onondaga gray limestone from near Syracuse, and the Lockport encrinal limestone are good examples.

The fossil remains are less prominent and scarcely visible in some of the common blue limestones, as in the lower beds of Calciferous and in some of the Helderberg series. These rocks are compact, homogeneous and apparently uncrystalline and unfossiliferous. They are usually more silicious or argillaceous, that is, they contain quartz or clay, the latter often in seams rudely parallel with the bedding planes. On weathering, the difference in composition is often markedly apparent at a glance. Similar differences in composition are seen in the more crystalline marbles, and are evident either by variation in color, or in the presence of foreign minerals, as mica, quartz, hornblende, pyrite, etc.

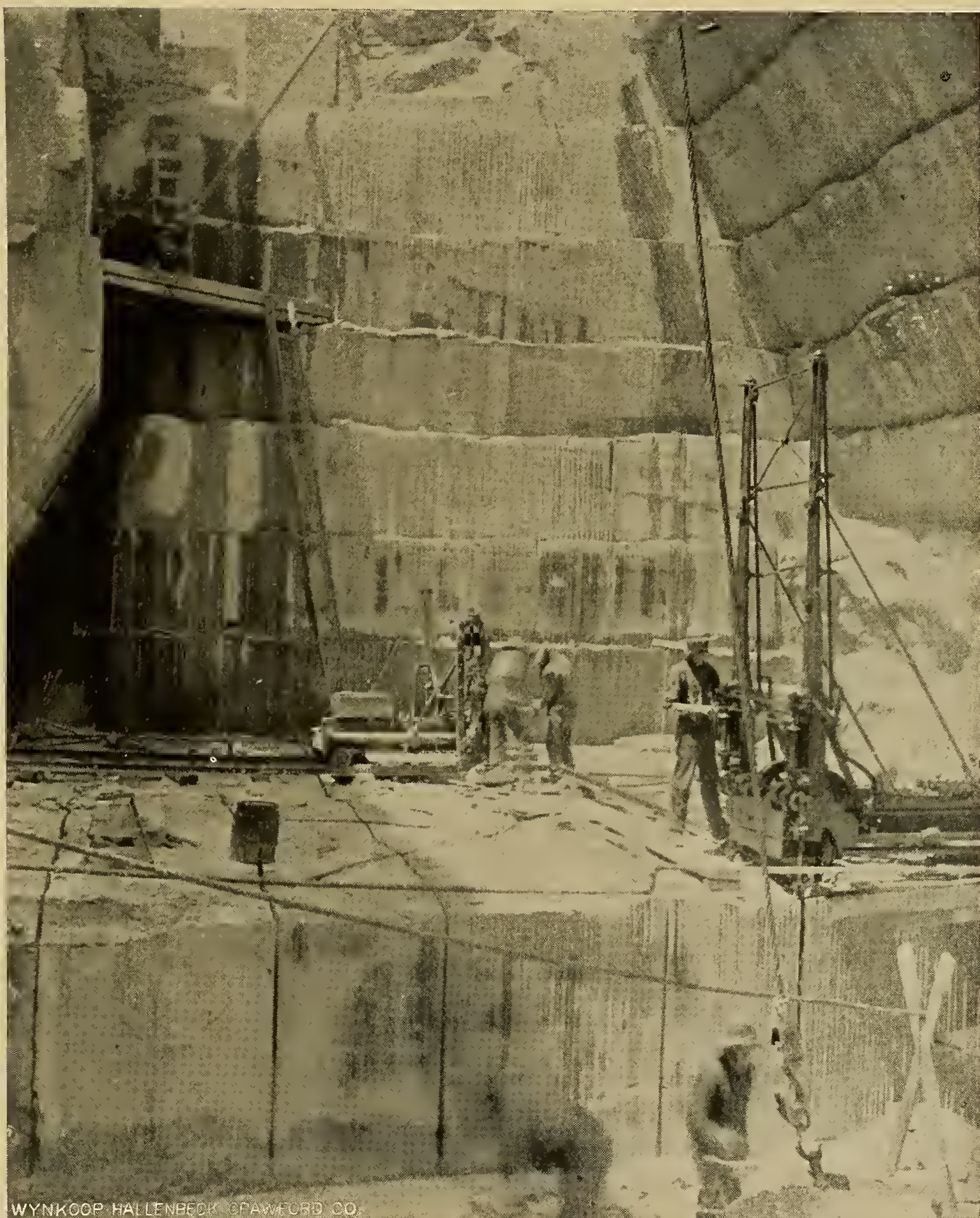
The variations in the strength and durability is as great as in the composition and texture. Some are stronger than many granites in their resistance to crushing force, and equally enduring; others consist of loosely cohering grains, and are friable and rapidly dissolved by atmospheric agencies. The more silicious and compact limestones are generally the more durable and stronger; in the marble the well-crystallized and more homogeneous texture consists with endurance and strength. Both the magnesian and dolomitic varieties are good stone as is proven by the Calciferous and the Niagara limestones, and in the marbles of Tuckahoe and Pleasantville, in Westchester county.

PLATE CVII.—To face page 198.

H. Ries, photo.

MARBLE QUARRY, TUCKAHOE, WESTCHESTER CO. METAMORPHOSED CALCIFEROUS-TRENTON LIMESTONE.

PLATE CVIII.—To face page 198.



J. N. Nevius, photo.

INTERIOR OF NORTHERN NEW YORK MARBLE CO.'S QUARRY, NEAR GOUVERNEUR, ST. LAWRENCE CO. PRECAMBRIAN.

Crystalline limestones occur in New York and Westchester counties, and in the Highlands of the Hudson. In the Adirondack region there are numerous localities. The rock in many of them is too impure and has too many foreign minerals to admit of its use as marble. Quarries have been opened in Westchester, Putnam and Dutchess counties, which have yielded a large amount of fine white marble. In the northern part of the state, the Port Henry and the Gouverneur quarries have been productive. The geological horizon of some of these marbles is in doubt. The belt in the eastern part of Dutchess and Putnam counties belongs to the Vermont marble range, and is probably metamorphosed Trenton limestone. The Westchester marbles are of the same age.

The limestones which furnish building stone in this state are the Calciferous, Chazy, Birdseye, Black river, Trenton, Niagara, Lower Helderberg, Upper Helderberg, or Corniferous, and Tully. The geographical distribution is given in the following notes, and in the order of geological succession, from the lowest to the highest.

Calciferous sandrock

The rocks of the Calciferous formation in the Mohawk valley and in the Champlain valley are more silicious than at the southwest, in Orange county and in the Hudson valley, and hence the designation as a sandrock. Much of it at the north is a limestone rather than a sandstone, and may be termed a magnesian or silicio-magnesian limestone. Nearly all of the limestones, which are quarried for building stone, in Orange and Dutchess counties are from this formation. The stone occurs generally in thick and regular beds. It is hard, strong and durable and is adapted for heavy masonry as well as for fine cut work. The quarries near Warwick, Mapes' Corners and near Newburgh in Orange county and those on the Hudson river, near New Hamburg, are in the Calciferous. The Sandy Hill quarry and those at Canajoharie and Littlefalls are also in it.

Trenton limestone

Under this head the Chazy, Birdseye, Black river and Trenton limestones are included.

The Chazy limestone crops out in Essex and Clinton counties and in the Champlain valley—its typical localities. The beds are thick and generally uneven. Regular systems of joints help the quarrymen in getting out large blocks. Quarries at Willsboro Point and near Plattsburg are in the horizon of the Chazy. The stone is suitable for bridge work and for heavy masonry.

The members of the Trenton above the Chazy limestone are recognized in may outcrops in the southeastern part of the state; in the Hudson-Champlain valley; in the Mohawk valley; in the valley of the Black river and northwest, bordering Lake Ontario; and in a border zone on the north of the Adirondacks, in the St Lawrence valley. In a formation so widely-extended there is, as might be expected, some variation in bedding, texture and color. Much of the Trenton limestone formation proper is thin-bedded and shaly and unfit for building stone. In the Birdseye also the stone of many localities is disfigured on weathering, by its peculiar fossils. Generally the stone is sub-crystalline, hard and compact and of a high specific gravity and dark-blue to gray in color. But the variation is wide, as for example, between the black marble of Glens Falls and the gray, crystalline rock of the Prospect quarries near Trenton Falls. The variation is often great within the range of a comparatively few feet vertically; and the same quarry may yield two or more varieties of building stone. In several quarries the Birdseye and Trenton are both represented. Many quarries have been opened in the formation and there are many more localities where stone has been taken from outcropping ledges, which are not developed into quarries proper. The more important localities which are worked steadily are: Glens Falls, Amsterdam, Tribes Hill, Canajoharie, Palatine Bridge and Prospect in the valley of the Mohawk; and Lowville, Watertown, Three Mile Bay, Chaumont and Ogdensburg in the Black river and St Lawrence valleys. The railroad and canal lines, which traverse the territory occupied by these formations, afford transportation facilities and offer inducements to those who are seeking new quarry sites where these limestones may be found in workable extent.

Niagara limestone

The Niagara limestone formation is well developed west from Rochester to the Niagara river; and there are large quarries in it at Rochester, at Lockport and at Niagara Falls. The gray, sub-crystalline stone in thick beds is quarried for building purposes. It is filled with encrinal and coralline fossils and the unequal weathering of the matrix and the fossiliferous portions are sometimes such as to give the dressed surface a pitted appearance with cavities which roughen and disfigure it. For foundations and heavy masonry it is well adapted. It has been extensively employed in the western part of the state.

Lower Helderberg limestones

The Water-lime, Tentaculite and Pentamerus limestones are included in this group. The outcrops are in the Rondout valley, southwest from Kingston to the Delaware river; in the foothills east of the Catskills—in Ulster and Greene counties; on Becraft's mountain, near Hudson; and in a belt stretching west from the Hudson valley, along the Helderbergs and across Schoharie into Herkimer county.

The Tentaculite limestone is dark-colored, compact and in thick beds and can be quarried in large blocks. Some of it can be polished and makes a beautiful black marble, as for example, that of Schoharie.

The Pentamerus limestones, both the lower and the upper, are in thick beds and are gray, sub-crystalline in texture, and look well when dressed. They are adapted to heavy masonry as well as for cut work.

Quarries are opened in this group of limestones in the Schoharie valley, at Howe's Cave, Cobleskill, Cherry Valley and in Springfield. The quarries west of Catskill and in Becraft's mountain, near Hudson, are also in it.

Upper Helderberg limestones

The Upper Helderberg formation appears in the Hudson valley at Kingston; thence it runs in a belt west of the river, to the Helderberg mountains, bending to the west-northwest, and thence west it continues across the state to the Niagara river and Lake Erie. The subdivisions are known as the Onondaga, the Corniferous and the Seneca limestones. The first is more generally recognized as the 'Onondaga gray limestone' and the last as the Seneca blue limestone.

There is much diversity in the limestones of this group in its long range of outcrop. The Onondaga gray stone is gray in color, coarse crystalline; and makes beautiful ashlar work, either as rock face or as fine tooled, decorative pieces.

The Corniferous limestone is hard and durable, but it is so full of chert that it can only be used for common wall work.

The Seneca blue limestone is easily dressed and is a fairly good building stone.

Limestone of the Upper Helderberg epoch is quarried extensively at Kingston, Ulster county, and is a valuable building stone. In Onondaga county there are the well-known Splitrock and Reservation groups of quarries, which have produced an immense quantity of excellent and beautiful stone and which has found a market in all of the central part of the state. They are in the lower member of the group. Going west, there are the large quarries in the Seneca limestone at Union Springs, Waterloo, Seneca Falls and Auburn. The LeRoy, Williamsville, Buffalo and Black Rock quarries are in the Corniferous limestone.

The aggregate output of the quarries in the Upper Helderberg limestones exceeds in value that of any other limestone formation in the state. The many quarries of the Trenton probably produce more stone.

Tully limestone

The Tully limestone lying above the Hamilton shales, is a thin formation which is seen in Onondaga county and to the west—

disappearing in Ontario county. It does not furnish any stone other than for rough work and in the immediate neighborhood of its outcrops.

Calcareous tufa

As a supplement to the limestones the quarries in calcareous tufa at Mohawk, in the Mohawk valley, and at Mumford, Monroe county, should here be mentioned, although they are only of local importance.

