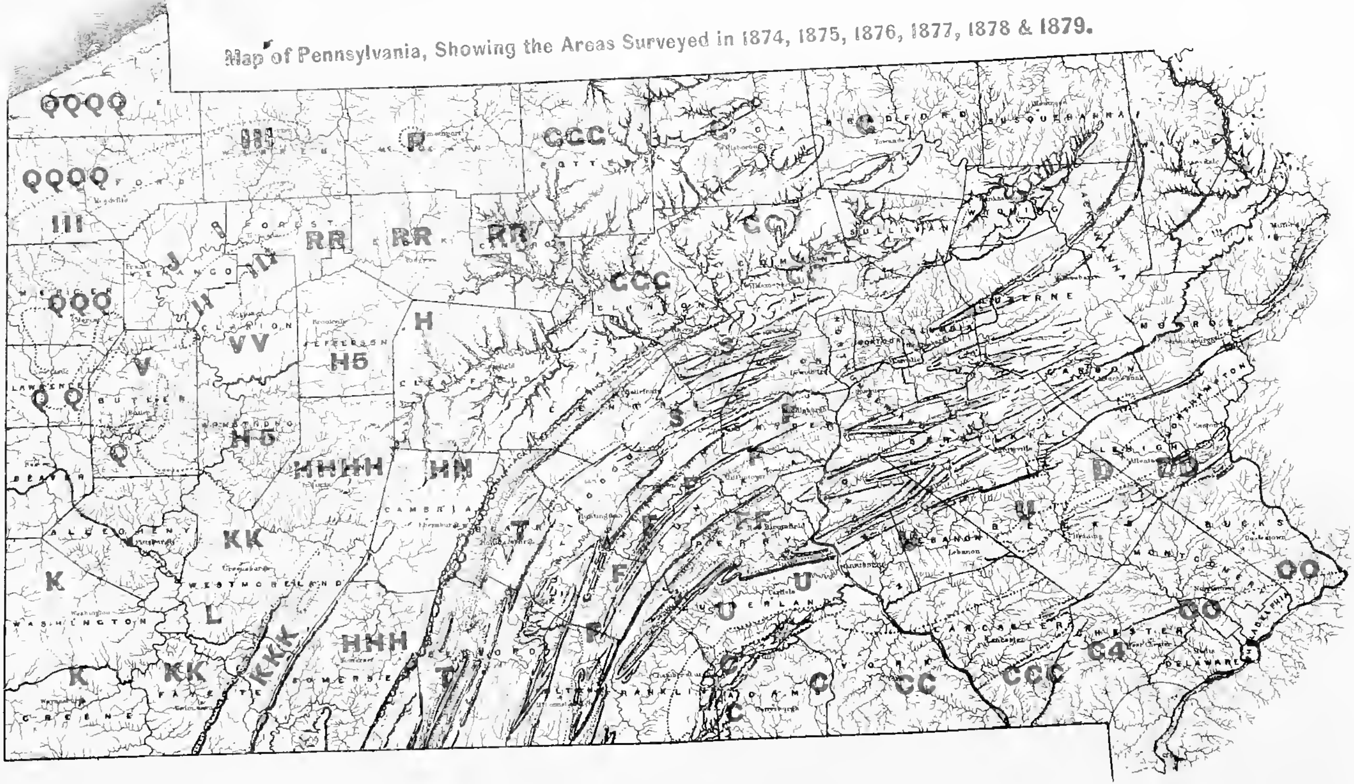
Map of Pennsylvania, Showing the Areas Surveyed in 1874, 1875, 1876, 1877, 1878 & 1879.



SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA:
1875 to 1879.

THE GEOLOGY

OF THE

OIL REGIONS

OF

WARREN, VENANGO, CLARION, AND BUTLER COUNTIES,

INCLUDING

SURVEYS OF THE GARLAND AND PANAMA CONGLOMERATES
IN WARREN AND CRAWFORD, AND IN CHAUTAUQUA CO., N. Y.,

DESCRIPTIONS OF OIL WELL RIG AND TOOLS, AND

A DISCUSSION OF THE PREGLACIAL AND POSTGLACIAL DRAINAGE OF THE LAKE ERIE COUNTRY.

BY
Franklin
JOHN F. CARLL.

WITH TWO INDEXES, 23 PAGE PLATES, AND AN ATLAS OF 22 SHEETS OF MAPS, WELL-SECTIONS, AND WORKING DRAWINGS OF WELL RIG AND TOOLS.

HARRISBURG:
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LETTER OF TRANSMISSION.

PHILADELPHIA, *October 25, 1880.*

To His Excellency Governor Henry M. Hoyt, Chairman of the Board of Commissioners of the Second Geological Survey of Pennsylvania:

SIR: The important report on the oil regions of Venango, Clarion, and Butler counties, which I have the honor to transmit to you for publication, covers more ground than is indicated by its title, and will be found to be not only a description of facts, but a statement of the principles established by them, regarding the origin, location, abundance and character of our Petroleum deposits, and of the history and mode of their exploitation.

These facts and principles were clearly but briefly indicated by Mr. Carll, in his First Report of Progress, (I,) a volume of 127 pages, published by the Board in 1875.

His second report, consisting almost entirely of oil well records, was published by the Board, in a volume of 400 pages, in 1877.

Three years have passed, and the value of that report has been fairly tested. It is a treasury of facts, obtained at a great expense of time, labor, and thought, corrected and verified by every possible means, and classified and indexed so as to be at the ready command of the statistician, the geologist, the well sinker, the civil and mining engineer, and the general reader.

The value of such a record of facts can hardly be overestimated, and oil men have acknowledged this value. The facts given in that report were sifted from a much larger collection of similar data of every grade of reliability, some of which proved on examination to be worthless, and the rest so doubtful as to be dangerous if published with those of good character. If the board be of opinion that they should all be given to the public, it will only be necessary to classify them to make another volume of well records equal in size to that of 1877.

The present report (III) makes a volume of about 500 pages, with a separate atlas of illustrations in 20 sheets, consisting of:—maps of the two principal oil regions, that of Venango and Warren, and that of Clarion and Butler counties; maps of special localities, like Spring Creek, Titusville, Franklin, and Parker; maps of northwestern Pennsylvania and contiguous parts of New York and Ohio, showing the pre-glacial drainage and its conversion into the present post-glacial river system; a map of the line of survey through Warren and Crawford counties into Ohio, to establish the outcrop of the Garland Conglomerate, on which the geology of the oil-sands depends for its explanation; a large number of vertical sections, carefully selected from the most authentic oil-well records, and so adjusted to the horizon of the Ferriferous limestone as to exhibit to the eye the geological structure of the region; and finally, a general profile section from Lake Erie to the Virginia State line, showing all the various horizons of the Dunkard Creek, Smith's Ferry, Butler, Venango, Warren, Bradford, and Canada petroleums, their mutual super- and sub-positions, their universal hypsometrical slopes southward and their several relations to tide-level.

The preparation of these illustrations has caused Mr. Carll and his aids, as may well be supposed by those who are acquainted with such work, infinite labor and trouble, which, however, will be amply repaid in the shape of usefulness to this and future generations of oil men.

For a special trial map of the Bradford oil-field, which has recently superseded and in a good degree eclipsed the others, the reader of this report must be referred to the atlas accompanying Mr. Ashburner's Report of Progress in McKean county (R) just published by the Board.

The main feature of the report is the settlement of the true character of the Venango oil-sand group as a distinct and separate deposit, with characteristic marks distinguishing it from the Palæozoic formations of a preceding and a succeeding age; the differentiation of the group into three principal and other subordinate layers of gravelly sand, holding more or less oil and gas; the local variability of these sands, their singular persistency beneath long and narrow belts of country, their change into barren shales elsewhere, and their independence of other oil-bearing sands and shales of an earlier and of a later date.

Seeking for oil in unexplored ground, is like seeking for tobacco in a smuggler's trunk. The traveler and his luggage look suspicious; that is the full extent of the customs officer's knowledge. The tobacco must be found, if at all, with the probe. The officer's instinct *may* be deceived; the trunk *may* have no false bottom; or the false bottom may hold no tobacco.

Just so, the geologist who knows the district knows more than the oil man, but he does *not* know whether sand exists at a given spot beneath the surface, nor whether, if there be a sand, it holds oil or not, nor whether, if the oil be there, it will flow towards a drill-hole. But this ignorance of facts, all of them out of sight and out of reach before experiment, he shares with everybody else. *No one*, absolutely no one can know such facts before a well is bored.

But what the geologist does know is the depth beneath the surface at a given spot at which a given oil-sand in the series ought to lie, and consequently the depth of a required trial hole. This fact men who are not geologists may also be acquainted with in the immediate neighborhood of productive wells, or in a local district where they are familiar. But let them go to other localities, more or less distant, and their knowledge becomes ignorance, because it is restricted by special experience. Whereas the geologist carries his knowledge of one locality with him to another, because *his* knowledge is theoretical, that is, reduced to system, and subject to well established laws of earth structure. He knows that no two well records are alike in detail. He is therefore obliged to discover their general or classical resemblance.

Until practical oil men learn to value the theoretical principles established and illustrated by Mr. Carll in this report it cannot be expected to reach its highest pitch of usefulness. That these principles are not visionary will be clear to every thoughtful reader of it. That they are supported by a great multitude of harmonized facts is plainly shown by its maps and sections. That they have virtually governed geologists, even when less well comprehended than Mr. Carll has now made them to be, is a historical fact put on record by printed reports of experts. That they ought to govern explorers of new territory follows as a matter of course; and so far as oil seekers consent to respect the reasonable results of long, close, and experienced investigation, so far will their pecuniary risks be diminished, and the actual cost of discovery be reduced to a minimum.

A flagrant example of this truth is given by Mr. Carll on page 137, where he describes the disastrous consequences to a great many people of a purely *geological*, purely *theoretical* mistake, made by the oil men of the "Fourth Sand Belt of Butler county," calling themselves practical men but working on a theory all the same. Practical men, so-called, are just as theoretical, and much more theoretical, than men of science; the distinction being, that the latter base their theories on a wide range of well connected facts, while the former establish theoretical prejudices upon the basis of a comparatively narrow circle of the facts with which they happen to be very familiar.

The Venango well sinkers had grown accustomed to the three oil sands of Oil creek, and they constructed and carried with them into the new field a *theory of three sands* which was merely a local prejudice. The first sand they struck, was to them, theoretically, the Venango First Sand, and when they reached a second, they theorized upon it as the Venango Second Sand. All they had to do now, according to their former practice and present theory, was to go one stage lower to the Venango Third Sand, and they would be sure (theoretically) to get great wells. But when they reached their theoretical third sand, it proved to be poor in oil. Their theory, however, arrested them here in spite of their being practical; in fact, precisely because they were practical men. They could not be induced to go deeper; they knew what they were about; no geologist could teach them anything; they had worked on Oil creek; they knew by long experience and at great cost that there existed no oil beneath the third sand; why then should they go deeper.