GLACIAL DRIFT

This material, consisting of unsorted clays, sands, gravels, cobbles and boulders, is found in all parts of the state. The nature of the imbedded stone varies greatly both as to variety and amount. In places the deposits are full of large blocks of stone and of more or less rounded and scratched boulders; in other localities the hard, quartzose cobbles and small boulders predominate. In the sandstone districts of the southern and western parts of the state the surface deposits of glacial drift contain much sandstone, as in the Medina sandstone belt, the Hudson river blue stone territory and the red sandstones at Haverstraw and Nyack. In the Highlands and in the Adirondacks the rounded, crystalline, granitoid and gneissic rocks predominate. On Long Island the terminal moraine includes a great amount of stone, and of many kinds.

The cobblestones were formerly used for paving roadways, but this kind of pavement is no longer laid. From the fact of the stone being picked off the fields in the clearing of land for tillage, the stone fragments from the drift have been known as 'field-stone;' and they were used in the earlier constructions for walls, foundations and buildings, in localities where no quarries had been opened.

Some of the oldest houses on the western end of Long Island, and in the Hudson river counties are built of such field stone. At Yonkers the excavations for foundations and in street grading afford an abundant supply of stone for common wall work. In parts of Brooklyn the drift furnishes a great deal of stone in the shape of huge boulders.

The stone of the drift is generally hard and durable, having resisted the wear of rough transportation. The economic use of the surface stones of the drift in constructive work, where they can be laid up in walls, is a desirable utilization of what is still in many parts of the state worse than waste—a nuisance in the tilling of the soil. This formation can not, however, be considered as one of the important sources of stone in the quarry industry, although capable of yielding a great deal of rough stone. It will no doubt do so in the future clearing and improvement of the country.

Road Metal

In New York the best materials for road metal are trap, granite and magnesian limestone.

Trap is a general term for some of the basic eruptive rocks, the word being related to or derived from the German *Treppen* which signifies a flight of steps and is suggested by the somewhat regular manner in which the rock is jointed.

The trap which is used in New York for a road metal is a diabase and consists chiefly of the minerals augite and labradorite, the former being a silicate of iron and magnesia and the latter being a lime-soda feldspar. Other minerals are present in small quantity but do not influence the properties which make the rock valuable as a road metal.

While sufficiently hard to resist the wear of heavy traffic to a satisfactory extent, it possesses a high degree of binding or cementation power. This means that the dust produced by wear when moistened unites quite firmly and forms a cement which binds the larger fragments to a considerable extent.

This property is most noticeable in rocks containing much lime, magnesia and alumina.

Good trap is found only in Richmond and Rockland counties, and in the intermediate area of New Jersey bordering the Hudson river. Its outcrop is known as the 'Palisades.'

Granite consists chiefly of quartz mixed with one or more of the feldspars and hornblende or a mica. Hornblende has essentially the same composition as augite which occurs in trap; and a hornblende granite should be a very good road metal. Where hornblende is absent one would expect to find less binding power.

Granite is harder than trap and therefore should resist wear better, but this quality is offset by its usually smaller binding power so that trap should be preferred as a rule.

Granite is found in the Adirondack region and in the Highlands of the Hudson, also in Westchester county. The commercial term granite includes various kinds of gneiss.

Magnesian limestone has great binding power but is quite soft and therefore not very durable for heavy traffic. Chemically, this rock is a carbonate of lime, containing also magnesia, alumina and silica. It has been suggested that it might be used profitably as a binder with stone of less binding power.

Sandstone has usually no lime, magnesia or alumina and therefore has no binding properties and never makes a first rate road, as the fragments continually break loose.

Limestone is found chiefly in areas parallel to and near the main line of the New York Central railroad and in a zone around the Adirondacks.

In New York the best road materials occur in certain limited areas, and at points distant from these the cost of transportation is the controlling feature.

For high class road building, trap and granite will be preferred and used in all places where their cost is not prohibitory. Experience shows, however, that unless these materials are used under the direction of experienced road engineers, they are less satisfactory than limestone, and when it is proposed to macadamize a road by simply covering it with broken stone, the latter though less durable, will be more satisfactory.

When granite and trap are properly laid, on a well prepared bed and rolled with a heavy steam roller to the proper standard of firmness, nothing can be better, but where no steam roller is available and the subgrade is not properly prepared, the trap and granite are liable to afford only an unpleasant and uneven surface of hard angular fragments which ceaselessly roll about on the surface of the road injuring the horses and making pleasure driving impossible.

Limestone from its softness and greater binding power is more easily rolled into an even surface under the wheels of vehicles, and while not having the durability to support heavy traffic for a long time, can be cheaply renewed if the source of supply is not far distant. This fact has been recognized for a long time at points within easy reach of the limestone quarries. In Onondaga county at many points a portable crusher has been used to crush the blocks for road metal from the limestone fences which are cheerfully donated by the residents for the improvement of the roads. There are many other counties in which this might be done as may be seen from the geologic map. In most of these areas limestone will be found in the fences and may be crushed for road metal at small expense.

Many of the local stone quarries, which are scattered over the state, sell for road metal the rock obtained in stripping off the upper layers from their quarries.

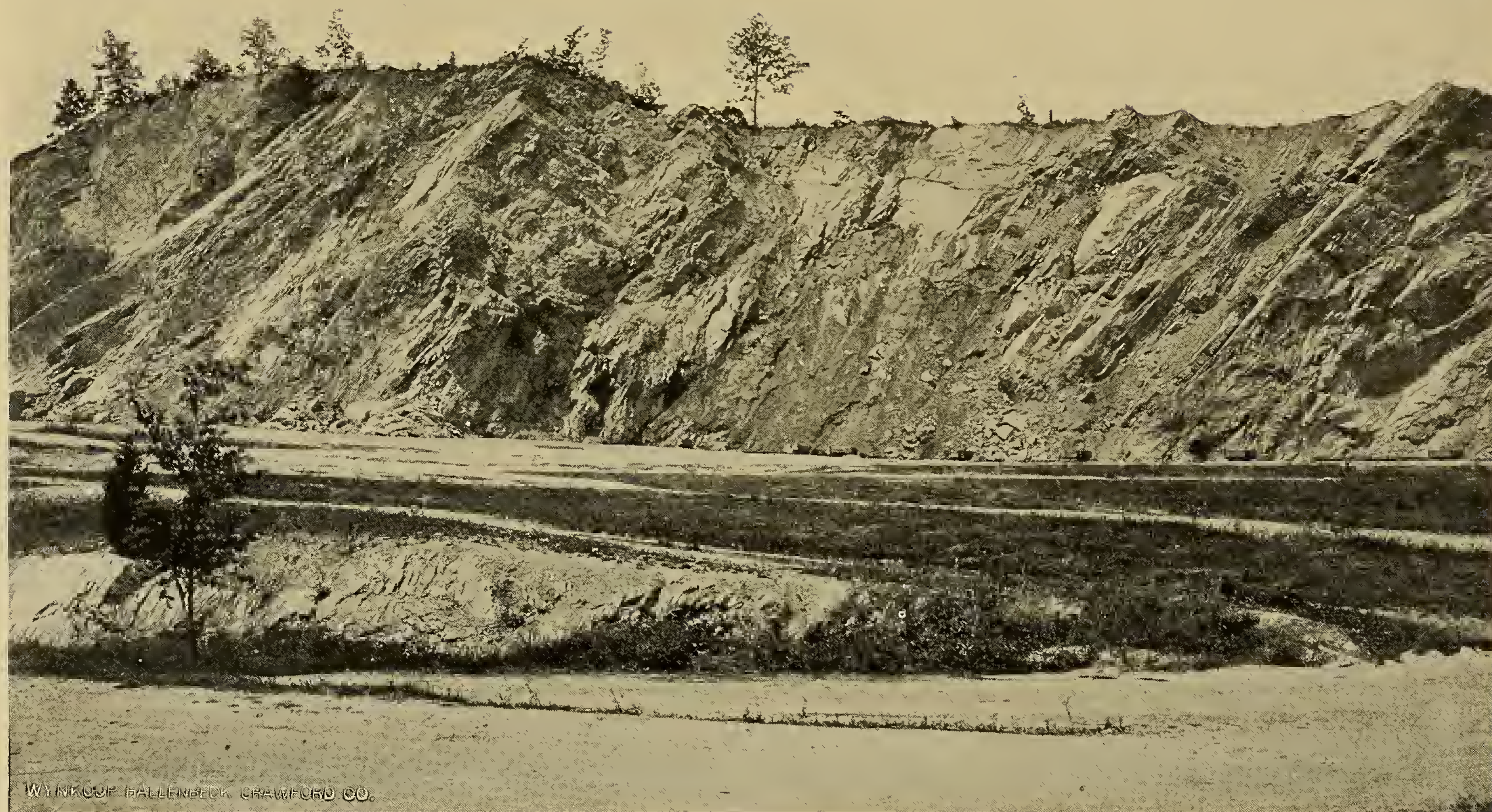
A few large quarries are operated for road metal alone and deserve special mention.

Many tons of material are quarried annually from the Palisades range near Piermont. The material, which is exceedingly tough, is either dressed for paving blocks or crushed for road metal.

Farther up the Hudson river the limestone quarries of Tomkins Cove have been in operation for a number of years and supply large quantities of rock for macadam. Other quarries are at South Bethlehem, Albany county, Howe's Cave, Schoharie county and there are several near Syracuse and Buffalo. This magnesian limestone is one of the best materials used. It is hard, packs easily and makes a good surface, but the cost of maintenance is considerable.

At Iona Island a granite is quarried and crushed to five or six different sizes for road metal and concrete. The fine residue or dust is sold for polishing.

PLATE CIX.—To face page 206.



H. Ries, photo.

LIMESTONE QUARRY, TOMKINS COVE, ROCKLAND CO. METAMORPHOSED CALCIFEROUS-TRENTON LIMESTONE.

PLATE CX.—To face page 206.

H. Ries, photo.

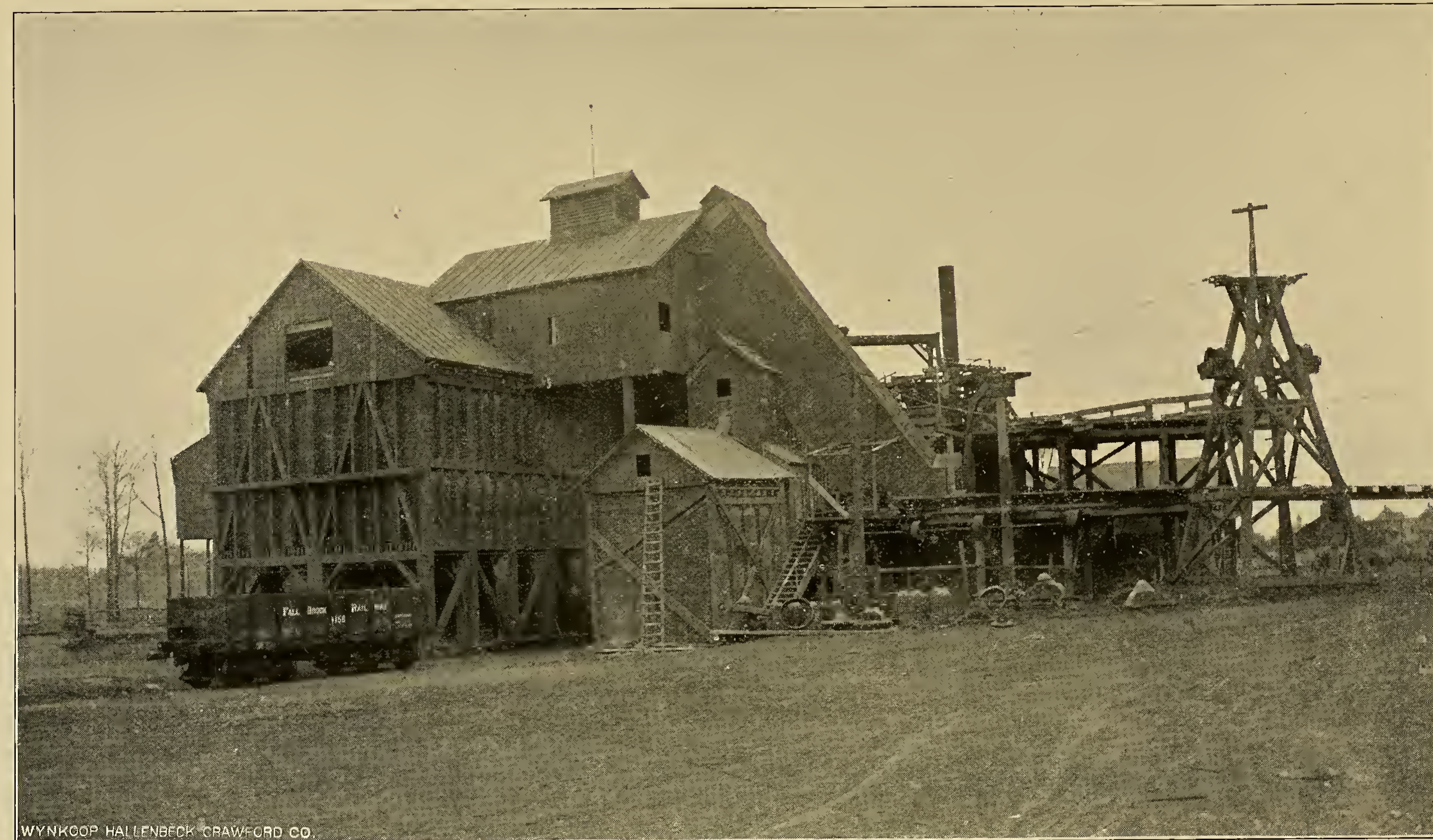
QUARRY IN LOWER HELDERBERG LIMESTONE, SOUTH BETHLEHEM, ALBANY CO.