Now the fact is, that as long as they remained practical men on Oil creek they were all right; their local theory was a good one. But being merely practical men they were unconscious of the great law that a local theory is not good off its own ground, and must subject itself everywhere else to some larger theory, constructed slowly and painfully not by practical but by theoretical men, by men of science, by men who know the *relative value of the theories of practical men.*

Had the land owners and oil producers of the Fourth Sand Belt respected geological theories enough to take them into consideration, they would have made progress towards profitable truth by steps taken in the following order: 1. Although their first sand resembled the first sand on Oil creek, they would have suspected that the same kind of sand might be deposited at different times in different parts of the old water area, and therefore that resemblance did not prove identity. 2. They would have considered the evidence which Mr. Carll published in his first report, proving that the three sands of Oil creek (sometimes locally subdivided into four or five) form a single group, with hundreds of feet of soft drilling ground over it, and a great depth of soft drilling ground under it; and they would have kept an extra careful record of their drillings to see if this proved true in their new field. 3. They would have found thus that their three sands in Butler county did *not* form a single group, as on Oil creek, but that the upper soft drilling ground lay between their Butler first and second sands. 4. This would have led them, *theoretically*, to deepen their wells in order to make their oil group complete, and they would have found a fourth sand to correspond with the bottom (or third) sand of Oil creek.

The consequences of their scorn of theoretical geologists are depicted on page 137 of this volume. Concluding that they were working in a poor field of the Third sand, (whereas they were really exploiting the Second sand,) they sold out and moved off. The newcomers, influenced insensibly by the light thrown on the region by the Geological Survey, tried the experiment of sinking deeper, struck the true Third sand, and restored the prosperity and reputation of the Butler belt.

But clinging still to the old error of supposing the uppermost sand to be the Venango First (whereas it was the Third Mountain Sand, or Berea Grit of Ohio; the Pithole Grit of this Report) they called the rich new lowest sand thus obtained the Fourth Sand, and insisted on placing it underneath the Venango Third, whereas it is identical with it.

Not only do "practical oil-men" theorize in spite of themselves (as their drillings along certain compass lines show in a remarkable manner) but they are as capable of theorizing well and reaching just conclusions as thoroughbred geologists are, if they would take the pains 1, to observe the facts, 2, to exhibit them properly on paper, and 3, to compare together a sufficient number of them, so as to discover their real connection and relationship. No shrewder or more intellectual people exist. No better observers live. If they only believed in scientific methods of research they would need no enlightenment from geologists. But they despise a slow, painstaking, accurate, wide extended systematic investigation. They bring a handful of sand to a geologist and expect him to declare from an examination of it alone, apart from all other circumstances, what rock it comes from, how much oil that rock probably holds, and how fast the oil from it will probably flow or be pumped. To furnish such an opinion would be mere quackery. And yet on such specimens and such opinions—opinions called "practical" but which are purely and simply "theoretical," mere prejudices adopted from some former and distant experience—costly and futile attempts are made to open new oil fields in barren measures.

Oil men ought to make themselves their own geologists. The elements and principles of geology ought to be part of their stock in trade. They have more ample opportunities for acquiring this kind of useful knowledge than any other class of men living. They know and feel the necessity for examining with minute attention the oil sands, and they do this work admirably well when they reach them; but they pay no heed to the geology of the other parts of their bore-hole. If they did, the knowledge they would thus get would be of far more importance to them, for it would enable them to compare one well with another and thus cover the true relationships of the oil sands. They form a theory and then examine the facts. A geologist collects and puts together the facts before he allows himself to construct a theory. They theorize that the oil sand they want lies so many hundred feet beneath the surface, and they pay little or no attention to the hundreds of feet of various measures through which they pass in descending to that depth. No wonder that they are as liable to blunder in sinking a second hole as in sinking the first. In fact by this utter disregard of his well records, except just where low sands lie, a man may sink a hundred wells and have no more true, safe, reliable knowledge of the subject than he had at first. Nor does time seem to cure the evil, but only to confirm it. What was a reproach to the oil well sinker of ten or fifteen years ago, is a reproach to the generality of oil well sinkers in 1880. Where are the records of the scores of thousands of holes bored? And how absurdly, suicidally indefinite, inexact, fragmentary and unreliable are the few records which have been made and preserved! What an immense, what an irretrievable loss, not to science merely, but to the intellectual stock in trade of oil men, has happened!

It is impossible for a geologist not to feel and speak warmly on such a subject; and it would be shirking a sacred duty if the Geological Survey of Pennsylvania did not do its best to place this flagrant omission of common business precaution, this wholesale waste of valuable business information, this fruitful source of business embarrassment, distraction, and disaster, in its true form and colors before the eyes of the whole oil producing community.

To return to the subject of the importance of geological generalizations as seen in a practical light, I may be permitted to describe in the first person a singular case in point.

In 1841, I was ordered by the chief of the First Geological Survey to report on the counties lying along the New York line, and down the eastern bank of the Allegheny river, as far as the Kiskiminitas. Other assistants on that survey had already discovered and reported the geological structure of the Allegheny river and Beaver river water basins; and the rate of descent of the rocks southward and southwestward in relation to tide level had been calculated. My business was to follow and locate upon the map the anticlinal and synclinal rolls which locally change and modify this general dip, and to identify the principal coal beds over a large area.

After the discovery of petroleum (which of course did not in the least set aside or essentially change the structure of western Pennsylvania as established by the First Survey) I happened to be employed by the Brady's Bend Company to examine their property, and to give them, among other items, an opinion upon the probable existence and depth of oil beneath it. To do this, I merely did what any geologist who had thoroughly studied that country would have done; I calculated the vertical distance from the oil sand on Oil creek up to coal A; then I calculated the dip of the measures between Oil creek and Brady's bend; and then I identified coal A at Brady's bend. I reported that the Venango oil sand, *if it extended under ground as far as Brady's Bend*, ought to lie at 1100 feet beneath water level. Any geologist who knew the country could have done this. It required no genius, no uncommon knowledge, nothing but a plain, simple, systematic, or scientific, in other words, true theoretical method of applying known facts for discovering the unknown. Any oil man could have done the same, if he had noticed the rock-layers as he went up and down the river, and put this and that carefully together.

Yet, when after a few months oil was actually struck at Brady's bend within a few feet of the depth which I had assigned to it, the astonishment of all classes of oil men was ludicrously extravagant; a score or two of copies were made from the manuscript report, and these copies passed from hand to hand as precious things, and their author was looked upon as a prodigy of mental penetration, and was offered large sums of money to locate wells in different districts; none of which offers, of course, were accepted, because he was as ignorant of the *actual existence of an oil bearing sand in any given locality* as everybody else.

The story has its moral. Let "practical men" believe in and respect the slowly, carefully reached conclusions of "theoretical men" enough to take them into consideration, so far as to comprehend them, and to govern themselves by them in their own collection and collation of facts relating to their own pecuniary interests.

When a geologist like Mr. Carll has spent years in sifting and comparing the data of a great geological problem, and publishes his mature conclusions in a modest, earnest, plain, unvarnished report like that which is contained in this volume, it is probable, to say the very least, that its value to practical men like oil producers, struggling with immense obstacles to fortune, will be real in proportion to the pains they take to understand it.

It will be noticed that great pains was taken and much time and labor spent outside of the oil region proper, along the northern outcrop of the remarkable pebble rock deposit which caps the hills on both sides of the Brokenstraw above Garland station in Warren county, as well as the plateau east of Warren, and the hills on both sides of the Philadelphia and Erie railroad, south and east from Warren into McKean county. Outlying masses of this rock crown isolated summits to the west of Wrightsville and Lottsville, and within three miles of the New York State line. Further north nothing of it is seen; but similar outlying patches exist in Crawford county, and are marked on the geological colored map of Crawford and Erie counties, intended to accompany Professor Wright's Report Q^4*. The survey of

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*The geological map of Warren county has been prepared for the press, but awaits important additions.

the general line of outcrop is described in the first five chapters of this report (I.I.I.) where its close study is justified; since it plainly appears that this so-called Garland conglomerate is the Sharon conglomerate of Crawford and Mercer counties, and the Ohio conglomerate west of the State line; is also the Olean conglomerate of McKean county; is the bottom sub-division of the great Pottsville conglomerate (No. XII) of northern, middle, and eastern Pennsylvania, surrounding the Anthracite coal basins, and is the Second Mountain sand of the oil producers on Oil creek and elsewhere. It is, therefore, in a good degree, the key to the whole geology of Northwestern Pennsylvania.

But when these facts were settled, there arose questions concerning a great pebble-rock formation at Panama, and around Lake Chautauqua in New York; and it was important to know whether this passed into Pennsylvania underneath the Garland; and at what distance; and whether it bore any relation to the Venango oil sands. Professor White will present in his report on Erie county his reasons for believing it to be the Venango Third Sand. Mr. Carll, in chapter 6 of this volume, describes the rock as far east as Salamanca, and shows that it fades away into fine sands and shales southward in Pennsylvania before reaching the Venango oil belt, just as the Garland or Olean conglomerate fines away into soft sands and shales southward. The coarseness of these deposits at their extreme northern outcrops seems to point to a Palæozoic shore in that direction; but every trace of the rivers which brought these pebbles down to the shore of the ancient sea, of the currents or tide-runs which distributed them laterally, and of the high lands which such rivers must have drained, has been swept away in the ancient general and profound erosion of the country now occupied by the chain of the Great Lakes.*

Between the upper Garland-Olean deposit and the much older and deeper Panama-Salamanca deposit, Mr. Carll has reason to believe that one and perhaps two other similar deposits exist, forming rock cities along the State line; but he is not prepared in this report to present the facts on

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*See discussion in report T, on Blair county.

which this opinion is founded. One of these may possibly represent the Third Mountain Sand (Pithole or Berea Grit) and the other one of the oil sands; but this must be left to future investigation. The relationships of the Pithole Grit of Venango to the Berea Grit of Ohio, however, is amply discussed in Chapters 7 and 8 on the Mountain Sands.

The attention of oil men will no doubt be chiefly directed to the description of the oil sands themselves, and of the areas which they occupy, in Chapters 9 to 16, 23, 24, and 25; while the curiosity of business men everywhere will be gratified by the elaborate descriptions of the whole process of oil seeking, drilling and pumping; its machinery, its methods, its obstacles, its improvement, its rate, quantity, and cost, as given in Chapters 27, 28, and 29.

The origin of petroleum is still an unsolved problem, and Chapter 26 merely suggests queries respecting it. That it is in some way connected with the vastly abundant accumulations of Palæozoic sea weeds, the marks of which are so infinitely numerous in the rocks, and with the infinitude of coralloid sea animals, the skeletons of which make up a large part of the limestone formations which lie several thousand feet beneath the Venango oil sand group, scarcely admits of dispute; but the exact process of its manufacture, of its transfer, and of its storage in the gravel beds, is utterly unknown. That it ascended rather than descended into them seems indicated by the fact that the lowest sand holds oil when those above do not, and that upper sands hold oil where they extend beyond or overhang the lower.

The chemical theory, so-called, which looks upon petroleum as condensed from gas, the gas having been previously distilled from the great black shale formations (Marcellus and Genessee) must face the objection that such a process, if chemically possible, which is doubtful, ought to have distributed the oil everywhere, and permanently blackened and turned into bituminous shales the entire thickness of this part of the earth crust for several thousand feet. It fails to explain the petroleum obtainable from the Cannel coals, and from the roof shales of Bituminous coal beds. And it fails also to explain the entire absence of petroleum from immense areas of not only shales, but sand and gravel rocks, equally underlaid by the Marcellus and Genessee formations.

The supposed connection of petroleum with anticlinal and synclinal axes, faults, crevices, cleavage planes, &c. is now a deservedly forgotten superstition. Geologists well acquainted with the oil regions never had the slightest faith in it, and it maintained its standing in the popular fancy only by being fostered by self-assuming experts who were not experienced geologists.

The case of the oil-bearing glacial and river gravels about Titusville is very curious; their description and the history of the "Grasshopper well" flurry given in Chapter 36 will repay perusal.

These river gravels are connected with a wonderful deposit of Canadian rock fragments not only upon but to the depth of several hundred feet beneath the present surface of Northern Pennsylvania, a deposit which forms a great belt more than a thousand miles long across the continent, from Cape Cod in Massachusetts to Iowa and Minnesota beyond the Mississippi river. Brought from the north by a sheet of moving ice which once filled the great lakes and rode over the highest mountains to the south of them—burying all New England and New York, Northern New Jersey, Northern Pennsylvania, the Western Reserve in Ohio, and large portions of the States lying further west—projecting long tongues or slowly moving torrents of solid ice southward as far as and even beyond the Ohio river in Kentucky, and driving slowly before it the reindeer, musk ox, caribou, moose, and other arctic animals whose bones are found in the diluvial clays of the Kentucky caves; while the walrus inhabited the shores of the Atlantic as far south as the Ashley river in South Carolina,* and the Esquimaux

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* Even if the walrus tusks found at Long Branch, N. J., by Prof. J. F. Frazer in 1853 and Prof. George H. Cook afterwards, (described by Leidy, in Trans. A. P. S. Phila. XI, 1857), in Accomac county Virginia (described by Michell, Smith and Cooper, Ann. Lyc. Nat. His. N. Y. II, 1828,) had been brought down on ice bergs by the Arctic in-shore current, the skeleton found (1878) at a depth of 7 feet in the clay beds of Portland, Me. (described with the others, by J. J. Allen in Hist. N. A. Pinnifids, Hayden's Survey of the Terr. 1880, p.

race no doubt accompanied these animals into the Gulf States (just as it did in France as far south as the Pyrenees) this deposit of moraine matter, sand, clay, scratched rocks and hugh bowlders filled up the valleys by which our rivers had previously flowed into Lake Erie, and turned their waters southward into the Ohio.

This interesting episode in the drama of the Glacial Age of geology is described in great detail by Mr. Carll in Chapters 30 to 34, adding largely to our knowledge of a subject which is commanding the close attention of the best geologists of Europe and America, and which demands much more attention than the Survey has been able to give to it yet in the northeastern counties of the State.

Besides the two maps which will be found in the Atlas accompanying this report, and which are intended to show how our rivers flowed before the invasion of the Ice, a map was partially prepared to show the barrier divide through from central New York to Illinois; but difficulties of construction arose which would have delayed too long the publication of the report. This map is spoken of in the text as Map II *bis*.

It only remains for me to express the hope that the Legislature will provide for and the Board order as close and detailed a survey and report of the Bradford oil-field as of the older and just at present less important fields. The time will come however when a larger, less exciting, but more healthy and profitable exploitation of the now almost abandoned belts will recur; and then the facts and principles embodied in this report will receive a proper estimation.

Very respectfully,

J. P. LESLEY.

60, 61) the skull found (1874) in the inland diluvium at St. Menehoulde in France, (Bull. Geol. Soc. France II 1874), and the tusk found in the Ashley river phosphate beds (described by Leidy, Jour. Acad. Nat. Sci. Phila. VIII. 1877,) all show that the Walrus was a resident of our Atlantic coast in the Ice age; as a different and now extinct species of it had been in Tertiary times.

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ON THE PROGRESS OF THE SURVEY

IN THE

OIL REGIONS

OF

WARREN, VENANGO, BUTLER AND CLARION COUNTIES

FROM 1875 TO 1879.

Chapter I.*

The topography and drainage of the country lying between the northern outcrop belt of the Garland conglomerate and the Lake Erie divide, in Warren and Crawford counties.

§ 1. A line drawn from Sugar Grove in Warren county to Jamestown in Mercer county represents approximately the northwestern margin of the outcropping *Garland conglomerate* as instrumentally traced from New York to Ohio in the second year of the survey, 1875.

§ 2. The bearing of this line is about S. 58° W., N. 58° E. being parallel with the average trend of the shore of Lake Erie and distant from it say 30 miles. (See map Plate I.)

§ 3. The outcrop of the *Garland conglomerate*, thus indicated, is, however, by no means an unbroken escarpment;

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*Report of the work done in 1875.

but a range of hilltops or outliers, separated by numerous shallow vales, through which streams flow towards the south; all of them being tributaries of the Ohio river; and some of them having their head-springs within 8 or 10 miles of Lake Erie, on the crest of the "great divide" or water-shed, the gently sloping southern side of which is drained into the gulf of Mexico, while its steep northern slope is drained into the gulf of St. Lawrence.

§ 4. The original gaps in the ranges of conglomerate capped hills were gradually, in course of time, deepened and widened into valleys between elevated upland ridges; and these ridges in their turn were worn down and cut through sideways, more or less, by the general rain-fall and smaller lateral streams, until now only an occasional detached outlier of the Garland conglomerate (or sandstone) remains on the crowns of the highest hills along the line above referred to.

§ 5. *Pike's ridge*, an outlier of this kind, the most northwesterly in the State of Pennsylvania, may be found about 2 miles from Wrightsville and 4 miles from Sugar Grove in Warren county, on the divide between Little Brokenstraw and Stillwater creeks.

§ 6. To the north and west, the Garland conglomerate, with all the rocks above it in the series, has been removed by the general erosion of the country, which, deprived of its protection, has been carved into broad valleys and gracefully rounded hills and ridges of the softer and more homogeneous measures below it. The contrast is very striking to the sharp and rugged topography of all the country to the southeast, where most of the higher eminences are still protected from erosion by a considerable capping of the massive, current-bedded, micaceous sandrock deposits, underlying the Coal measures.

§ 7. At the *Olean Rock City*, in Cattaraugus county, N. Y. is found the next prominent exposure of the Garland conglomerate to the north and east of the one last mentioned. It bears N. 80° E. from Pike's ridge, distant 47 miles, and near the Pennsylvania State line, about 6 miles southwest of Olean.

§ 8. If now we start at the *Olean Rock City* and glance southwesterly along the line indicated on the map (Plate I) first to Sugar Grove, and thence to Jamestown, we notice that the principal streams cutting the line come in the following order: 1. Tunangwant creek, flowing north into the Allegheny; 2. the Allegheny river, flowing south; 3. Conewango creek, delivering the waters of Chautauqua and Cassadaga lakes southward into the Allegheny; 4. Little Brokenstraw creek; 5. Blue Eye run; 6. Big Brokenstraw creek; 7. Oil creek, with two branches; 8. French creek; 9. the Conneaut outlet; 10. Crooked creek, and 11, the Shenango river, all of them flowing south.

§ 9. More or less of the Garland conglomerate (or sandstone) remains in place along the line, on all of the ridges which intervene between these streams; and in some instances (as in the vicinity of Meadville) spurs of hills capped with it extend still further north. The actual outcrop therefore, if followed along its windings, would make a very irregular line upon the map; while several isolated patches exist to the north of the general strike-line completely cut off from the main body by lateral streams running nearly at right angles to the leading arteries of drainage.

Spring creek in Warren county, and *Hyde* (or *Little Oil*) *creek*, in Crawford county, are lateral streams of this character. The crown of the southerly water-shed of these two streams trends in nearly a due southwest course from Big Brokenstraw to Oil creek, and is virtually an unbroken ridge capped with the Garland conglomerate; while over all the country to the northwest the rock lies only in detached masses on isolated knobs of the spur-ridges.

§ 10. *Valley features.*—To repeat what was said above, the configuration of the country and the character of the streams north of the main outcrop line of the Garland conglomerate are in striking contrast with those south of it.

To the north, the erosion of ages, after accomplishing the complete destruction of the sandstone, has attacked the underlying shales, producing innumerable hills rounded to a graceful contour; the valleys are broad, with bottom lands through which the sluggish streams sweep in curves and loops and flow almost entirely between banks composed of lacustrine or fluviatile re-worked Drift. Scarcely an exposure of bed-rock can be seen in all their meanders.

To the south, on the contrary, the hilltops protected by massive sandrock are angular and rugged; the valleys are narrow; the streams are hemmed in between high and precipitous bluffs; and flow with considerable speed and directness through rocky channels, holding comparatively small accumulations of re-worked Drift.

§ 11. *Water basins.*—On a further examination of the hydrography of the region, the water-courses draining these trenched summit plateaux or basins arrange themselves naturally into *four groups*, the members of each group converging toward a common outlet, deeply eroded through the sandstones and shales at the south; but the waters of all four groups eventually commingle in the Ohio river at the mouth of the Big Beaver, below Pittsburgh.

These groups of streams, or water-trees, are designated upon the map (Plate I) by the following names:

Chautauqua.
Oil Creek.
Conneaut.
Pymatuning.

§ 12. *The Chautauqua water basin.*—All the drainage of the Chautauqua group, gathered from the numerous headwater branches of the Allegheny, from the Conewango and its lake feeders, and from the Big Brokenstraw and its affluents, flows down the Allegheny river in one body after passing Irvineton, which is situated near the centre of Warren county.

Near Thompson's station, six miles below Irvineton, there appears to be a slight anticlinal crossing the river; but just where exactly located and of how much importance it would be difficult to determine without an extensive instrumental survey. Here the southerly rim of the Chautauqua water basin is cut by the Allegheny river valley.

Following the rim or dividing ridge around, it may be seen on the map to commence a little west of the head of

Chautauqua lake; thence, southward, passing near Corry in Erie county, to Thompson's station in Warren county; to Kane in McKean county; to Keating Summit in Potter county; and sweeping around by the east of Coudersport, and the head of the Allegheny river, to the noted "Continental summit" near Raymond's Corners in Potter county.*

The outlet of this group of streams, at Tidioute, drains a larger area than that of all the other three groups combined.

§ 13. The *Oil Creek water basin* is comparatively small, including only Oil Creek and its branches. Its waters enter the deep cut through the lower carboniferous sandstones a short distance below Titusville, and after following a tortuous course for seventeen miles, along a narrow bed hemmed in by high walls on either side, commingle with those of the Allegheny river at Oil City.