PLATE CXI.—To face page 206.

I. P. Bishop, photo.

Road Metal and Paving Block Quarry of the Barber Asphalt Co., Near Humboldt Parkway, Buffalo, Erie Co.
Corniferous Limestone.

PLATE CXII.—To face page 206.



I. P. Bishop, photo.

Stone Crushing Plant of the Barber Asphalt Co., Buffalo, Erie Co.

The Hudson River Stone Supply Company has an extensive plant for quarrying and crushing granite, at Breakneck Mt, north of Cold Spring. The same company operates a second plant for supplying crushed limestone at Stoneco, north of New Hamburg.

One of the largest quarries in the state is that of P. Callanan at South Bethlehem, Albany county. The Lower Helderberg limestone is the rock used and it makes a good road.

The Cauda galli grit of Albany county is used in small quantities locally and makes an excellent road, though it is not durable.

At Duanesburg, near Schenectady, sandstone of the Hudson river group is crushed for road metal.

At Port Chester, Westchester county, a coarse-grained granite is quarried and is considerably used locally, but the best macadam roads of that district are of limestone from Tomkins Cove.

The gray gneiss has been considerably used as a road material in Westchester county.

On Staten Island the yellow gravel is much used for road making; also the diabase or trap from the Graniteville quarries, which is being extensively used on a system of county roads with the most satisfactory results.

The materials used for making roads in the state vary with the locality. If the traffic on the road is moderate it is generally safe to use the local material, whatever its nature, unless it be shale, but if there is a heavy traffic it will pay in most instances to get a stone of superior quality from elsewhere.

The requisite qualities of a road metal are hardness and toughness. Where both these qualities are not obtainable in the same stone the latter is perhaps preferable.

Silicious rocks, though often hard, do not consolidate as well nor so quickly as limestone, owing to the sandy detritus formed by the former having no cohesion. The detritus of magnesian limestone acts like a mortar.

Granite and gneiss, especially if very micaceous, are apt to disintegrate rapidly and produce dust and mud.

Shale is to be avoided, as it breaks up rapidly, forming a sticky mud.

Gravel, while making a serviceable road, does not pack well, and is not durable. If it has to be used, some of the difficulty may be overcome by cracking the pebbles so as to produce an angular form.

Clay and Clay Products[a]

Deposits of clay occur in nearly every county of New York. They belong to three geological periods, namely:

Quaternary, Tertiary and Cretaceous.

The clays of the first age are by far the most common. Those of the second are somewhat indefinite in extent, but they probably include a large number of the Long Island deposits. Of the third class there are undoubted representatives on Long Island and Staten Island.

The clays of the mainland are all Quaternary so far as known. The problems of Quaternary geology in New York are by no means solved, and it is not always possible to decide on the causes leading to the deposition of any particular body of clay by a single visit to the locality.

A great majority of the deposits are local, lying in the bottoms of valleys which are often broad and fertile. They vary in depth from four to 20 or even 50 feet; as a rule they are underlaid by modified drift or by bed rock. The clay is generally of a blue color, the upper few feet being weathered mostly to red or yellow. Stratification is rarely present, but streaks of marl are common. In some of the beds small pebbles, usually of limestone, are found, and these have to be separated by special machinery in the process of manufacture. In many instances the clay is covered by a foot or more of peat.

These basin deposits are no doubt the sites of former ponds or lakes, formed in many instances by the damming up of valleys, which have been filled later with the sediment of the streams from the retreating ice sheet. The valleys in which

a Abridged from Bulletin No. 12 New York State Museum, by Heinrich Ries.

these deposits lie are usually broad and shallow. The broad flat valley in which the Genesee river flows from Mt Morris to Rochester is a good example. The waters of the river were backed up by the ice for a time, during which the valley was converted into a shallow lake in which a large amount of aluminous mud was deposited. This material has been employed for common brick.

Around Buffalo is an extensive series of flats underlaid by a red clay. A thin layer of sand suitable for tempering overlies the clay in spots, and limestone pebbles are scattered through it. Similar deposits occur at several localities to the north of the Ridge road and around Niagara Falls, also at Tonawanda and La Salle, to the north of Buffalo, as well as south of it along the shore of Lake Erie. No doubt much of this clay was deposited during the former extension of the Great Lakes.

Prof. James Hall mentions deposits of clay at the following localities: at Linden, one mile south of Yates Center; [a]along the shore of Lake Ontario, east of Lewiston; on Cashaqua creek [b]deposits of tenacious clay due to the crumbling of the argillaceous green shales; in Niagara county [c]beds of clay are said to occur in every town, but they often contain a considerable amount of lime.

At Levant, four miles east of Jamestown, Chautauqua county, is an interesting bed of blue clay having an area of several acres. It is probably of post-glacial age.

At Breesport, near Elmira, is a bank of blue clay rising from the valley to a height of 50 feet. It was evidently formed when the valley was dammed up, and has subsequently been much eroded so that all that now remains is a narrow terrace along the side of the valley. A similar deposit is found at Newfield, south of Ithaca. A moraine crosses the valley a mile or two south of it.

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[a] Geology of New York, 4th District, 1843, p. 437.
[b] Ibid., p. 227.
[c] Ibid., p. 444.

In the southern portion of the state we find clays in abundance, in all the valleys, and lowlands. The extensive marshes near Randolph and Conewango are said to be underlaid by clay throughout their entire extent.

A bed of blue and red clay is being worked at Brighton near Rochester. This deposit lies near the head of Irondequoit bay.

Clays are also found at several points in the valley of the Oswego river from Syracuse to Oswego, an important one being at Three Rivers.

Deposits of clay suitable for brick and tile occur extensively in the lowlands bordering the Mohawk river from Rome to Schenectady. The beds vary in thickness from six to 15 feet and are mostly of a red, blue or gray color.

An extensive bed of red and gray clay, 20 acres in extent and horizontally stratified, occurs at Watertown. The deposit is 20 feet thick and rests on Trenton limestone.

Another deposit of considerable size is being worked at Ogdensburg. The clay is blue and has a depth of 60 feet.

HUDSON VALLEY

Among the most extensive and important clay formations occurring in New York are those of the Hudson valley. These deposits indicate a period of depression, and deposition in quiet water. The clay is chiefly blue, but where the overlying sand is wanting or is of slight thickness, it is weathered to yellow, this weathering often extending to a depth of 15 feet below the surface, and to a still greater depth along the line of fissures. The depth of oxidation is of course influenced by the nature of the clay; the upper portion weathering easily on account of its more sandy nature and hence looser texture. Horizontal stratification is usually present, and the layers of clay are separated by extremely thin laminæ of sand. At some localities the layers of the clay are very thin and alternate with equally thin layers of sandy clay. This condition is found at Haverstraw, Croton, Dutchess Junction, Stony Point, Fishkill, Cornwall, New Windsor, Catskill and Port Ewen. At all of the above-mentioned localities except

H. Ries, photo.

PLEISTOCENE BRICK CLAYS, HAVERSTRAW, ROCKLAND CO.

the last two, the clay is overlaid by the delta deposits of rivers tributary to the Hudson, and the alternation of layers may be due to variations in the flow of the rivers emptying at those points, the sandy layers being deposited during periods of floods. Isolated ice-scratched bowlders are not uncommonly found in the clay.

There is often a sharp line of division between the yellow weathered portion and the blue or unweathered part of the clay. The line of separation between the clay and overlying sand is also quite distinct in most cases. Of the blue and the yellow clay the former is the more plastic, but both effervesce readily with acid, due to the presence of 3 to 6% of carbonate of lime, and are, therefore, properly speaking, marly clays. The clay is underlaid by a bed of gravel, sand, hardpan, bowlder, till or bed rock. From Albany to Catskill the underlying material is a dark gray or black sand with pebbles of shale and quartz. The sand grains are chiefly of pulverized shale, the rest being silicious and calcareous with a few grains of feldspar and garnet. This sand can often be used for tempering, but at Catskill contains too much lime for this purpose.

From Catskill northward the clay is in most cases covered by but a foot or two of loam. South of Catskill the character of the overlying material varies.

THE CLAYS OF THE CHAMPLAIN VALLEY

The clays of the Champlain valley are estuary formations and of the same age as the Hudson river clays. They underlie terraces along the lake which have been elevated to a height of 400 feet above the lake surface. These terraces may be traced almost continuously from Whitehall, at the head of Lake Champlain, to the northern end of the lake and beyond it, but on account of the extensive erosion which has taken place, they are usually narrow, and it is only at sheltered points, like Port Kent and Beauport, that they are especially prominent. The section involved is yellowish brown sand, yellowish brown clay and stiff blue clay, the latter being rather calcareous. The upper clay is somewhat silicious, and its coloring is due to the weathering of the lower layer. This formation has a thickness of about 15 feet, but sometimes, as at Burlington, it reaches a thickness of 100 feet. Isolated bowlders are occasionally found in the clays. The clays are usually horizontally stratified, and contortions of the layers are extremely rare. Numerous marine Quaternary fossils have been found in the overlying sands; the skeleton of a whale has also been found in them.

Openings have been made in these deposits for the purpose of obtaining brick clays at Plattsburg and a few other localities.

LONG ISLAND CLAYS

Clay beds are exposed along the north shore of the island and at several points along the main line of the Long Island railroad.

There is still some doubt as to the exact conditions under which the beds of clay and gravel which form the greater portion of Long Island were deposited, but it is probable that the clays represent shallow water marine deposits of Cretaceous and Tertiary age.

The age of the clays is still largely a matter of speculation, and will probably remain so in many cases unless palaeontologic evidence is forthcoming. Those on Gardiner's Island are quite recent, as shown by the contained fossils, and the clay on Little Neck, near Northport, is Cretaceous. The age of the Glen Cove clay is probably Cretaceous.

Cretaceous leaves in fragments of ferruginous sandstone have been found along the north shore of Long Island from Great Neck to Montauk Point,[a] but they are usually much worn and scratched and have evidently been transported from some distant source. The clays at Center Island, West Neck, Fresh Pond and Fisher Island are very similar and are very probably of the same age, possibly Tertiary, but we lack palaeontologic or stratigraphic evidence. At West Neck the clay underlies the *yellow gravel,* and the latter is covered by the drift, so that is Prepleistocene.

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a Hollick, *Notes on Geology of the North Shore of Long Island*, Trans. N. Y. Acad. Sci., XIII.

STATEN ISLAND CLAYS

The clays of Staten Island are chiefly Cretaceous, as proven by the fossils found in them. The chief outcrops are at Kreischerville, Green Ridge and Arrochar. Besides the clay there are several 'kaolin' deposits.