§ 14. The *Conneaut water basin* includes French creek and its branches, some of them streams of considerable importance. It collects its water from the Lake Erie divide, the westerly rim of the Chautauqua basin, and the northerly and westerly sides of the Oil creek basin, and delivers it through French creek into the Allegheny river at Franklin.

§ 15. The *Pymatuning water basin.*—The area above Greenville drained by this group is inconsiderable in extent, but the physical features of the basin are worthy of note. It includes the Pymatuning swamp with its several small feeders and two outlets—the Shenango and Crooked creek: These outlets come together at Greenville in Mercer county, and, re-inforced lower down by the Pymatuning from the west, the Neshannock from the east and the Mahoning from the west, from the Big Beaver river which enters the Ohio about 30 miles below Pittsburgh.

Pymatuning swamp lies only about 35 feet below Conneaut lake, and is separated form it by a low and narrow

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* Where the rainfall on a fifty acre tract is carried off in one direction through the Genesee river into Lake Ontario and the St. Lawrence, in another through the Allegheny, &c., into the Gulf of Mexico, and in still another through Pine creek and the Susquehanna river into Chesapeake bay.

divide.* At the point where the old Beaver canal (taking its water-supply from the summit reservoir (Conneaut lake) passed through this divide; but a short cut about 25 feet in depth, and entirely in drift, was required. The amount of Drift piled in here, and the configuration of the hills on either side, make it seem not at all improbable that the Pymatuning waters once flowed into the Conneaut basin.

Comparative levels of the Water Basins.

§ 16. To aid in obtaining a comprehensive idea of the relative levels of these groups of drainage channels, let us now imagine the *Allegheny river* at Thompson's station, where the conglomerate-capped hills rise abruptly between six and seven hundred feet above the stream, to be checked by an obstruction raised in the valley 200 feet above the present surface of the water. This dam, although slight as compared with the hilltops, would throw back the water of the Allegheny river to the north, and flood the wide valleys of all its principal tributary streams. It would raise the surface of Chautauqua lake about 31 feet above its present level, and Cassadaga lake 25 feet. It would cause slackwater to extend up the Allegheny and its branches beyond the New York State line; flood the Conewango valley and a large part of the country between Warren and Chautauqua and Cassadaga lakes, and fill the trough of the Brokenstraw to a point above Garland.

Let us in like manner suppose *Oil creek* dammed to the

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* To the southwest of Conneaut lake and swamp, just under the comb of the ridge, between 30 and 40 feet lower in level, is to be found the great Pymatuning swamp. This marsh is very extensive, as its western boundaries lie some distance within the State of Ohio. The river Shenango finds its source in this swamp, a river which runs in a southerly direction until it meets the Neshannock, in Lawrence county, at New Castle, and thus forms the Beaver river, which falls into the Ohio about thirty miles below Pittsburg. The area of the swamp, as near as could be ascertained by this cursory survey, is nine thousand acres. I believe that all the water which flows from it contributes to the Shenango. A small bay on its eastern extremity, is cut off by the Erie extension canal, and forms a subsidiary reservoir for that work at Hartstown; out of this end of the swamp flows Crooked creek, which joins the Shenango about four miles above West Greenville.—*Surveys of the Pymatuning and Conneaut swamps, by Col. Jas. Worrall, C. E., Under the joint resolution of February 28, 1868.*

height of 200 feet where it enters the highlands just below Titusville. The side walls here rise about 400 feet above the stream. This would flood all the low country along Oil creek nearly up to Oil lake and form a sheet of water two or three miles in width in some places. The valley of East Oil creek would also be filled as far up as Colorado, and Caldwell creek as far as to Pleasant valley.

An obstruction of 100 feet on *French creek* between Franklin and the mouth of Sugar creek, would cover the Conneaut marsh, and the broad valley of French creek to Meadville, thus enlarging the boundaries of Conneaut lake and forming a sheet of water of no mean dimensions.

An obstruction 100 feet high in the *Shenango river* at West Greenville would form a lake with a large island in the center, extending up both branches of the Shenango, and embracing within its outlines the great Pymatuning swamp.

The surface of the Chautauqua basin were it filled with water as we have imagined it to be would lie at an elevation above the ocean of about 1330 feet; the Oil creek basin, 1360 feet; the Conneaut basin, 1080 feet; the Pymatuning basin, 1070 feet.

§ 17. Into these four basins all the drainage between the Lake Erie divide and the almost continuous range of outcropping Garland conglomerate now centers; and if they were flooded, as supposed, the inflowing streams from the north and the dividing ridges, would simply be feeders to these long, narrow, irregularly outlined lakes; and the surplus accumulations of water from all this country, would pass out, as they pass now, only through the four gaps in the conglomerate first indicated.

§ 18. Going still further in this line of illustration, let us now compare these four imaginary sheets of water and note the probable effects of a change in their respective levels.

By increasing the obstruction in the *Allegheny river* at Thompson's station 10 feet, the Chautauqua basin would *overflow to the north* through Cassadaga lake into Canadaway creek and thence to Lake Erie.

By raising the *Oil creek* obstruction 10 feet, the Oil creek basin would *overflow to the northwest*, through the west branch of Oil creek into Muddy creek and thence into French creek.

By raising the *French creek* obstruction 10 feet, the Conneaut basin would *overflow to the west* into the Pymatuning basin, thus converging all the waters from the Oil creek, Conneaut and Pymatuning basins into the Shenango river.

But if we should now raise the *Shenango* dam 30 feet, bringing it up to 1100 feet above tide, and build up the French creek obstruction to the same level, we should probably *check the southern flow of water from all this area*, and a new channel would be opened for it at the north, from Conneaut lake into Conneaut creek and thence into Lake Erie.

§ 19. We must bear in mind that the southern boundary of these basins is a highland capped with several hundred feet of the coarse sandy measures outcroping from beneath the coal fields of the south. At *Thompson's* gap the average top of the ridge may be put at about 1800 feet above tide; at *Oil creek* about 1600 feet; at *French creek* about 1400 feet; and at the *Shenango* about 1200 feet.

§ 20. *Thompson's gap.*—We have seen that an obstruction in the Thompson's station cut, if raised to an elevation of 1340 feet above tide, would stop the passage of water at this point and open a new outlet for the drainage of the Chautauqua basin through Cassadaga lake into Lake Erie. By what agency, then, and when, was this gap (at Thompsons) opened; since whatever it was that opened it must have commenced its work in the upper rocks at an elevation of 1800 feet at least—460 feet above the place where the water now would have a free outlet to the north?

§ 21. *Oil creek gap.*—So too on Oil creek, when the water is stopped, and thrown back until it finds an outlet to the north, by an obstruction 1370 feet above tide, 230 feet of the upper part of the chasm remains as a witness of the work of other agencies than the waters of the present basin.

§ 22. *French creek gap.*—The French creek gap also presents similar features. If its channel were filled to a sufficient height (1090 feet above tide) to cause the Conneaut basin to deliver to the west, there would still be an erosion of 310 feet of the upper part of the old gap in the hills to be accounted for.

§ 23. *Date of the formation of the gaps.*—It appears therefore quite certain from the above presentation of the case that these southern outlets through this escarpment of massive conglomerates and sandstones, were opened long anterior to the time when the drainage of this area began to be influenced by its present topography, and before the waters were confined within the rims of the respective basins as we now find them. Otherwise the overflowing waters could not have cut through several hundred feet of sandstones and shales on the south, lying at a higher level than their surface; but would have found a more ready outlet and a more rapid delivery through the softer measures of the north and west—the Chautauqua, through Cassadaga lake into Lake Erie—the Oil creek through Muddy creek into the Conneaut—the Conneaut into the Pymatuning—and the three latter (combined) into the low levels of the Shenango river country.

§ 24. *The agency glacial.*—The peculiar arrangement of these basins between the Lake Erie divide on the north and outcropping conglomerates on the south; the positions of their several outlets, which singularly enough are cut down through the highest and hardest portions of their inclosing barriers—the highest reservoir having cut the deepest outlet; and the immense amount of northern drift, accompanied by erratic bowlders, spread over nearly all this section—seem to point clearly to the inference that these features are not due to the action of aqueous and atmospheric erosion alone, but that the general outlines of the present topography were "carved out in the rough" prior to and during the glacial epoch, and afterwards modified and smoothed down by the gradually receding waters as the ice disappeared.

§ 25. *No continental rock barrier.*—We can hardly imagine that the levels of the country between the Cincinnati anticlinal and the Chautauqua highlands were ever so adjusted as to hold a fixed body of water to the north at the high elevation of the Chautauqua basin; and if they were so adjusted, then, when the first outlet opened to the south, down the dip of the strata, wherever that outlet might be, the erosion would be so rapid that only one waste weir would be required. This outlet, deepening, widening and lowering the surface of the water to the north, would be likely to leave in the basin behind (as the waters subsided by drainage) a system of streams all converging towards the common outlet. But instead of one basin of this description we have shown that there are four; each one having an independent outlet, cut down deeply through ponderous rocks lying high above the average level of the country drained by it.

§ 26. *No general submergence.*—Neither are we prepared to accept the hypothesis of submergence below sea-level to account for the superficial deposits and the facial peculiarities of this section. For in that case, when the land again emerged, and drainage commenced in any direction, we should have the same features as those above referred to repeated. Or, if an isolated basin remained unemptied, it would overflow and open an outlet for itself at the *lowest* point in its barrier, and not through sandstone cliffs rising hundreds of feet above its surface.

The orographic features of the district stand out boldly as witnesses of a fact which will hardly be questioned by any one after an examination of the country. They offer the best of evidence in themselves that they are not the results of the action of water alone, but of ice and water combined. In just what way the erosion was accomplished; what its status was at the beginning of the glacial epoch; and what the measure of its progress has been during and since that time, we can as yet only surmise.

CHAPTER II.*

The GARLAND (*Olean*† *or Sharon*‡) CONGLOMERATE *and* SUB-GARLAND (*Sub-Olean*† *or Shenango*‡) SANDSTONE *placed and traced.*

a. Leveled Line of Survey.

§ 27. In selecting a route over which to run *a spirit level line* across northwestern Pennsylvania in 1875, for the purpose of connectedly tracing the several *outcrops of Garland conglomerate*, that they might thus be identified with contemporaneous rocks in the State of New York on the one side and in the State of Ohio on the other, a due consideration of the amount of time that could be appropriated to the undertaking without prejudice to interests of equal importance in other parts of the oil district made the adoption of a route imperative which offered fewest obstacles to the speedy execution of the work.

In addition to the levels, *courses and distances* also were to be taken, in order that the line might be used as a base for future operations if occasion required. It was therefore desirable to follow some highway; and, under these circumstances, the choice naturally fell to the "State road" commencing at *Busti*, in Chautauqua county, N. Y. and running through *Sugar Grove* and *West Spring creek* in Warren county, Pa.; *Riceville*, *Meadville*, *Adamsville*, and *Jamestown* in Crawford county to *Kinney's Corners* in Trumbull county, Ohio.

§ 28. Although the selected line of survey does not keep constantly upon the outcrop of the Garland conglomerate it is an excellent one along which to study the geology of the

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* Report of work done in 1875.

† Names assigned by Mr. Ashburner in his Reports (R, RR) on McKean, Cameron, Elk, and Forest counties.

‡ Names assigned by Mr. White in his Reports (QQ, QQQ, QQQQ) on Lawrence, Mercer, Crawford, and Erie counties.

country, and it is as direct a line as any highway at our command between the points named.

§ 29. Messrs. F. A. Hatch and Arthur Hale, with C. A. Dodge as rodman, performed the work. The distances were measured with a ten foot odometer-wheel. Bearings were taken by transit-telescope and needle. Elevations were observed on the vertical circle of the transit instrument, and reduced to ocean level by reference to the data given in the profiles of the several railroads crossed.*

§ 30. The region traversed by this line of survey, rapidly executed for a special geological purpose, affords ample scope for the investigations of a field-party during an entire season, even if all the time were devoted to a study of its *Drift phenomena* alone. Its glacial grooves—its bowlders scattered at all elevations along the hillsides—its old water channels, some of them now filled to a height of 400 feet or even more—its drift-clays and lake beaches—each and all of these deserve close and careful study, and proffer the material data for a very interesting chapter in the geology of the State.

§ 31. But for the present, attention must be chiefly given to the more important task of tracing the *Garland conglomerate* (the *Second Mountain sand* of the oil wells) along its northerly outcrop across Pennsylvania; identifying it with certain conglomerate strata outcropping in New York and Ohio; and endeavoring to fix its horizon definitely in relation to the overlying coal measures and the underlying oil-bearing rocks.

The following chapters will deal chiefly with these topics, other matters being incidentally noticed as they were observed.

b. Place of the Garland Conglomerate in the Series.

§ 32. The term *Garland conglomerate* is used in these pages as a convenient local geographical name for the low-

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* As the survey along this line has not been amplified or extended in any direction, as it was originally intended to be, only a portion of their notes have been used in the preparation of the contour map and profiles (Plates 3 and 3B) herewith presented.

est member of the *Carboniferous Conglomerate series* in this part of the State.

It is apparently identical with the *Olean* conglomerate in McKean county; with the *Sharon conglomerate* in Mercer county; with the *Ohio conglomerate* in Ohio; and with the *Second Mountain Sand* of the oil wells.

§ 33. There has prevailed hitherto great confusion of ideas respecting the massive conglomeratic sand deposits underlying the Productive coal measures.

The Conglomerate (XII) at Pottsville in Schuylkill county (where it is more than 1000 feet thick) has been traced around the Anthracite coal basins and along the Allegheny mountain to the Maryland State line, without much difficulty; and it has been recognized *as a whole*, throughout western Pennsylvania, wherever it appears upon the anticlinals, in gorges, and along the sides of valleys. But it is as thin in the west as it is thick in the east; and the Mauch Chunk red shales (XI) which underlie it, and measure more than 3000 feet in thickness east of the Susquehanna river, and more than 1000 feet on the upper Juniata river, dwindle to 100 feet in Clinton county, and almost disappear on the Allegheny river and Beaver river waters. This brings almost into contact with the base of the Pottsville conglomerate (XII) the top of the Pocono sandstone formation (X) in western Pennsylvania; and caused the heavy conglomeratic sandstone strata in the upper part of X to be confounded with the conglomeratic sandstones of XII.

The *Garland conglomerate* in Warren county, the *Olean conglomerate* in McKean county, the *Panama conglomerate* in Chatauqua county, N. Y. and the *Salamanca conglomerate* in Cattaraugus county, N. Y. have been looked upon not only as local exhibitions of one and the same deposit, but as the common representatives (in a thin form) of the whole Pottsville Conglomerate formation (XII) of eastern and middle Pennsylvania.

§ 34. But it will be seen in the progress of this report that both of these suppositions have been mistakes, due to superficial observations at far distant and necessarily unconnected points. More elaborate, connected, instrumental surveys have placed clearly in light the true state of things, namely:

1. That the Panama and Salamanca conglomerates in the State of New York are different (and lower) formations from the Olean and Garland conglomerates in Pennsylvania.

2. That the Olean and Garland are two outcrops of one and the same conglomeritic sandstone deposit.

3. That this again is a different (and lower) formation from the Homewood conglomeritic sandstone of the Allegheny river and Beaver river valleys, defined as No. XII by the First Geological Survey of Pennsylvania in 1835-1841, but which is only the upper part of No. XII.

§ 35. Between the *Homewood sandstone* of Butler county, (underlying the lowest bed of the Productive coal series, and therefore the representative of at least the upper part of the great conglomerate) and the *Garland conglomerate* exists a vertical interval of more than 200 feet.

In this interval lie the Mercer group of coal beds and the Sharon block coal bed—the variable coal beds of Crawford county to be mentioned further on,—the thin coal beds north of the Allegheny river in Venango and Warren counties—and the most northerly coal beds of McKean county.

These intermediate groups of coal beds attain their best development in Mercer county; but they appear to be similar in physical character wherever they are found. They lie in "swamps," irregular in outline and uncertain in extent, and are often liable to "pinch out and terminate when least expected." They may be *locally* traced with considerable uniformity as to levels and position, but can seldom be relied upon as persistent over wide areas.

The interval in which these coal beds occur is occupied largely with sandy measures, and local layers of pebbles; changing frequently from conglomerate to sandstone and from sandstone to slate and shale; sometimes thin bedded, sometimes very massive; one bed fading out and another of a different character coming in.

§ 36. The Pottsville conglomerate, (XII, the Seral conglomerate of Prof. Rogers,) the recognized base of the coal measures in eastern Pennsylvania, is 1000 feet thick at

Pottsville, as said above, and cannot be looked upon as a solid homogeneous formation, but as a series, or group, of pebble-rock and sand-rock layers, separated by beds of coarse shale and slate, black slate, and coal. At the west end of the Pottsville basin it holds a number of small coal beds, and one—the Lykens valley bed—of great size and value.

It may very well be represented then in western Pennsylvania by the interval above described, extended to include the Homewood sandstone at the top, and the Garland conglomerate at the bottom,—an interval of full 300 feet in thickness, and with a character which closely resembles the description just given.

§ 37. It may be pertinently asked, therefore, why the Homewood sandstone at the top of this interval, should be regarded as the sole representative in the west of *the whole* of the Pottsville conglomerate formation No. XII in the east, seeing that the whole series of strata between the top of the Homewood and the base of the Garland has a general constitution imitating so closely the general constitution of No. XII in the physical character of its members or alternations?

In other words, why should not the *Garland conglomerate* be viewed as the bottom member of No. XII, and the Sharon and Mercer groups as *intra-conglomerate coals?*

c. *The Pottsville conglomerate described in 1858.*

For the convenience of the readers of this chapter, portions of the excellent description of the formation (No. XII) in eastern and middle Pennsylvania, by Prof. H. D. Rogers, in his Final Report of 1858,[*] is here appended.

§ 38. "At *Mauch Chunk* its thickness is about 950 feet.

"It is here composed of hard gray siliceous conglomerate in ponderous beds, coarse gray sandstones, sandy clay shales, and a few thin layers of fissile black coal, slate, and fireclay.

§ 39. "At *Tamaqua* its thickness is about 803 feet.

"Here it is an alternation of very coarse siliceous con-

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[*] Vol. I, page 146.

glomerate in massive beds, the pebbles of the size of an egg or orange down to that of a nut or pea; also of interposed coarse and fine gray sandstones, and here and there a sandy shale. There are also two or three imperfectly developed beds of coal in it.

§ 40. "At *Pottsville* its thickness is about 1030 feet.

"Here the rock contains a less amount of coarse conglomerate, a larger proportion of rough argillaceous sandstone, two or three bands of coarse shale, two or three beds of coal slate, and a very thin imperfectly formed layer of very slaty coal."

"It is divisible at Pottsville into three members.

§ 41. "The *upper division* of the formation, both in the Sharp mountain and around the Anthracite basins, generally has a more uniform composition than the beds beneath. Many of the more massive strata are composed solely of large pebbles of white quartz of nearly similar size and shape, packed together with great regularity. These are somewhat ovoid, smooth, or actually polished, and in close contact, their larger dimensions parallel with the plane of the bedding."

This would correspond with the *Homewood* sandstone of the Beaver river country, in western Pennsylvania.

§ 42. The *middle division* of the formation consists chiefly of thick irregular obliquely-deposited beds of a hard blue rock made up of quartz, sand, clay, and small pebbles of slate. In the Sharp mountain this part of the formation embraces beds of slate, almost identical with the slates which inclose the coal-seams.

"At least one bed of coal, sometimes of a thickness fit for mining, usually occurs in this division.

"Near the east end of the basin the thickness of this *middle group* is probably not less than 200 feet. It is the cause of the flatness of the summits of both the Sharp and Locust mountains throughout the range from Mauch Chunk to the Little Schuylkill."

This division would seem to correspond well with the *Mercer coal group* of western Pennsylvania, underlying the

Homewood sandstone and overlying the Connoquenessing sandstones. See Reports of Progress Q, QQ and V.

Or it may represent the entire interval of 200 feet between the base of the Homewood sandstones and the top of the Sharon conglomerate, and therefore include not only the Mercer coal group, but the next lower Sharon coal group.

§ 43. The *Lower division* is subdivided by Professor Rogers in another part of his Final Report* in the following manner:

"4. Chiefly yellow and white sandstones, with included layers of a grey grit, composed of pebbles of crushed slate . . .

"3. A coarse silicious conglomerate of large and irregular pebbles, chiefly of milky quartz, but with others resembling the Primal and Matinal slates; and a few of dark grey sandstone, of perhaps the same age . . . . .

"2. Massive beds of a conglomerate composed of quartz pebbles in a paste of disintegrated green slate. These beds also include layers of red shale. The thickness of this portion is from 10 to 20 feet. In the very lowest bands of this rock, especially those which alternate with, or are imbedded in, the upper layers of the Umbral red shale, this imbedding material is greenish, and sometimes quite yellow . .

"1. Yellow and grey sandstones, alternating with thin beds of *red shale*, identical with the Umbral red shale, and containing a few scattered quartz pebbles, some of which are large. This division, which exhibits a passage from the Umbral to the Seral deposits, is from 60 to 70 feet thick.

"At *Bear gap*, Wiconisco basin, it measures 460 feet.

"At this locality, and indeed in the outcrops of the base of the coal measures throughout the western part of the Wiconisco basin, the group consists wholly of coal measures, having lost entirely that preponderance of conglomerates and coarse sandstones which it contains throughout the Sharp mountain, and indeed in both borders of the Pottsville basin as far west as Dauphin. It possesses here even less of the Sharp mountain or conglomerate type than

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*Geol. of Penn., 1858, Vol. II, p. 21.

it exhibits in the Shamokin basin still further northwestward.