These clays are used in the manufacture of drain tile, terra cotta, etc.

CLAY PRODUCTS

The increasing value of clay for the manufacture of brick, tile, terra cotta, pottery, etc., and the ever growing demand for these products have given rise to an industry which is rapidly assuming vast proportions, and will, in the near future, become one of the most extensive and important in the country. Scattered over New York are extensive deposits of clay, many of them cap ble of being used for the manufacture of terra cotta, roofing tile and the coarser grades of pottery. To add to their value the most extensive beds of clay are situated in close proximity to the waterways and railroads which lead to the principal cities of the state. The commoner kinds of clay products, such as building brick, are marketed within the state, but the higher grades, such as terra cotta and roofing tile, have found good markets outside of New York.

At present bricks are the chief source of income. That the other branches of the clay industry are not further advanced is probably due in a large measure to the fact that the clay deposits of the state have been so little exploited or otherwise examined. Though many of the deposits have been opened up and are still being worked, there are numerous others scattered over the state which are still untouched. Few of the clays are found to be of sufficiently refractory character to be used for making fire brick, gas retorts, or other products which in use are subjected to a higher degree of heat; but for the manufacture of coarse pottery, terra cotta, paving brick, etc., many of the clays are eminently suited.

Shales and Shale Products

Within the last seven or eight years the manufacturers in New York have turned their attention toward the extensive beds of argillaceous shale which the state contains, and which on trial have given very satisfactory results. Several large firms are using them for the manufacture of sewer pipe, terra cotta, paving brick and roofing tile. The shale formations at present used are the Salina, Hamilton and Chemung. The Hudson river shales are no doubt sufficiently argillaceous over many areas to be used for the manufacture of clay products, and the same may be said of the Niagara shale, which weathers to a clay.

Iron Ores

The iron ores of New York have been carefully studied and described by Prof. J. C. Smock, who has published his results in Bulletin No. 7[a] of the New York State Museum and by Mr. Bayard F. Putnam, who contributed an article on this subject to the volume on Mining Industries (No. XV) in the report of the tenth census. These two important papers, taken together give a most complete review of the sources of iron in New York. Our knowledge of the Adirondack ores is supplemented by the work of Prof. J. F. Kemp, which is contained in Bulletin No. 13 of the New York State Museum, entitled the Geology of Moriah and Westport townships. The localities of all the principal mines are shown on the economic map.

Iron in its native or metallic form is not known to exist within the state of New York, nor is it at present anywhere a commercial source of the metal. We are therefore chiefly dependent upon the combinations of iron with oxygen for our supply of that indispensable substance.

The ores of iron, which occur in beds and deposits of workable size in the state of New York, may be classified by their chemical composition, into oxides and carbonates of iron, and these may be subdivided, following the mineralogical characters, into

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[a] The following description is abridged with some alterations and additions from Bulletin No. 7.

species and varieties. The following tabular arrangement shows the natural grouping of the species:

	Chemical name	Mineralogical species and common names
Oxides	Ferric and ferrous oxides. Proto-sesquioxide of iron. 72.4 % of iron.	Magnetite. Magnetic iron ore. Titaniferous iron ore.
	Anhydrous ferric oxide. Sesquioxide of iron. 70 % of iron.	Hematite. Red hematite. Specular ore. Clinton ore.—Fossil ore. Red ochre.
	Hydrated ferric oxide. Sesquioxide of iron. 60 % of iron.	Limonite. Brown hematite. Brown ochre. Bog iron ore.
Carbonates	Ferrous carbonate. Carbonate of iron. Spathic 48 % of iron. Iron ore	Siderite. Carbonate ore. Clay iron stone. 'White Horse.'

A general law of occurrence of iron ores is that certain species occur in, or are characteristic of, definite geological horizons. For example, the magnetic iron ores and the red hematite are found in the crystalline rock areas of the Pre-cambrian; the fossil ore, the limonite or brown hematite and the carbonate are found in the Palaeozoic rocks; and the bog iron ore in the more recent formations of Tertiary and Post Tertiary ages. There are, as might be expected, many exceptions; but in the greater number of these apparently exceptional cases, the surface alteration, due to weathering or other atmospheric agencies, explains the occurrence.

This relation between the geological formation and the mineralogical species or *kinds* of iron ore indicates the areas in which they may occur, and determines roughly their limits. Hence, a geological map of the state shows approximately correct boundaries of the several iron-ore districts, and is, as it were, an iron mines map. The geology of a county or district gives the clue in searching for ore; and its importance can not be too strongly stated, both as a guide, suggesting exploration, and warning against unnecessary and fruitless surveys and wasteful outlays of time and money. For example, the magnetites belong to the crystalline rock districts, and the search for them in the later, sedimentary rocks of the adjacent territory would be a hopeless task; or, again, the exploration of the Highlands or Adirondacks, for carbonate ores, would be equally unscientific and destitute of good results.

The geological formations, which are characterized as definite ore horizons, become the basis of a natural arrangement of the ore districts of the state. They are well marked geographically also.

Following this geologico-geographical arrangement, the groups and iron-ore districts are:

1 The Highlands of the Hudson.—Magnetic iron ores.

2 The Adirondack region, including the lake Champlain mines.—Magnetic iron ores.

3 The hematites of Jefferson and St Lawrence counties.

4 The Clinton or fossil ores.

5 The limonites of Dutchess and Columbia counties.

6 The limonites of Staten Island.

7 The carbonate ores of the Hudson river.

A few isolated mines can not be thus classified, as the hematite near Canterbury, Orange county, Ackerman's mine near Unionville, Westchester county, the Napanoch and Wawarsing mines, in Ulster county, the hematite of Mt Defiance in Ticonderoga, and the bog iron ores which are scattered in all of the great divisions of the state. The iron sands of the shores of Long Island are left out, as not properly a natural source of iron.

MAGNETIC IRON ORES

The Highlands of the Hudson

Magnetite is one of the common minerals in the crystalline rock region of the Highlands. It occurs as an accessory constituent in the granitic and gneissic strata; and by itself, forms beds of considerable extent and thickness. Accordingly as it is more or less free from foreign minerals it is rich or lean, varying from the pure magnetic iron ore which contains 72.4% of iron to rock containing only traces of iron in its mineralogical composition. The beds of ore show lamination and are faulted, folded and contorted as the inclosing strata of rock, and have the same general strike and dip in common with the latter. They are generally of irregular form, in places widening into thick deposits or lenticular shaped masses, in others contracted in thin sheets, which are not mined profitably. The ore is found in some cases to separate into thin layers, and masses of rock ('horses') are met with entirely surrounded by the ore. The phases of variation are almost as many as there are mines, where they can be studied. In the larger and older mines the ore has been followed for thousands of feet in the line of strike or on the course of the ore, and for hundreds of feet in depth (on the line of dip) without reaching its limits. Owing to the unprofitable nature of working such thin ore beds, they are often not followed to the end, and the real extent of few of these ore deposits is known. In general, it may be stated that in this region the ore beds stand nearly on edge and have a northeast and southwest strike and a descent or dip at a steep angle to the southeast. In consequence of their highly inclined position and their irregular shape these ore bodies are called 'veins,' less frequently 'chimneys' and 'shoots' of ore.

The magnetic iron ore has not been found distributed uniformly throughout the Highlands. There appear to be certain ore *ranges* or belts in which the larger and more productive mines are opened. There are mine groups also, as the Sterling Iron and Railway Company's mines, the Greenwood mines, in Orange county; the Todd-Croft and Sunk mines, and the Croton-Brewster ranges in Putnam county. The boundaries of these ore-bearing belts and the intermediate barren territory have not been determined, since the exploration has been largely made by individual effort and without any general plan covering the whole area.

Mines have been opened in Orange, Rockland, Westchester and Putnam counties in this iron ore district and from the New Jersey line at the southwest to the Connecticut boundary on the east. Some of the largest and most productive mines in Orange county have been worked more than a century.[a] This county was famous for its iron manufacture during the revolutionary war.[b] The greatest development of the iron mines in Putnam county has been since the opening of the Tilly Foster and Mahopac mines or during the last 25 years. The distance from public lines of transportation, the increased cost of working the smaller 'veins' at greater depths, the low prices for iron ore and the competition with the richer ores of other parts of our country have necessitated the suspension of work in some of the mines and led to the permanent abandonment of those most unfavorably situated. The ores of the Highlands district are the hard, crystalline magnetites. They are generally rich, free from titanium, but contain a slight excess of phosphorus above the limit for the manufacture of Bessemer iron, excepting the Mahopac and Tilly Foster mines, which have yielded a large amount of Bessemer ore, and a few small mines, but which are no longer worked.

The Adirondack Region, Including the Lake Champlain Mines

The Adirondack region, the great mountain plateau of northern New York, is bounded by the valleys of Lake Champlain on the east, of the St Lawrence river on the north and northwest, of Black river on the west, and the Mohawk on the south.

Magnetite is one of the common minerals in the Adirondacks, and is widely distributed, both as a constituent or accessory mineral in rocks, and in beds of workable extent. Mines have been opened in all parts of the region, but the greatest development has been in the valley of Lake Champlain, and hence the ores are known in the market as Lake Champlain ores.

The beginnings of iron-ore mining in the Lake Champlain valley were early in the present century. Some of the forges were

[a] Ore was discovered on the Sterling tract as early as 1750; the Forest of Dean mine was opened about the same time.

[b] See *History of the Manufacture of Iron in all Ages*, by James M. Swank, Philadelphia, 1884, pp. 102-106.

in operation in 1801 and 1802, and they were run upon the ores in their vicinity. But the output was small, in the aggregate a few thousands of tons. The rapid increase was after 1840.

THE HEMATITE ORES OF ST LAWRENCE AND JEFFERSON COUNTIES

The hematites, or red hematites, as distinguished from the brown hematites (limonites) are mined in a narrow belt, scarcely 30 miles long, stretching from Philadelphia, in Jefferson county, northeast into Hermon, in St Lawrence county. The ore deposits are found associated with a so-called *serpentine* rock, and lying between the Potsdam sandstone and the crystalline rocks of the Archaean age.

The hematite of these mines is generally firm and massive, of a deep red color, soiling whatever it touches. In some of the mines there is a specular ore, which has a crystalline structure, metallic lustre and is of a steel-gray to black color. Calcite, carbonate of iron, ferruginous quartz, pyrite and millerite occur in the ore. These ores average from 48 to 53% of metallic iron. They contain an excess of phosphorus above the limit demanded by furnace managers for making Bessemer iron. For mixing with more refractory ores they are sought after, being almost self-fluxing. In the market they are often known as 'Antwerp red hematites' and 'Rossie hematites.'

Charcoal furnaces were built early in this century at Rossie, St Lawrence county, and at Sterlingville and Antwerp, in Jefferson county, for smelting these ores.

THE CLINTON OR FOSSIL ORES

The red hematite of the Clinton group bears several names; from its aggregated grains it is termed 'oolitic ore' or 'lenticular iron ore;' from its fossiliferous character, it is widely known as 'fossil ore,' and from its place in the geological series, it is often called 'Clinton ore.' It is remarkable for the thin, yet persistent beds over wide areas, which lie between green shales and calcareous strata. Following the outcrop of the Clinton group, the ore has been found in Herkimer, Oneida, Madison, Cayuga, Wayne, and Monroe counties. West of the Genesee river Prof. Hall reports that it was not seen.[a] There are two beds, generally about 20 feet apart, according to Vanuxem's report on the Clinton group, thin, averaging little more than a foot, and distinguished by more abundant oolitic particles in the lower bed and by the larger grains and concretions in the upper bed.[b] Very little mining has been done, excepting in the towns of Clinton, Oneida county, and Ontario, in Wayne county. The average thickness of the beds in these mines is 30 inches, and one bed only is worked. They lie almost horizontal, dipping slightly to the south; and in the extraction of the ore a part of the overlying shales has to be removed and the roof supported by timbering.