§ 44. "In *Shamokin gap* No. XII measures 630 feet.

In the mountain at the village of Shamokin, the lower or conglomeritic group of coal measures—restricting its limits, as we have done elsewhere, to the top of the hard rocks below the fifth seam of coal ascending, which is very generally the commencement of the softer coal measures—consists of an alternation of ribs of nut coarse conglomerates, pebbly and fine grained sandstones, with coarse shales and coal slates in about equal proportions. It is made up of five of the hard siliceous strata and four of the softer argillaceous, each of the latter including a bed of coal: some of these are of good quality and thickness.

§ 45. "In *Zerbe's gap* it measures about 500 feet.

"Here, at Treverton, we see the most natural section of the conglomeritic coal measures in the Shamokin basin. The mass consists of five ponderous strata of silicious conglomerate and coarse sandstone, and four thick beds of argillaceous shale and slate in regular alternation with them —the two kinds of rocks in about equal quantity. Each argillaceous member encloses a thick and valuable bed of semi-anthracite. In this western end of the Shamokin basin these coals of the conglomerate group are far thicker and of higher average purity than anywhere else in the corresponding part of the coal measures around the anthracite region.

§ 46. "Of the reduction in the *coarseness* of the conglomerate, as we compare it in its successive outcrops more and more towards the northwest, there is the amplest evidence. Passing from the Sharp to the Broad mountain on the north side of the same basin, there is a perceptible diminution in the pebbles, and an approximation to greater uniformity of size.

"Advancing to the outcrop of the Spring mountain, the conglomerate is seen at the notch or gap of Hazle creek with its pebbles considerably smaller, the beds of slate somewhat thinner and less numerous, and the sandstones and conglomerates less abruptly separated. The pebbles are more even in size, and are packed together with less of interposed sand.

"In the bituminous coal field of *Broad Top mountain* in Huntingdon and Bedford, the rock exists chiefly as a light grey coarse siliceous sandstone, with but little of the conglomeritic character. At Uray's hill, on the edge of this high plateau, it measures not more than 250 feet. And this estimate accords well with observations made at other places in the basin. In this district as in the anthracite basin, the rock embraces one or more beds of coal, showing that it is as elsewhere a part of the coal formation."

§ 47. It would be misleading to quote from the final report of 1858 the author's generalizations respecting the conglomerate in western Pennsylvania, because the facts on which they were founded have been virtually set aside by the closer examinations of that part of the State in recent years; but all that is quoted above stands good, no new facts having appeared to interfere with the abundant materials collected by the first survey.

d. The Sub-Garland sandstone.

§ 48. The importance of this *yellow sandstone* as an auxiliary in tracing the *Garland conglomerate* was not fully appreciated by me in 1875, and only after the work in other districts had sufficiently advanced to admit of comparison of sections on the east and west, did its true significance come to be understood.

§ 49. Both at Pike's rocks, which was the first exposure of Garland conglomerate surveyed, and at Snodgrass quarry, near which was the last or westernmost upon the line, as well as other exposures of it passed in carrying on the survey, this *yellow sandstone* was noted.

At Pike's rocks it lay about 25′ below the Garland conglomerate, if the water well record be correct; and at Snodgrass' quarries, 41′.

§ 50. An investigation of this yellow sandstone was not followed out at that time in either direction, except in a general way; the equivalency of the *Garland* rock with the *Olean* of N. Y. and with the conglomerate of northeastern

Ohio seeming to be satisfactorily assured by what had already been done. But in 1877, Prof White, extending his detailed survey of the Shenango river country to Jamestown, joined on to my section there, and identified my *yellow sandstone* with his *Shenango sandstone*, and my *Garland conglomerate* with his *Sharon conglomerate,* To him therefore belongs the credit of having first called attention to the importance of this sub-conglomerate sandstone.

§ 51. Meantime, explorations in Warren county by Mr. Chance, Mr. Randall, and myself had shown that a similar stratum of sandstone was traceable *beneath the Garland conglomerate* in that county; and Mr. Ashburner had also discovered it *beneath his Olean conglomerate* in McKean county.

§ 52. It thus seems to be a very persistent rock and coextensive with the carboniferous conglomerate on its northern outcrop.

§ 53. The two rocks may also be seen in more southern exposures at the *quarries at Franklin* and in the *bluffs at Oil City* in Venango county, in the *river hills at Warren*, at *Big Bend* in Warren county, and in several places in McKean county.

§ 54. The interval between the *Garland conglomerate* and the underlying *Shenango yellow sandstone* in these several exposures varies only between 25′ and 55′, but in some parts of Forest county and southern McKean the interval increases to 100′ or more.

§ 55. Facts then seem to warrant the conclusion that Prof. White's *Shenango sandstone*, my *Yellow sandstone*, Mr. Randall's *Sub-Conglomerate*, and Mr. Ashburner's *Sub-Olean* are merely different names for the same stratum, and there is a general sentiment among the geologists of the survey that in *this interval** are to be sought the representatives of the Mauch Chunk red shales of formation XI.

§ 56. The constitution of the rock in question (Shenango yellow sandstone) varies greatly in different localities. West of French creek it is a yellowish sandstone of medium grain; contains many pockets or balls of *iron ore* and clay; and often runs into beds of flags. Further east it assumes

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*That is between the Olean and Sub-Olean.

sometimes a conglomeritic character. Northeast of Warren it is often a homogeneous mass of pebbles of the size of wheat grains; contains much *iron ore* in irregular seams and balls; and frequently many fragments of *fish remains.* It weathers in small, irregular pieces; and when lying in the tops of hills forms a very characteristic terrace, surrounded by steep and regular escarpments; giving a hilltop the appearance of a truncated pyramid, or of some extensive earthwork fortification.

§ 57. Southeast of Warren this (Sub-Olean) rock takes on a more conglomeritic character, enclosing pebbles even an inch and a half in diameter. It here forms *rock cities*, the blocks of which are 40′ or 50′ in thickness. These are often in the near vicinity of *rock cities* made by the Garland (Olean) conglomerate; and the two exhibitions are then so much alike as to be geologically as well as geographically confounded.

§ 58. At least four characteristic features of composition however serve to distinguish the lower from the upper—the sub-Olean from the Olean—conglomerate.

1. The lower rock is conspicuously current-bedded, the face of the great walls of horizontal strata being crossed by multitudes of oblique lines, suggesting their deposit in rapid waters, the direction of the current being frequently changed.

2. The pebbles of the lower rock are remarkable for their flattened or lens-shape form; and the examination of many and distant localities by several independent observers has put beyond doubt this peculiarity. On the contrary, the pebbles of the upper rock, and generally of all the conglomeratic sandstones upwards, to and into the coal measures, have a round or rudely round or oval shape; and observation has shown that this also is true over wide areas of country, to whatever cause it may be assigned.

3. Fish spines and fragments of bones, and land plants, have been found in the lower rock in many places. And from the interval between the lower and the upper conglomerate, where it is fairly exposed in the vicinity of Warren, Mr. Randall has made a very large collection of fossils

of well known Waverly types which have been secured for the Museum of the Survey. But where the rock has been passed through in borings for oil, further south, fossils have not been noticed; partly, no doubt, because not looked for by the borers; partly because they are ground up by the boring tools; but chiefly perhaps because the deposit changes its thickness and composition in that direction.

4. The lower rock is deeply discolored with iron in all its seams and crevices; and the whole mass is evidently ferruginous; having a yellow and sometimes a brownish tint. Mr. White reports it in his district charged habitually with balls of iron ore to such extent as to induce him at first to name it the *Ferriferous sandstone.*

CHAPTER III.*

The Garland Conglomerate, and underlying measures in Warren county:—Pike's rocks; Freehold township; Garland; Spring Creek; West Spring Creek; McClay Hill.

Pike's Rocks.

§ 59. The dividing ridge between Little Brokenstraw and Stillwater creeks, in Sugar Grove township, Warren county, rises to an altitude of 1980′ above ocean level.

Several fine exhibitions of conglomerate occur on it, the most remarkable one of which is called *Pike's Rocks.*

§ 60. This is a huge mass of conglomerate, broken and fissured, irregular in outline, and covering an area of about two acres. It presents mural exposures on all sides, and looks in the distance, whatever point of perspective may be chosen, like the ruins of some Cyclopean structure built by a pre-historic race.

§ 61. Unlike other *Rock cities*—most of which rest on wooded eminences obscured from distant view, or run as an escarpment of rock along the crest of some dividing ridge—these rocks stand out in bold relief against the sky on the summit of one of the highest hills of the country, surrounded by well-cultivated fields, stretching from the base of the rocks over gracefully rounded hillsides into the valley below.

The rock-walls rise about 30 feet in height—perpendicular or overhanging, and weathered into fantastic profiles. Avenues wind in all directions through the ruins, and pebble-covered slopes lead over natural arches to the summits.

§ 62. The whole rock is a massive conglomerate from top to bottom, but very uneven in composition, and irregular in structure. Here a layer of three feet of clear pebbles,

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* Report of work done in 1875.

white, coarse, and occasionally as large as hens-eggs, with scarcely enough of sand-matrix to hold them together—there a stratum of finer conglomerate, and a larger percentage of sand; here oblique bedding in one direction—there in another.

The disintegrated pebbles and sand-grains spread all around the base of the exposure like a sea-beach, and become, when screened, valuable for masonry.

§ 63. A zone of warm, sandy, pebbly soil encircles the rocks, beyond which the land becomes more cold and clayey.

From the top no hills can be seen as high as this one except to the southeast and one to the northeast.

Several pine-stumps two feet and a half in diameter remain on the bare summit where there is scarcely a foot of mould—their roots penetrating deep into the fissures and reaching over the naked rock. Some 30 or 40 large pines are said to have grown upon and immediately around the rocks, the only trees of the kind in the vicinity.

§ 64. *The Sub-Garland yellow sandstone.*—Within 30 rods of these rocks and about 15 feet below their exposed base a well was recently sunk for water by Mr. J. S. Jaquay, which passed down through 10 feet of drift clay and then 32′ of coarse *yellow sandstone;* water here came in and stopped the workmen before they reached the base of the sandstone. The water is good but somewhat roily and liable to fail in dry weather.

In blasting the rock in the well it was found to be full of crevices running in a northeast-southwest direction, one of them ten inches wide and eight feet deep. These fissures doubtless prevent the water from being constant, as it has an opportunity of flowing freely through them to appear in copious springs, along the base of the sandstone, lower down the hillside, leaving dry the upper portions of the rock in seasons of long continued drouth.

The *Yellow sandstone* (according to Mr. Hoppins who lives near by and has sunk a great many water wells in this section of the country) is found on all of the high ridges, resting upon a "blue, hard, flaggy sandstone or slate." Unlike the conglomerate above it, it is not reliable for affording water. Wells sunk a few feet in the "blue bed rock," however, universally furnish a never failing supply, and that of good quality.

§ 65. *Chemung shales* underlie the yellow sandstone and exhibit themselves in the road gulleys and side ravines, in spite of the fact that the whole of this country is covered to considerable depth with Drift-clays, principally local, or derived from the glacial abrasion of the country rocks. The bedded rocks wherever exposed beneath the clay consist of characteristic Chemung brown and olive shales, wave-marked, and inclosing fossil shells, and fucoids.

§ 66. *Drift heaps.*—It is a noticeable feature here, that the bed-rock appears nearer the surface on the northerly slopes of the hills than on the southerly. (See § 78.)

It is also noteworthy that the southerly ends of ridges, at the confluence of streams flowing south, are almost always covered with heavy deposits of rather angular remnants of the local rocks, intermixed with foreign Drift.

These accumulations suggest the idea that the mingled drift has been brought down the valleys in separate currents and thrown off their margins, as they closed around the point to fill the one channel below.

Lottsville rock city.

§ 67. In Freehold township, on a bold spur between Swamp run and Little Brokenstraw creek, about half way between Lottsville and Wrightsville is another Rock city of conglomerate, in plain sight of and almost equal in extent to Pike's rocks.

This is the most northern *Garland* outlier in the western part of Warren county.

A line drawn from this point to Spring Creek station on the Big Brokenstraw would very closely define the northwestern limit of the rock.

Considerable bodies of it lie in the ridges to the southeast and in some places quite continuously.

Our profile shows it on the State road between the two Brokenstraws and again between Little Brokenstraw and

Stillwater creek; but beyond this range to the northwest it has all been swept away.

Garland quarries.

§ 68. The Garland quarries are found on the crest of the ridge between Blue Eye run and Big Brokenstraw creek, about one mile northwest of Garland, in Pittsfield township, Warren county.

The base of the rock, where worked, lies 480′ above the Philadelphia and Erie railway track, or 1810′ above tide.

The summit of the ridge is 55′ higher, *i. e.*, 1865′.

§ 69. Two quarries are opened here, both of which lower their material to railroad level by gravity cars, operated by wire cables, over steeply inclined tram-ways. But although there is no lack of good stone, and the shipping facilities cannot be surpassed, very little is being done at present (1875) at either one of them.

§ 70. The sandstone is 40′ thick; massive; coarse-grained; obliquely bedded; colored yellow and white in some parts, iron stained in others. Pebbly horizontal layers and pockets occur; and the pebbly layers seem to recur more frequently near the base; but it can hardly be said that the lower portion is uniformly conglomeritic, or the upper portion a consistent sandstone.

The rock works remarkably free when fresh from the ledge, being soft, and easily dressed into any desirable shape; but it hardens on exposure to the atmosphere into a durable building-stone, useful, when a proper selection is made, for all architectural purposes.

§ 71. *Fallen masses.*—The face of the cliff overhanging the Brokenstraw valley at this point has been undermined, and huge blocks, 40′ in thickness, have become detached from the brow of the hill and been arrested in all attitudes in their descent to the stream below; some standing on edge; some turned completely over. Those that stand on edge are easily split in the lines of deposition, and therefore preferred by quarrymen to the rock in place above.

§ 72. *Fossil tree.*—On one of these half revolved blocks, where the free side has been split off, is visible the impression of a carboniferous tree stem, 8 inches in diameter and 12 feet long. The surface markings being too imperfect to indicate its species.

It is evident from an inspection of the fossil that this tree stem was stranded on a sandy shore or sandbank, and caused an eddy in the current which deposited coarse, gravel on one side of the tree to the distance of a foot or more, while on the other side of the tree only fine sand is seen. The cast of the tree body is composed principally of fine sand.

Now if the exact position of this mass of rock before it was displaced could be discovered, then the direction of the current which stranded its fossil log might be ascertained from these circumstances with considerable accuracy.

§ 73. *The Sub-Garland yellow sandstone* seems to be poorly developed at Garland, a thin band of fine pebble conglomerate being all the representative of it that could be found; but as the talus from the upper rock obscures its horizon it quite possibly may have been overlooked.

§ 74. *Garland section, Fig. A, page* 31.—On the point of the bluff, about 80 rods west from the Philadelphia and Erie railway station at Garland the following section was obtained; and it possesses peculiar interest as being the only observable exposure, in the six miles between Garland and Spring creek station, of a massive sandrock of any considerable thickness occupying the interval between the conglomerate and water level of Brokenstraw creek:

Shale, blue and brown, sandy, 1365′,	15 ′	to 1350 ′
Sandstone, weathering brown, a mass of *spirifers*,	2 ′	to 1348 ′
Shale, brown,	5 ′	to 1343 ′
Sandstone, fine-grained massive, grey,	10 ′	to 1333 ′
Shale,	½′	to 1332½′
Plate of sandstone with *fossils*,	½′	to 1332 ′
Shale, fissile, brown and blue,	18 ′	to 1314 ′
Thin sandstone with spirifers,	½′	to 1313½′
Shale to R. R. level,	2 ′	to 1311½′
Concealed to creek level about,	18½′	to 1293 ′

§ 74. On the *Cotter farm* about one mile above this point may be seen a clean exposure at this horizon in which no massive sandstone appears. The section there is as follows, descending:

Rocks concealed.	
Flaggy sandstone, (1385′ above tide,)	5′
Shale, brown and olive; upper half somewhat sandy· lower half argillaceous and fissile,	50′

The elevation 1385′ seems to be too high to permit this flaggy sandstone to represent the sandstone at Garland.

§ 75. *South of the Brokenstraw* the valley hills are generally capped with conglomerate. In fact it may be said to extend in almost an unbroken ridge (with the exception of the low divide between the heads of Caldwell creek and Mullingar run) but at varying distances from the creek, all the way from Thompson's station on the Allegheny river, to the high bluff-point at the junction of Spring creek with the Brokenstraw, beyond which, to the northwest, it is not to be found, as the hills are not high enough to hold it.

§ 76. *Horn's cliffs.*—About three miles northwest of Garland, cliffs of Garland conglomerate rise from the south bank of the Brokenstraw, near the residence of Mr. C. Horn, and they are similar to those at the Garland quarries on the north bank. The rock is here at least 30′ thick; white, fine-grained, solid, and with no appearance of pebbles. A little back of the brow it is covered to the depth of ten or fifteen feet with surface deposits sustaining a heavy growth of pine, hemlock, beech, maple. and other woods.

*Spring Creek.**

§ 77. The junction of this stream with the Brokenstraw forms a broad basin bounded by hills. Terraces or foothills of *Drift* on each side of the basin and extending some distance down the Brokenstraw, indicate that the water level some day has been at least fifty feet higher than at present. The stream has cut down through this Drift in changing channels, now sweeping to this side now to that, leaving islands or mounds scattered all about the bottoms. These mounds are composed of coarser and less water-worn materials than the Drift found at lower levels along the margins of the present streams. They have been covered

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* See Plate 3B.

with a forest of immense pines; some of the stumps still remaining measure from 3 to 4 feet through.

§ 78. *An accumulation of Drift*, such as described in § 66 above, occurs at the junction of Dry run on the north side of the basin, on the point of the nose between the two streams. It has been quarried for railroad ballast, and the excavation shows a large percentage of northern rocks, among which are frequent gneissic bowlders a foot or more in diameter.

§ 79. *Erosion.*—There are good reasons for inferring that the stream once flowed through this basin at a level considerably higher than its present bed.

§ 80. *Buried valley.*—There are equally conclusive proofs that it has also flowed at a much *lower* level. For, an oil well on the Cotter farm was carried down nearly 200′ through gravel and clay before reaching bed rock; and one at Spring Creek station, 137 feet. Within 20 rods of the last named well a trench was dug, but a few feet deep, for a mill foundation and yet the walls were laid upon the stratified rocks in place.

This interesting feature of old filled-in channels is noticeable in all the broadly eroded valleys of our northern streams where oil wells have been sunk. But when the valleys in going southward become narrow and the streams enter the deep cuts between the *conglomerate-capped* hills, the bed rock is always found nearer the surface.

§ 81. *Fossils.*—*The measures beneath the Garland conglomerate* in all this section of country may be briefly described as blue, olive, and brown shales, with occasional thin bands of grey and yellowish sandstone. The most common fossils are *Fucoids* and *Spirifers*, with less frequent specimens of *Productus*, *Cypricardia*, and *Aviculopecten.*

West Spring Creek.

§ 82. The little settlement of West Spring creek is located in the broad drift-filled valley of Spring creek where it is joined by the West branch, about 3 miles above its confluence with the Brokenstraw. The "bottom lands" here are some 80′ higher than those along the Brokenstraw. A mill-pond lies on either side, near the base of the inclosing hills and the dwellings are built on the triangular flat between the two streams.

§ 83. *Water wells.*—A rather remarkable feature is noticed here in connection with the water wells. They are sunk to a depth of 30′, through coarse gravel, to a point at least 15′ below the surface of the mill-ponds; and yet it is affirmed that the water in the wells never rises to the level of the ponds and seems to be in no way affected by them. In dry weather the most shallow of these wells fail, the ponds being still full of water, but on being sunk deeper in the gravel a good supply of water is always found.

These facts seem to indicate a drainage of the gravel beds through the lower levels of the Brokenstraw gravels independently of the ponds and streams at the surface.

§ 84. *Bates' Section.*—In the face of the bluff, south of the residence of F. Bates, and about one mile and a quarter northeast of West Spring creek, may be seen a fair exposure of rock in place for about 240′ above water level.

Bluish shale, (at the top as far as seen,)	30′
Thin-bedded, shaly sandstone,	50′
Conglomerate, fine-grained, in layers 2″ to 4″ thick; pebbles firmly cemented, apparently by some lime-iron solution,	2′
Sandstone, yellowish brown, fine-grained, micaceous, massive,	5′
Shales, bluish-gray, argillaceous, with occasional sandy layers approaching to thin sandstones,	150

§ 85. *Section at Johnson's saw mill,* on West Spring creek. See Fig. B, page 31.

	Top of observations above tide,		1477′
1.	Shale, (concealed above,)	10′ to	1467′
2.	Sandstone, with shale partings,	6′ to	1461′
3.	Shale, brown,	3′ to	1458′
4.	Sandstone, in thin layers,	5′ to	1453′
5.	Shale, brown,	4′ to	1449′
6.	Sandstone, brown, laminated,	2′ to	1447′
7.	Shale, brown and blue,	6′ to	1441′
8.	Sandstone, pebbly, contorted, *coal films*,	2′ to	1439′
9.	Sandstone, brown,	1′ to	1438′
10.	Shale, brown,	1′ to	1437′
11.	Sandstone, yellow, rather massive,	6′ to	1431′
12.	Sandstone, greenish, soft, friable, almost crumbling in the hand when wet. This sandstone probably		

SECTION AT JOHNSON'S SAW MILL.

Fig. A.
abv. Garland.