The ore consists of lenticular-shaped grains, closely aggregated in a firm solid mass, which has to be broken up by blasting and heavy sledging. It is more friable and soft on the outcrop. It is brownish red in color and soils like a paint. The percentage of metallic iron varies less than in the magnetic iron ores and in the brown hematites. The average is 44 to 48%. The phosphorus is above the Bessemer limit. It is well adapted for making foundry iron and is used for that class of iron mainly. Local furnaces take nearly all the output of the mines. The first lease for digging Clinton ore was given in 1797.[c]

THE LIMONITES OF DUTCHESS AND COLUMBIA COUNTIES

The ore deposits and mines, as here grouped, are in two principal ranges and limestone valleys. First, the Fishkill-Clove belt, stretching northeast, from the Highlands of the Hudson, across the towns of Fishkill, East Fishkill, Beekman and Unionvale; second, the north-south valley, traversed by the New York and Harlem railway, from the Highlands across Dutchess county, and to Hillsdale in Columbia county. The limonite, or brown hematite ore, is found in small pockets of irregular shape, and

a Hall Report on *Survey of the Fourth Geological District*, Albany, 1843, p. 61.

b Vanuxem Report on *Survey of the Third Geological District*, Albany, 1842, p. 83.

c BIRKINBINE; *The iron ores east of the Mississippi River*, in Mineral Resources of the United States for the calendar year 1886, p. 50.

also in large deposits, which are associated with ochreous clays, and in some cases, with a gray carbonate of iron, in beds underlying it. These ore bodies are wholly in the limestone or between the limestone and the adjacent slate or schist formations, or they are in the latter, and as a rule of occurrence they are found on or near the dividing line between these formations. Near Fishkill and at Shenandoah the deposits are at the border of the Cambrian sandstone and at the foot of the Archaean ridges. The existence of the carbonate ore in the deeper parts of some of the mines and interstratified with the limestones is suggestive of the origin of the oxide (limonite) by the decomposition of the ferriferous beds through oxidation and the agency of carbonated waters, and of the great masses of colored clays, also, through the disintegration and decay of the slaty rocks and more argillaceous limestone. The limestone of these valleys and the overlying slaty rocks have been studied by Prof. Dana, and are referred by him to the Trenton limestone and the Hudson river slate formations.

The ore occurs, (1) in large masses, somewhat cellular, having the interstices filled with clays or sandy earths, (2) in cavernous and hollow 'bombs' often with beautiful mammillary or stalactitic incrustations on the interior, and, (3) in irregularly shaped, fragmentary masses, distributed unevenly through the ochreous clays ('ochres') and sandy earths.

The earliest iron manufacture in the state was in Columbia county, on Ancram creek, and was probably on these ores.

THE LIMONITES OF STATEN ISLAND

The group of iron mines on Staten Island is in a superficial deposit probably derived from the underlying rock in the process of decomposition which has produced the serpentine of that region.

THE CARBONATE ORES OF THE HUDSON RIVER

The mines of spathic iron ore, or carbonate ore, are in the valley of the Hudson river, in Columbia county, south of the city of Hudson, and in Ulster county near Napanoch. The mines south of Hudson are known as the Burden iron mines; and, on account of their extent and productiveness, and the comparative insignificance of the Ulster county mines, they may be considered as practically the whole of this group. The range in which the Burden mines are opened is between one and two and a-half miles east of the river, opposite Catskill, and is four miles in length, from north to south. It lies partly in the town of Greenport and partly in Livingston. The ore crops out in the western face and near the crest of Plass Hill at the north, and in Cedar Hill and Mount Thomas at the south. It is stratified, and its bed dips at angles of 20° to 40° to the east.

The first mining of considerable extent done on this range was in 1874.

LIME AND CEMENT.

Lime is produced throughout the State on the outcrops of the Calciferous, Trenton, Niagara and Helderberg limestones. Some of the chief localities are Glens Falls, Howe's Cave, Rochester, Buffalo, Sing Sing, Pleasantville and Tuckahoe. Hydraulic cement or water lime is chiefly produced from beds of hydraulic limestone in the Water lime group at the base of the Lower Helderberg. Rondout and Rosendale, Howe's Cave and the vicinity of Syracuse are important commercially for this product. At Akron and Buffalo much water lime is made, but from a lower formation, probably the Salina Group.

Portland cement is made from marl and clay at Warner's near Syracuse, and at Wayland, Steuben county; from lime and clay near Glens Falls and at other points.

LIMESTONE FOR FLUX.

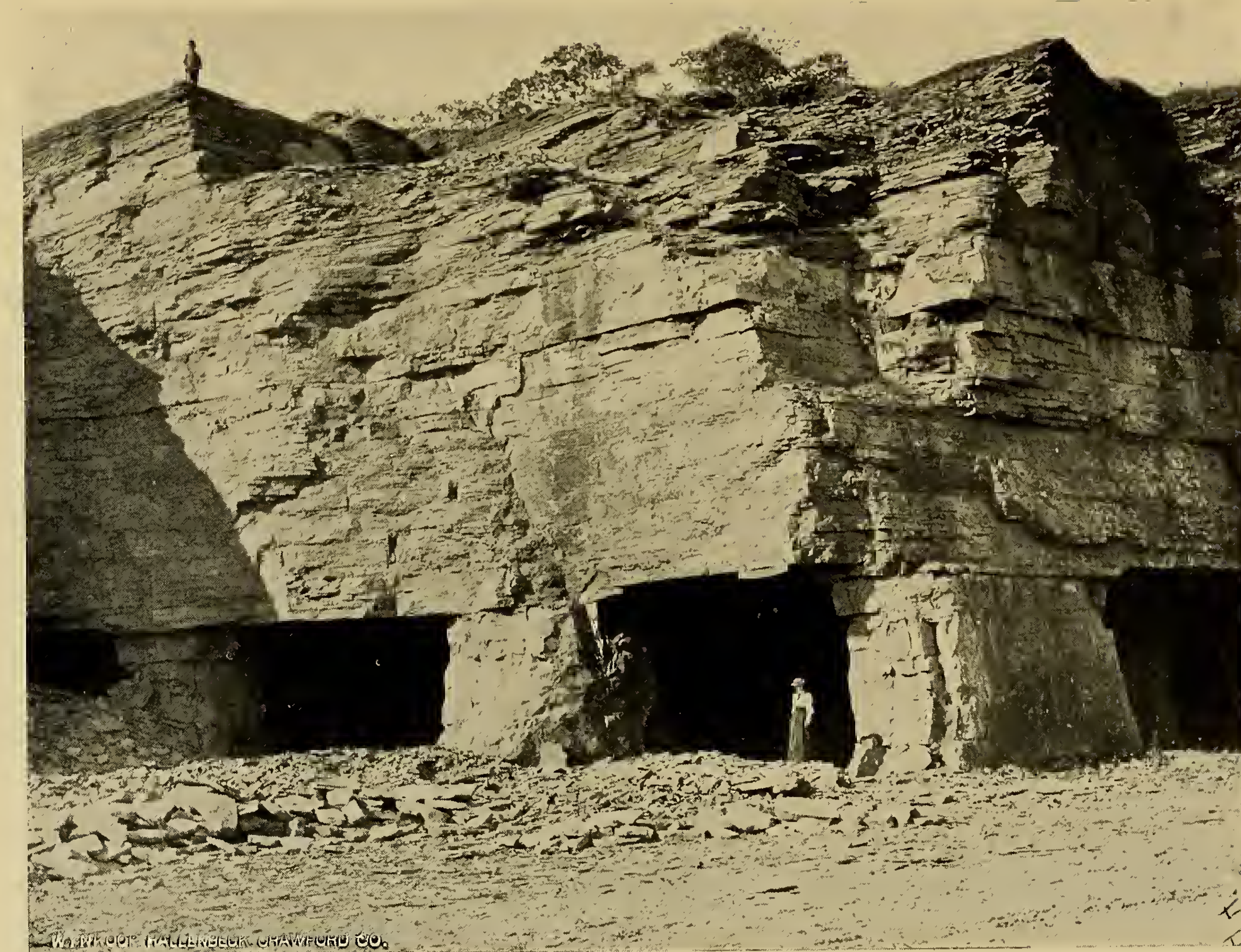
In the present depressed condition of the manufacture of iron in New York, the production of limestone for flux is but a small industry.

MINERAL PAINT

The mineral paint of New York state is from comparatively few localities, and is manufactured from rocks of five formations:

1 From Rossie iron ore.

2 From Cambrian red and green slate, near Whitehall.



N. H. Darton, photo.

QUARRY IN TRENTON LIMESTONE, SARATOGA CO., SOUTH BANK OF HUDSON RIVER OPPOSITE GLENS FALLS. ROCK QUARRIED FOR QUICK-LIME.

PLATE CXV.—To face page 222.

H. Ries, photo.

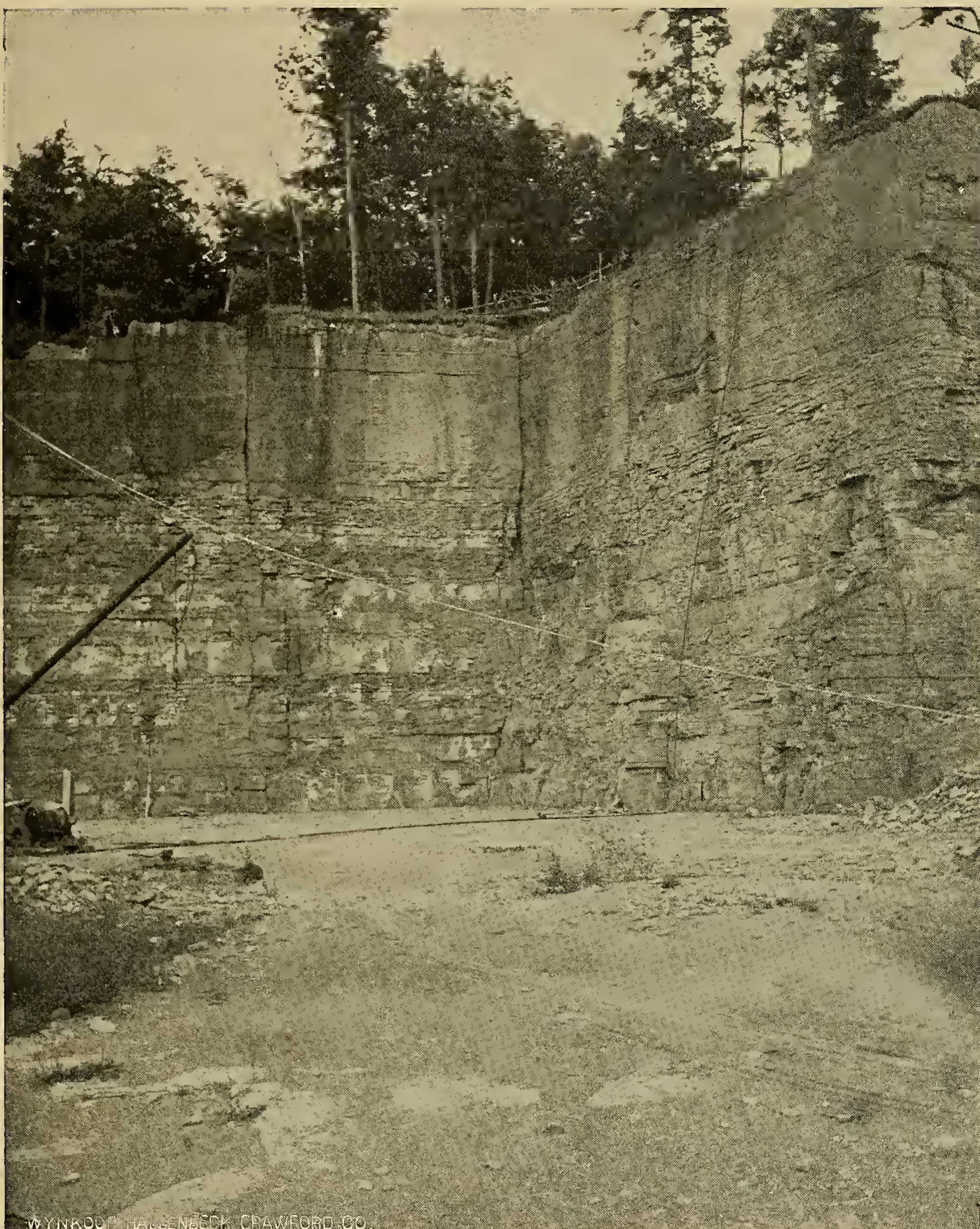
INTERIOR VIEW OF CEMENT MINE AT ROSENDALE, ULSTER CO. WATERLIME GROUP.

PLATE CXVI.—To face page 222.

N. H. Darton, photo.

CEMENT QUARRIES, ONE MILE SOUTH OF WHITEPORT, ULSTER CO. WATERLIME GROUP.

PLATE CXVII.—To face page 222.



N. H. Darton, photo.

QUARRY IN LOWER PENTAMERUS AND TENTACULITE LIMESTONE, HOWE'S CAVE, SCHOHARIE CO.

PLATE CXVIII.—**To face page 222.**

Corniferous limestone.

Onondaga limestone.

Impure cement rock.

Beds from which cement is made.

I. P. Bishop, photo.

QUARRY OF THE BUFFALO CEMENT CO., BUFFALO, ERIE CO.

PLATE CXIX.—To face page 222.

I. P. Bishop, photo.

QUARRIES OF THE BUFFALO CEMENT CO., BUFFALO, ERIE CO. RAILWAY FOR DRAWING STONE TO THE CRUSHER.

3 From Clinton iron ore.

4 From Chemung shale, at Randolph.

5 From Catskill shale at Roxbury and Oneonta.

This material is produced as a by-product in several industries. For instance near Whitehall red and green mineral paint are produced by grinding up the refuse of the slate mills. At Clinton, Oneida county, paint is manufactured from the Clinton iron ore. At Randolph in Cattaraugus county, paint is made from red shales of the Chemung group. At Roxbury, Delaware county, paint is made from red Catskill shales and at Oneonta a similar pigment has been made.

Marl

This material is found in many places throughout the state. Dutchess, Columbia, Orange, Ulster, Greene and Albany counties have many small deposits; in central and western New York there are large deposits in Onondaga and Madison counties, particularly in the Cowaselon swamp; it is also found in Cayuga, Wayne, Seneca, Ontario, Monroe, Genesee and Niagara counties.

It is a deposit formed in standing water and consists chiefly of carbonate of lime. It is largely used as a fertilizer, but is also employed in the manufacture of Portland cement as at Warners, Onondaga county, by the Empire Portland Cement Co., at Montezuma and at Wayland, Steuben county, by Millen & Co.

Millstones

Millstones for grinding paint, feed, cement and other purposes are quarried from the Oneida conglomerate in Ulster county in the town of Rochester at Accord, Granite and Kyserike and in Wawarsing at Kerhonkson.

Salt

The salt industry of New York is of great importance. Originally Syracuse was the center of this industry, but since the discovery of rock salt in and near the Genesee valley where richer brines can be obtained than at Syracuse, the center of the industry has been transferred to this new district and the manufacture of salt at Syracuse has gradually diminished.

The salt mines of the Retsof, Livonia and Greigsville companies produce immense quantities of salt for the beef and pork packing industries, and in this respect are not directly competitors of the companies manufacturing salt from brine. About 15 miles south of Syracuse the Solvay Process Company having found rock salt in great quantity, by boring a large number of wells and availing itself of an abundant water supply is, by the aid of gravity, enabled to bring brine in a highly saturated condition to its works at Syracuse through a pipe line. This is the basis of a very large industry in soda ash. The Solvay Company also sells brine for the manufacture of salt.

In the Genesee valley and near Warsaw and Wyoming are many salt wells. There are others at Ithaca and Watkins.

A detailed description of the salt and gypsum deposits of New York is given in Bulletin No. 11 of the New York State Museum.

Gypsum

Gypsum is quarried in New York on the outcrop of the Salina group in Madison, Onondaga, Cayuga, Ontario, Monroe and Genesee counties. It is chiefly used as a fertilizer in the form of land plaster, though at Oakfield, Genesee county, a factory has been established to utilize the gypsum in the manufacture of wall plaster.

Graphite

Graphite of excellent quality is obtained near Ticonderoga, the deposit being controlled by the Dixon Crucible Company of Jersey City. The mineral occurs in a mica schist and in crystalline limestone. It is used in the manufacture of pencils, crucibles, lubricants and for a variety of other purposes.

Quartz

This material is quarried for pottery at Bedford, Westchester county, and is shipped to Trenton, N. J. White quartzite of

Cambrian age, quarried at Fort Ann in Washington county, has been ground for use as a wood filler. It has also been used at the Troy Iron Works for lining Bessemer converters and for similar refractory purposes. A similar rock is quarried for wood filler at Billings, Dutchess county.

At Ellenville, Ulster county, quarries and mills are operated by the Crystal Sand Manufacturing Company. The product which is called 'glass sand' is obtained from the Shawangunk grit, which is crushed very fine. Much of it is sent to the glass works at Corning.

Glass Sand

Large glass sand deposits of Quaternary age occur at Durhamville, near Oneida lake. They are operated by William Williams. The sand is not as white nor as fine as that from Ellenville, and is used for the commoner grades of glassware. Much of it is shipped to Lockport. The sand contains 97–97.5% Si. O2.

Glass was formerly made at Sand Lake in Rensselaer County.

An artificial glass sand made at Ellenville is described under the previous head.

Molding Sand

Sand for molding is found in southern Albany county, near the Hudson river, immediately below the surface soil. When this is removed the sand is skimmed off to a depth of about six inches. It is quite extensively shipped from the town of Bethlehem. This is a Quaternary deposit. Near Poughkeepsie molding sand is obtained from a silicious Potsdam limestone, which, in decomposing, leaves a fine sand which has been found very satisfactory for this purpose.

Garnet

Garnet is mined or quarried in New York state in and near the valley of the upper Hudson river in Warren county on the borders of the Adirondack region. It all appears to be of the common variety, Almandite, and occurs in a formation of crystalline limestone which appears to form the bed-rock of the valley in the vicinity of North Creek and Minerva and in gneissic rocks which adjoin, or are intercalated with, the crystalline limestone. It is found in segregated masses of varying sizes from that of a pigeon's egg to a diameter of 20 feet. It is commercially classified as massive garnet, shell garnet and pocket garnet, the former being impure from the admixture of other minerals. The shell garnet is almost entirely pure and the most valuable for industrial purposes. The pocket garnet is that which occurs in small segregations or incipient crystals in the gneiss.

This garnet is used almost exclusively in the manufacture of sandpaper, or garnet-paper, as it is called, which is employed extensively for abrasive purposes in the manufacture of boots and shoes. It is also employed to some extent in the wood manufacturing industry. For metals garnet is not as good as emery, although some satisfactory results have been obtained from its use on brass. It has been experimentally mixed with emery in the manufacture of emery-wheels but without very satisfactory results.

Emery

The variety of Corundum known as emery is quarried at many points in Cortlandt township, Westchester county, from deposits which occur in the eruptive rocks known as the 'Cortlandt series.' It is used by the New York Emery Company at Peekskill.

Diatomaceous Earth — Infusorial Earth

This material consists of hydrated silica, and is the accumulation of the minute skeletons of microscopic forms of vegetable life known as diatoms. It accumulates in the bottom of ponds and lakes, and is found in recent as well as Tertiary and Cretaceous formations. While the living diatoms are found in all the waters of the state, deposits of diatomaceous earth have been reported from only two localities. One of these is in White lake, town of Wilmurt, Herkimer county, and the other is on the shore of Cold Spring Harbor, Long Island, on the property of Dr. Oliver Jones. The latter is a fossil deposit in beds probably of Tertiary age. The White lake deposit is the only one in use commercially at present. The material is dug from the bottom of the lake, which covers about four acres, and has a thickness of two to 30 feet, being covered by about four feet of water. It is washed and run through strainers and pipes to settling vats, where it stands for 24 hours. The water is then drawn off and the material shovelled into the press. Here it is made into cakes four feet square and four inches thick. These are subdivided into cakes one foot square and piled under sheds to dry. For this information I am indebted to the proprietor, Mr. Thomas W. Grosvenor, of Herkimer.

The White lake material is at present only used for polishing, though similar material is used for absorbing nitroglycerine in the manufacture of dynamite.

Talc

This material occurs near Edwards, St Lawrence county, N. Y., in a narrow belt several miles long and about a mile wide. There are several quarries on the line of this belt. It is ground in mills near Gouverneur under the control of the Asbestos Pulp Company. It is chiefly used in the manufacture of paper and a small quantity is used in soap, paint and other minor purposes. The annual product is about 30,000 tons, valued at about $240,000.

Peat

This material, which is the residue from the partial decay of plants in water, is of frequent occurrence, but is only used locally as a fertilizer.

Petroleum and Illuminating Gas

The occurrence of petroleum in New York was first recorded by a Franciscan friar who visited the oil spring at Cuba, Allegany county, in 1627. Late in the present century the oil from this spring was highly valued by the Indians for external applications and was thought to have a highly curative power. It was widely known under the name of 'Seneca oil.' The production of oil in New York is at present confined to Cattaraugus and Allegany counties. The Cattaraugus county field is a northward extension of the Bradford field of Pennsylvania and is continuous over the state line. The Allegany county field is more isolated, although the oil comes from the same geological horizon, which is a sandstone in the upper Chemung or Catskill. This has been discussed in great detail by Charles A. Ashburner in the Transactions of American Institute of Mining Engineers for 1887.

Natural illuminating gas was first used in New York at Fredonia, Chautauqua county, in 1821. It is still in use at the locality in question, but the quantity is insufficient to supply the whole village. Besides Fredonia, at the present time Buffalo, Honeoye Falls, Pulaski and Sandy Creek are using natural gas for heating and illuminating purposes and wells have been bored in the vicinity of Oswego, as well as at Fulton and Baldwinsville. Gas wells have been bored tentatively at a large number of places in New York State and small quantities of gas have been found, but the enterprises have not been financially successful. At present many of the wells in Buffalo have ceased to yield and a large quantity of the natural gas now consumed in that city is brought in pipe-lines from Canada. The gas of Fredonia comes from shales immediately over the corniferous limestone. The gas of the oil districts comes, like the oil, from the horizon of the Catskill. The gas of central and northern New York comes from the Trenton limestone.

Natural Carbonic Acid Gas

This material is obtained at Saratoga Springs and vicinity by boring wells to a depth of about 350 feet. Carbonated waters flow to the surface and are conducted through pipes to large gas holders, where the gas separates from the water and is then pumped into compressors from which it is forced into steel cylinders under a pressure of about 1,000 pounds to the square inch. These cylinders, when filled, are shipped to the consumers, who use it chiefly in the manufacture of soda water, both for the wholesale and retail trades. At present this gas is shipped from

Saratoga Springs to New York. New Jersey, Pennsylvania, Massachusetts, Connecticut and Rhode Island. In addition to the large quantities consumed for soda water, it is also being used for refrigerating purposes and in the manufacture of cod liver oil.

Mineral Waters

The mineral springs of New York are widely known. In addition to the revenue from mineral springs used for baths at health resorts, a large industry now exists in the bottling and shipment of mineral waters for domestic consumption.

List of Mineral Springs in New York which are Commercially Productive

Adirondack Mineral Springs (H. V. Knight), Whitehall, Washington county.

Avon Sulphur Springs (O. D. Phelps), Avon, Livingston county.

Artesian Lithia Spring (C. O. McCreedy), Ballston Spa, Saratoga county.

Cairo White Sulphur Spring (H. K. Lyon), Cairo, Greene county.

Cayuga Mineral Spring (Lucius Baldwin), Cayuga, Cayuga county.

Chittenango White Sulphur Springs (W. H. Young), Chittenango, Madison county.

Chlorine Springs (J. L. Grover), Syracuse, Onondaga county.

Clifton Springs (Dr. Henry Foster), Clifton Springs, Ontario county.

Dansville Springs (J. Arthur Jackson, secretary and manager), Dansville, Livingston county.

Deep Rock Spring (Deep Rock Spring Co.), Oswego, Oswego county.

Massena Springs (Shedden & Stearns), Massena, St. Lawrence county.

Nunda Mineral Springs (Daniel Price), Nunda, Livingston county.

Reid's Mineral Spring (J. R. McNeil), South Argyle, Washington county.

Richfield Springs (T. R. Proctor), Richfield Springs, Otsego county.

Champion Spring (J. Z. Formel), Saratoga Springs, Saratoga county.

Empire Spring (H. W. Hayes, manager), Saratoga Springs, Saratoga county.

Excelsior Spring (F. W. Lawrence), Saratoga Springs, Saratoga county.

Geyser Springs (Geyser Spring Co.), Saratoga Springs, Saratoga county.

Hathorn Spring (Hathorn Spring Co.), Saratoga Springs, Saratoga county.

Old Red Spring (E. H. Peters, superintendent), Saratoga Springs, Saratoga county.

Vichy Springs (L. A. James, superintendent), Saratoga Springs, Saratoga county.

Sharon Springs (John H. Gardner & Son), Sharon Springs, Schoharie county.

Slaterville Magnetic Springs (W. J. Carns & Son), Slaterville, Tompkins county.

Verona Mineral Springs (A. A. Hunt, M. D.), Verona, Oneida county.

White Sulphur Springs (T. C. Luther), Ballston Spa, Saratoga county.

White Sulphur Springs (J. Hochstatter), Berne, Albany county. Star Springs, Saratoga Springs.

Elkhorn Spring (Clark Snook), Manlius.

Royal Spring (A. Putnam, Jr., president), Saratoga Springs, Saratoga county.

Lebanon Thermal Spring (P. Carpenter), Lebanon Springs.

Crystal Rock Water Co. (L. G. Deland, president), Fairport.

Victor Spring (H. J. Dickinson, Buffalo), Darien, Genesee county.

Geneva Magnetic Mineral Spring (C. A. Steele), Geneva, N. Y., Ontario county.

Oneita Springs (Oneita Spring Co.), Utica, N. Y., Oneida county.

Empire Seneca Spring (M. W. Cobb, of Fredonia), Dunkirk, N. Y., Chautauqua county.

Crystal Spring (Asa D. Baker), Barrington, N. Y., Yates county.

Great Bear Spring, Fulton, Oswego county.

Minerals Not Commercially Important

In addition to the minerals which have already been mentioned there are many deposits in New York which are not at present of commercial importance. These may be roughly classified as metallic minerals and non-metallic minerals.

METALLIC MINERALS

In this class are iron pyrites, arsenopyrite, chromite, chalcopyrite, cuprite, galenite, cerusite, sphalerite, wad or bog manganese, millerite and molybdenite. The galenite and pyrites have respectively yielded small quantities of silver and gold at certain places, but *at no locality in New York have enough of the precious metals been found at any time to pay for the expense of extracting them.* From time to time capital is invested for the purpose of gold or silver mining in New York, but always without practical results. The experience of 50 years has shown that neither in New York nor in New England have either of the metals been found in paying quantities.

The following is a list of the principal localities at which the various metallic minerals are found:

IRON, SULPHUR, ARSENIC

Pyrite, iron pyrites, bisulphide of iron. Anthony's nose, Westchester county, mine formerly worked; Philips ore bed, Phillipstown, Patterson, southeast of Carmel and near Ludington mills, in Putnam county; with galena at Wurtsboro lead mine, Sullivan county; Flat creek, Montgomery county; near Canton, St Lawrence county, in extensive beds; Duane, Franklin county, large bed; Martinsburg, Lewis county; Eighteen-mile creek, Erie county, and many other localities, sparingly in rocks.

Arsenopyrite, mispickel. Near Edenville, Orange county, with arsenical iron and orpiment, in a vein in white limestone; near Pine pond in Kent, and near Boyd's Corner, Putnam county. These localities have been opened, but not worked for arsenic.

Chromite, chrome iron ore. In serpentine, Phillipstown, Putnam county; Wilks' mine, Monroe, Orange county.

COPPER

Chalcopyrite, copper pyrites; sulphide of iron and copper. Ancram lead mine, Columbia county; Bockee mine, Columbia county; near Edenville, Orange county; with arsenopyrite; near Wurtsboro, Sullivan county, with galena in considerable abundance; Ellenville and Red Ridge lead mines, Ulster county; near Rossie, and also near Canton, in St Lawrence county, once worked. Many additional occurrences are reported where it is in small quantity.

Cuprite, red oxide of copper. Near Ladentown, Rockland county, in thin seams, in trap rock.

LEAD

Galenite, galena; sulphide of lead. Otisville, Orange county; Ellenville and Red Bridge, Ulster county; with copper pyrites and blende, in a gangue of quartz in Oneida conglomerate, mines no longer worked; Wurtsboro, Sullivan county; near Sing Sing, in Westchester county; northeast township, Dutchess county; Ancram, Columbia county; strings of galena, blende and pyrites in limestone; White creek, Washington county; Martinsburg, Lewis county; Spraker's basin, Montgomery county; Rossie and vicinity, St Lawrence county; *mines largely worked years ago;* ore occurs in vein with blend, pyrites and copper pyrites. These mines have all been idle for several years.

Cerusite, carbonate of lead. Rossie, Robinson, Ross and other lead mines, in St Lawrence county; Martinsburg, Lewis county; near Sing Sing, on Hudson, associated with galena, in small quantity.

ZINC

Sphalerite, zinc blende; sulphide of zinc. Associated with galena at lead mines in Sullivan, Ulster and Orange counties; Ancram, Columbia county; Flat creek, Montgomery county; Salisbury, Herkimer county; Martinsburg, Lewisburg, Lewis county; Cooper's Falls, Mineral Point, and in Fowler, St Lawrence county.

MANGANESE

Wad, earthy manganese, bog manganese. In town of Austerlitz, Columbia county, are several localities; also in Hillsdale and Canaan, same county; smaller deposits near Houseville, Lewis county, and southeast of Warwick, Orange county.

NICKEL

Millérite, sulphide of nickel. Sterling iron mine, Antwerp, Jefferson county, famous for crystalline forms.

MOLYBDENUM

Molybdenite; sulphide of molybdenum. West Point and near Warwick, Orange county; Philips mine, Putnam county; Clinton county, but sparingly, in granite rocks.

NON-METALLIC MINERALS

Under the head of non-metallic minerals which have a commercial value but do not occur in New York in a quantity large enough to be of economic importance, may be enumerated apatite, asbestus, barite, biotite, calcite, fluorite, magnesite, muscovite and serpentine. The principal localities for these minerals are given herewith:

Apatite; phosphate of lime. Hammond, St Lawrence county, crystalline, with calcite, zinc ore and feldspar; near Gouverneur, St Lawrence county, crystals in calcite, Vrooman lake, Jefferson county; Greenfield, Saratoga county; near Hammondsville, Essex county; with magnetite in some of iron ores near Port Henry; other localities of occurrence.

Barite, barytes, heavy spar; sulphate of baryta. Ancram, Columbia county; near Schoharie Courthouse, with strontianite, in the

Water-lime group; Carlisle, Schoharie county; near Littlefalls and Fairfield, Herkimer county; near Syracuse, Onondaga county; Pillar Point, Jefferson county, in large veins; Hammond and De Kalb, St Lawrence county.

Calcite, calcareous tufa, travertine; carbonate of lime. Vicinity of Schoharie Courthouse, Schoharie county; Sharon Springs, a large deposit; Howe's Cave, Schoharie county; near Catskill, Greene county; head of Otsquaga creek, Stark, Herkimer county; Saratoga Springs; near Syracuse and in Onondaga valley, Onondaga county; between Camillus and Canton, same county; near Arkport, Steuben county; near Ellicott's mills, Erie county, and many lesser deposits.

Fluorite, fluor spar; fluoride of lime. Muscalonge lake, Alexandria, Jefferson county, very fine crystals; Lowville, Lewis county; Niagara county, at Lockport; Auburn, Cayuga county; Rossie and Mineral Point, St Lawrence county.

Magnesite, carbonate of magnesia. Near Rye, Westchester county; Warwick, Orange county; New Rochelle, Westchester county; Stony Point, Rockland county; Serpentine hills, Staten Island; everywhere in thin seams and strings.

Muscovite, mica. As a rock constituent, common. In large plates near Warwick and at Greenwood at Mount Bashan pond, in Orange county; Pleasantville, Westchester county, once opened and mined; Henderson, Jefferson county; Potsdam and Edwards, in St Lawrence county.

Serpentine. Staten Island, near New Rochelle and near Rye, Westchester county; Phillipstown, Putnam county; near Amity, Orange county, verd antique; Johnsburg and Warrensburg, Warren county; Shelving rock, Lake George, Washington county; Gouverneur, Fowler, Edwards and Pitcairn townships, in St Lawrence county; other localities of occurrence in small quantity.

COAL AND LIGNITE

Coal and lignite, while they occur in New York, can never be found in commercial quantities. The coal measures of Pennsylvania are not found north of the boundary line between Pennsylvania and New York, and what coal has been discovered in the latter state is in older formations which do not contain this valuable mineral in commercial quantities. Many thousands of dollars have been spent in fruitless efforts to obtain coal in New York, but year after year men appear in the field who seem anxious to pay for their own experience. It can not be too strongly urged upon the attention of the people of the state that *it is absolutely useless to seek for coal in New York.*

Coal. Woodstock, Ulster county, thin vein in the Catskill, worked out; in seams interstratified with shale, in Chautauqua, Erie, Livingston and Seneca counties.

Lignite, brown coal. Near Rossville, Staten Island, thin seam in clay; also in Suffolk county in clays.

PART 4.

SUGGESTIONS FOR STUDY

GEOLOGIC TEXT-BOOKS AND BOOKS OF REFERENCE

Geology is not, like history, a subject which can be learned wholly from books. Not even an elementary knowledge of it can be readily obtained without careful field study of some prominent district. The student must, however, use books to supply him with information as to the work of others who have gone before, while his powers of observation and inference are being trained on geologic phenomena.

When taking up the field study of a new district, it is important to ascertain what is already known concerning it. An attempt is made, therefore, to direct attention to the principal publications on New York geology.

The four geologic reports of Hall, Mather, Emmons and Vanuxem on the districts assigned to them in the original survey of the state which was begun in 1837 and concluded in 1841, are now out of print, but are found in most of the public libraries of New York, and can be purchased of the dealers in old books in the larger cities. They contain an immense amount of valuable detail and should be consulted by all persons interested in New York geology. The report on the fourth district by James Hall, is as valuable to-day as when it was written and comparatively little has been added by later investigators in the region described, except in regard to quaternary and economic geology.

In addition to these four quarto volumes on the geology of New York, there have been many papers published in the annual reports of the New York State Museum and the State Geologist of New York. A multitude of papers have also been published by persons not officially connected with the State

Geologist or with the State Museum. These will be found in the publications of various scientific societies; the New York Academy of Sciences, the American Association for the Advancement of Science, the Geological Society of America and others; in the American Journal of Science, the American Geologist and other periodicals; and in the publications of the U. S. Geological Survey.

Prof. John M. Clarke, in the 13th report of the State Geologist for 1893, also in the 47th report of the New York State Museum, has published a list of papers on the geology of New York from 1876 to 1893.

Attention is also directed to Bulletin No. 127 of the U. S. Geological Survey, entitled Catalogue and Index of Contributions to North American Geology, 1732–1891, by N. H. Darton, price 60 cents.

For a proper understanding of the geographic distribution of the New York formations, a geologic map of the state is necessary. For general reference the large map prepared by the State Geologist is invaluable, and for field use, the small Economic and Geologic map is recommended. This may be purchased through the Secretary of the University of the State of New York for 25 cents per copy unmounted, or 75 cents dissected and mounted on muslin.

The invaluable *Geological Railway Guide* of MacFarlane, published by Appleton & Co., is commended as a guide in travel. Dana's *Manual of Geology* is also indispensable as a compendium and reference book on the geology of the United States. The most excellent *Text-book of Geology* by Sir Archibald Geikie is highly recommended for reference. The *Principles of Geology* by Sir Charles Lyell is a work of great value which should be read by all students and teachers. Dana's *Text-book of Geology* is very useful.

While many are deterred from the purchase of these volumes by their seeming high price, it is, after all, but a small sum to pay for the liberal education in geology which can be obtained through their judicious use.

In addition to the more technical books described above, there are many accurate and important works written for popular reading both at home and abroad. The number of these is constantly increasing and they can be found in the large libraries or obtained through the book sellers.

FIELD WORK

OUTCROPS

There are in general two classes of geologic strata, the hard and the soft. In New York the hard strata include all rocks older than the Cretaceous. The soft include the formations of the Cretaceous, Tertiary and Quaternary. Almost everywhere the hard rocks are overlaid by soft deposits, usually of Quaternary age, so that in any locality there is generally both hard and soft geology.

The hard geology is probably best for the beginner to take up first, where he has a choice between the two. In Dana's *Manual of Geology* and Sir Archibald Geikie's *Outlines of Field Geology*, detailed directions are given for methods of study among the hard rocks.

The most important habit to be cultivated by the beginner in geology, is that of recognizing outcrops when they occur, or in their absence, of determining by surface indications the character of the rock which underlies the soil.

The beginner must form early, the habit of distinguishing loose fragments or boulders from ledges or outcrops, and in regions devoid of outcrops must study carefully the stone fences for fragments of the local rock. The fences as a rule represent the aggregate of loose rock fragments gathered from the surface of the agricultural lands and these fragments have usually come from the underlying rock. In parts of western New York, over the soft Salina shales no fragments of local rock are found because it decomposes into clay. There the fences are formed of small, hard cobblestones chiefly derived from the granite and gneiss rocks of Canada and brought to their present resting place by the great ice sheet.

Where the covering of soil and other loose material is thick, outcrops should be sought along the beds of rivers, creeks and rivulets. Running water usually cuts through the softer material and reaches the harder rock below. For this reason the gutters and ditches by the sides of roads should be examined for exposures, if no other source of information is available.

It is not possible here to give any adequate directions for the study of soft geology. This branch is still immature and is chiefly in the hands of specialists. The literature of Quaternary geology is, however, very large and by a careful study of it, the beginner may form some conception of its scope. A single field day with a good geologist is worth more than many weeks of reading.

FOSSILS

It is important for the beginner to realize that perfect specimens of fossils such as are exhibited in the museums and figured in the works on palaeontology are not every where to be found and that the more common examples are fragmentary. Were it not for the dissolving action of atmospheric water on carbonate of lime the study of fossils would still be in its infancy, as in many cases the fossil is wholly inclosed in a firm mass of limestone from which it can not be separated by the hammer alone. On the surface exposures of limestone, the action of the weather removes a part of the matrix, exposing for a time the surface of the shell. This after a few years may in turn yield to the dissolving action of atmospheric water and gradually disappear, another specimen at a lower level being gradually brought to view in its place. In sandstones, the calcareous fossils are usually entirely dissolved out of the surface layers and it is only by the impressions or casts which they leave behind, that we know of their existence. If means are afforded for excavation and blasting, below the reach of the rain water, will be found a bed of rock from which the calcareous matter has not been dissolved away, but in this case it is often difficult to separate the fossils except by long and tedious process of cleaning or developing with small tools.

Within the writer's observation, students at the beginning of their field experience are misled by the perfection of cabinet specimens and figures and hope to find everywhere such perfect forms; as a matter of fact, they must learn to be guided for the most part by fragments.

It does not seem possible to give within the limits of this publication any adequate description of the fossils which are characteristic of the different strata. It is better for these to refer to the original publications of the New York Natural History Survey. In the four reports on geology by Mather, Emmons, Vanuxem and Hall, numerous illustrations of fossils are given but the names are, in many cases, out of date. In the volumes on Palaeontology from I to VII, are described and figured most of the fossils of New York state from the Potsdam sandstone to the Chemung. Volume VIII gives a revision of the Brachiopoda. To these volumes, therefore, the student should refer for the identification of such forms as he may find in his field excursions. A few of the more common species are figured in Dana's *Manual of Geology*, which should be in the hands of every student. For those pursuing more critical studies, the work of S. A. Miller on *North American Geology and Palaeontology* is of great value as it gives a complete list of all Palaeozoic fossils described up to the date of its publication and indicates the more modern names in the many cases where there has been a change of nomenclature. Of the eight volumes of New York palaeontology mentioned, the first two are out of print and are only to be had from dealers in second hand books, but they will probably be found in most of the public libraries of New York state. The remaining volumes are sold at $2.50 each.

THE NATURAL HISTORY SURVEY OF NEW YORK AND THE ORIGIN OF THE STATE MUSEUM

The New York State Museum, organized by act of legislature in 1870 under the title of the State Museum of Natural History and placed under the trusteeship of the Regents of the University, is the result of the geological survey of the state commenced in 1836.

This survey was established at the expressed wish of the people to have some definite and positive knowledge of the mineral resources and the vegetable and animal productions of the state.

Hon. Stephen Van Rensselaer was the patron of the first enterprise of this kind, and had published much valuable information, but it was felt that a more thorough investigation was needed. The idea was fully expressed in a memorial presented by the Albany Institute to the state legislature in 1834, in which the object was thus stated: 'to form a grand and comprehensive collection of the natural productions of the state of New York; to exhibit at one view, and under one roof, its animal, vegetable and mineral wealth.'

In 1835 the New York Lyceum of Natural History presented a memorial to the legislature on the same subject, and it is presumed that this memorial and the influences prompting the request of the Albany Institute, induced the legislature of 1835 to pass a resolution requesting the secretary of state to report to that body a plan for 'a complete geological survey of the state, which should furnish a scientific and perfect account of its rocks, soils and minerals; also a list of its mineralogical, botanical and zoological productions, and provide for procuring and preserving specimens of the same, etc.'

Pursuant to this request, Hon. John A. Dix, then secretary of state, presented to the legislature of 1836, a report proposing a plan for a complete geological, botanical and zoological survey of the state.

The scientific staff of the natural history survey of 1837 was appointed by Governor Seward pursuant to an act of the legislature, and consisted of John Torrey, botanist, James E. De Kay, zoologist, Lewis C. Beck, mineralogist, W. W. Mather, Ebenezer Emmons, Lardner Vanuxem and James Hall, geologists, and Timothy A. Conrad, paleontologist. The state was divided into four districts, each of which was assigned to a geologist in the order given.

The heads of the several departments reported annually to the governor the results of their investigations, and these constituted the annual octavo reports which were published from 1837 to 1841. The final reports were published in quarto form, beginning at the close of the field work in 1841, and 3,000 sets have been distributed, comprising four volumes of geology, one of mineralogy, two of botany, five of zoology, five of agriculture and eight of palaeontology.

The collections in the several departments were supposed to require a room of some magnitude, and it was thought that such could be found in the third story of the old capitol, by taking away a partition and throwing into one, two rooms used by committees; but long before the completion of the survey it was evident that the collections would require much more space than the capitol rooms would afford, and in 1840 Gov. Seward, in response to a memorial urging 'the importance of providing suitable rooms or a separate building for the collections made during the survey,' recommended that the old State hall on the corner of State and Lodge streets be used for that purpose.

This old building was replaced in 1857 by a new one, Geological and Agricultural hall, and the collections which at first were to find place in two committee rooms, now occupy a large part of the main floor and three entire floors above, besides storage accommodations in the basement.

These collections form a scientific museum of great interest and value, and its publications are recognized among the works of standard authority in science. The geological survey of New York has been comprehensive and extended, yet some portions of the work are still incomplete; the northern part of the state has been but partially studied, and its geologic structure is but imperfectly known.

This museum, with its extensive and increasing collections and publications, plays an important part in the educational system of the state, since the importance of this kind of education has become so fully and generally recognized.

Although neither coal nor mines of gold or silver have been found within the state, it has been shown that New York possesses the most complete and unbroken series of the Palaeozoic or older fossiliferous rocks known in the world; and that for these the collections of the museum with the nomenclature adopted by the geological survey of New York will always be the standard of reference and authority.

It may justly be said that Hon. John A. Dix, as secretary of state, in 1836 laid the foundation of this museum and of all the scientific and practical results which have accrued from the inauguration of the geological survey of the state of New York.

At the time of the final arrangement of the collections of the geological survey, in 1843, very little was known in this country regarding museums of natural history, and no true appreciation of what such an institution should be, existed, except in the minds of a few persons. It is not strange, therefore, that there should have been a general acquiesence in the proposition that the collections of the geological survey should be deposited in the old State hall for 'safe keeping,' and the idea of constant and steady increase toward a great museum of natural history was scarcely, if at all promulgated. The collections and the rooms that they occupied were placed in charge of a curator, Mr. J. W. Taylor, who was succeeded by Mr. John Gebhard, Jr, and he in turn in 1857 by Colonel Jewett. The small annual appropriations made by the legislature were only sufficient for the custody and very moderate increase of the collection. Matters remained in this condition till 1865, when the legislature passed some resolutions tending to the expansion of the museum; and, following these, the secretary of the board of regents addressed a circular letter to numerous scientific men, professors and teachers, asking suggestions as to the best mode of putting in force the objects of the legislature as expressed in the resolutions referred to.

The communications in reply to this were published in the 19th report of the State Cabinet, together with a recommendation of the committee of the regents to whom the subject had been referred. This recommendation became the first step toward an improved condition, and a recognition of the necessity of regarding the museum as a series of collections in natural history which were to be increased and elaborated in every department. In 1865 Col. Jewett resigned and was succeeded by James Hall.

The discovery of the mastodon skeleton at Cohoes, in the summer of 1866, and its acquisition by the State Cabinet, attracted much attention toward the institution. At the next legislature successful application was made for $5,000 to purchase the Gould collection of shells and this accession of 60,000 specimens representing 6,000 species was generally appreciated.

The new capitol commissioners, wishing information as to the sources of building material, engaged the curator of the State Cabinet to make a reconnaissance which resulted in a report to the commissioners, and the acquisition to the State Cabinet, by this and other means, of a large collection of marbles, limestones, sandstones and granites which are now included in the collection which occupies two sides of the entrance hall of the museum.

At first the State Cabinet received no regular or fixed appropriation of money from the legislature, but in 1870 a law was passed organizing the same, under the designation of the State Museum of Natural History, and appropriating $10,000 annually to provide for the salaries of the director and three assistants, together with the expenses of increase and preservation of the collections. In addition to this, a sum was annually appropriated for the salary of a botanist, and special appropriations have been made from time to time.

In 1881 a state entomologist was appointed and in 1883 was made a member of the museum staff.

The present appropriation of $12,000 is quite inadequate to the requirements of such a museum, but a visible and substantial progress is made in each of the departments, as shown in the increasing order and the additions to the collections, as recorded in the annual museum reports.

In 1889 the State Museum was made an integral part of the University of the State of New York. In 1894 the present director was appointed. Most of the museum remains on the four floors of Geological hall on State street, at the corner of Lodge. Here are the collections in mineralogy, geology, palaeontology, zoology and ethnology and the offices of the director and his assistants. The state geologist and palaeontologist and his staff have their offices in State hall in Eagle street, and the entomologist and botanist are in the north east section of the fourth floor of the capitol. The State Museum in addition to its work of collecting material representative of the natural resources of the state, is also the seat of the geologic and natural history survey which has been in progress since 1832, and under the auspices of which numerous reports have been published on geology, palaeontology, zoology and botany. The museum is open to the public from 9 a. m. till 5 p. m. daily except on Sundays and other holidays.

Inasmuch as the State Museum comprises all scientific work intrusted to the regents it is proper to mention the resurvey of the boundary line between New York and the states of New Jersey and Pennsylvania. This was done in accordance with resolutions passed by the legislature in 1867 and in 1875, and by the laws of 1880 the boundary lines resurveyed and monumented under the direction of the regents were accepted as the true boundaries of the state.

OFFICERS OF THE STATE MUSEUM

Administrative division

Frederick J. H. Merrill, Ph. D. (Columbia)............Director
A. G. Richmond..............Honorary curator in archaeology
J. N. Nevius....................................Assistant
Joseph Morje.....................................Page

Research division

†James Hall, M. A. (Rensselaer polytechnic) LL. D. (Harvard)
State geologist and paleontologist
Charles H. Peck, M. A. (Union).................State botanist
*J. A. Lintner, Ph. D. (N. Y.)...............State entomologist
John M. Clarke, M. A. (Amherst)
Assistant state geologist and paleontologist
Philip Ast.........................Lithographer } Geologist's assistants
George B. Simpson..................Draftsman } Geologist's assistants
Martin Sheehy......................Messenger } Geologist's assistants
Jacob Van Deloo.........................Clerk } Geologist's assistants
Ephraim Porter Felt, B. S. (Boston) Sc. D. (Cornell)
Entomologist's assistant

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* Died May 5, 1898.
† Died August 7, 1898.

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