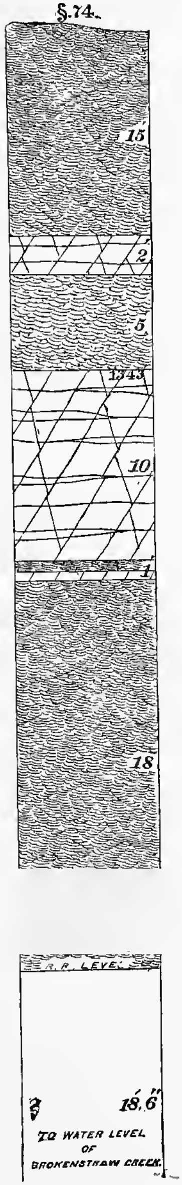
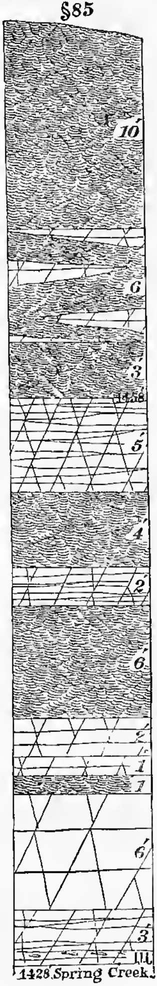


Fig. B.
Johnson's Mill.



extends below water level. It contains many fossils, among which Mr. Hall recognizes *Sanguinolites*, *Cardiomorpha*, and *Productella*. It also smells strongly of petroleum, and when crushed and dropped into water the iridescent colors, which constitute a "good oil show," are abundantly manifest, ... 3′ to 1428′

13. Water level below mill dam, (above ocean,) . . . . . 1428′

§ 86. *False coal.*—Several hundred dollars have been expended here in a vain search for coal. The "coal blossom," which was supposed to lead to a larger deposit beneath the hill, was seen in very thin films in the outcropping rocks along the creek bank, at 1439′ in the section.

Knowing that this horizon is at least 400 feet vertically beneath the Garland conglomerate, it needs but a slight examination of the situation to satisfy one that the "blossom" will not ripen into desirable fruit.

The stratum in which it is found is a gnarled conglomeration of clay, sand, pebbles, fossil mollusks, and thin masses of carbonized *plants*. It has every appearance of being a sea-shore drift containing just sufficient vegetable matter here and there to form slight films of coal. There is no under-clay, and no indications in any of the surroundings that could reasonably warrant the expectation of finding a paying coal bed. It is merely a local exhibition of vegetable matter, which cannot be traced far in any direction.

§ 87. *Hosmer run oil.*—The sandrock at water level, 1431′ to 1428′, appears to be deserving of more attention. From its position and elevation it may be supposed to have some connection with the Hosmer run oil rock, the ancient oil-pits along that stream being only about three miles to the southeast. This exposure may possibly represent, also, the northwestern outcrop of the *First oil sand* of Venango county. Still it is not to be presumed, judging from the experiences of operators on Hosmer run, in 1865, that the "oil show" here will lead to any very profitable results.

§ 88. *Are the oil sands Chemung?*—The presence of carbonized *plants* and films of coal in the section above given is good evidence that coal plants were flourishing within reach of the drifting currents at the time these strata were forming; and it would appear, also, from the peculiar character of the rock containing these evidences, that it must have been formed along the margin of some dry land. If, now, this sandstone *be* the equivalent of the *First oil sand*, these facts suggest an inquiry, rendered pertinent, also, by many other considerations to be noted hereafter:—Do the Venango oil sands belong to the Chemung period, or are they of more recent age?

§ 89. On *McClay* hill, the summit between Spring creek and West Branch, one mile southwest of West Spring creek, the *sub-Garland yellow sandstone* is in place, but so drift-covered as not to be noticed, except in sinking water wells. Large gneissic bowlders, with occasional blocks of sandstone, lie thickly strewn on its northeastern slope.

§ 90. *Fish.*—Here, in a bowlder of pea-conglomerate, a good specimen of *Ctenacanthus triangularis* was found by Mr. Hatch, the only one I have ever seen in so coarse a conglomerate.

The county line (Warren-Crawford) is but a short distance west of this hill.

CHAPTER IV.*

The Garland conglomerate and underlying measures outcropping in Crawford county—at Bates' hill; Southwick's summit; Hickory corners; and around Meadville;—with notes upon the drift.

§ 91. *The Survey line.*—Between McClay hill and Meadville the State road passes over but two or three elevations capped with the sandstones of the Garland conglomerate, the most conspicuous outliers being found a short distance to the south of it. It was our intention to run side-lines to connect these exposures with the profile, but time did not permit. There is sufficient rock in place, however, near the road, to assure the accuracy of general results; and

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*Report of work done in 1875.

where the sandstone is wanting, or its exact position obscure, we may be assisted in no small measure by a study of the characteristics of the landscape around us. The topography of the country the position of its springs, the composition of soil and the species of indigenous trees growing upon it indicate the lines separating soils derived from sandstone and soils derived from shale almost as unerringly as any system of leveling with good exposures could do; even in situations where considerable bodies of drift are present.

§ 92. *Bowlders.*—All across Crawford county erratic bowlders of gneissoid rocks, from 2′ to 6′ in diameter, are scattered along the road, and they spread out to the south as far as the ridge before referred to as the southeasterly watershed of Spring creek and Hyde creek. Approaching the Ohio line and in eastern Ohio they become more rare. No doubt they have been also deposited in quantity there; but the country is more thickly settled, building stone is not plenty, and they have consequently been broken up and removed.

Bates' hill.

§ 93. About one mile and a half southeast of Spartansburg, near the residences of A. Bates and J. Eastman a summit rises to an elevation of 1800′ above ocean. Large blocks of conglomerate and sandstone lie scattered on the slope facing the east, and smaller ones may be seen on the westerly side descending toward the east branch of Oil creek. The true position of the conglomerate is somewhat obscure; but the yellow sandstone, here a flat pebble conglomerate, caps a large portion of the ridge. It is found in water wells and the outcrop may be seen along the road coming from the east about 45′ feet below the summit. In several places both on its eastern and western slopes the under-shales are exposed at frequent intervals, being plainly of the same character as those seen at this horizon, elsewhere along the line, and containing similar fossils.

§ 94. From Bates' hill towards the southwest the hilltop levels fall to about 1600′ and then to 1500′ or less, and none of the ridges passed over by the State road are high enough to catch the conglomerate until the College Hill ridge east of Meadville is reached. We are compelled therefore to look to the south for an intermediate exposure to make the connection more continuous.

Southwick's summit.

§ 95. *Knob.*—In Richmond township, on the divide between Muddy creek and Woodcock creek, two miles south of New Richmond, rises a sharp knob of sandstone, the peak covering only about two acres. The sandstone is very similar in appearance to the Meadville rock, except that no pebble stratum is exposed in place. It is white and yellow, and contains small concretions of iron, by which it is discolored in some of its members. Three or four massive layers are exposed, having a thickness in all of about 30 feet.

§ 96. *Fossils.*—A few fragments of *Sigillaria* and some unrecognizable impressions of matted masses of long, narrow leaves were the only traces of fossils seen.

§ 97. *Drift heaps.*—On the northerly face of the peak the sandstone has been so cleanly swept away that its presence is only indicated by a drift-covered escarpment showing no traces of sandrock upon it. But on the south the conditions are quite the reverse; ledges of the rock are exposed and large blocks lie scattered over the surface of the slope, down to the stream below.

§ 98. *Stoss side and tailings.*—These facts are but the repetition here of notes made under similar circumstances in many other places; and their recurrence so often in my note-book leads me to confidently expect as a general rule that, where a hill top is but just swept bare of conglomerate, large blocks of it will almost invariably be seen on the southerly slopes, while very few will be found on the northerly. If some portion of the conglomerate is still in place the northern face will be abrupt and comparatively free from fragments, the southern sloping and covered for a long distance below the ledge with broken masses from the outcrop. With the erratic foreign bowlders, however, the conditions are reversed; more of them are found on the northerly slopes than the southerly, although they are in some situations quite thoroughly intermixed with the local sandstones. Do not these facts point to the probable action of the same agencies in both cases? Did not the ice-currents from the north bring down these erratics to be stranded on the northern slopes at the very time they were dislodging and slipping the local sandrocks to the south?

Hickory corners.

§ 99. *Knob.*—Two miles and a half southeast of Southwick's lies another sandstone-capped hill of about the same elevation of summit. It is on the west side of Woodcock creek, near the north line of Randolph township. No very noticeable outcrop occurs here, but local exposures of coarse *yellow sandstone* are quite frequent.

§ 100. *Coal.*—About 30 feet below the summit a seam of coal 16 inches in thickness is reported to have been found. It has been seen in a number of water wells, and is said to lie in the sandstone without any shale or clay above or below it. This I believe is the most northerly point in Crawford county where *coal* is known to exist. It occurs, however, at a number of places to the south, in Randolph, Mead and Wayne townships, but in no locality has it yet been found of sufficient importance to be extensively mined.

Meadville.

§ 101. *College Hill*, a mile and a half northeast of Meadville, contains a broad thick cap of conglomerate and sandstone, the highest point of which (at *Ellis' quarry*) is 1558′ above ocean level.

The elongated summit, from its northerly slope throws its drainage into tributaries of Woodcock creek, and from its southerly into Little Sugar creek; while to the west several small ravines find a direct outlet into French creek. The preservation of conglomerate upon it no doubt is due to its peculiar situation in relation to the denuding currents which have so cleanly swept the country to the east and west of it.

§ 102. In ascending this ridge from Blooming valley, the State road rises to the top of the conglomerate and continues above it, across an almost level plateau, for a mile and a half, until the westerly slope towards Meadville is reached. To the southeast the conglomerate extends irregularly, according to the circumstances of erosion, to a distance of perhaps a mile, and to the northwest in some places nearly as far.

§ 103. *Quarries.*—The old *Ellis qarry* (now Thorp's) is at the northeasterly point of the rock; *College Hill quarry* (Carroll's) at the northwesterly point; and *True's quarry*, near the State road, as it begins its descent into Meadville. Besides these well-known openings, the rock has been worked less extensively in several other places.

Ellis or Thorp quarry.

§ 104. From this quarry the stone used in constructing the new court house at Meadville was obtained.

About 25′ of rock is exposed, and the bottom has not been reached.

The upper 10′ may be called a ferruginous sandstone; it contains many iron-nodules and clay-filled cavities coated with iron, among which are remnants of *Calamites*, *Lepidodendron*, *Sigillaria*, and also imperfect impressions of broad flat leaves.

The under part is more homogeneous in structure, and contains less iron, which is evenly disseminated through it.

It is a massive, coarse-grained sandstone throughout, but divided into bands of varying thicknesses by well-defined lines of bedding, which are beautifully and distinctly *ripple-marked.* These ripple-marked surfaces are generally oxydized more or less, and the furrows appear to run at right angles to the dip of the rock, which is to the south-southwest as nearly as could be ascertained here and in the other quarries.

The color of the rock is remarkable, being a purplish-pink and yellow, blended in clouded or watered lines, making when dressed a style of graining, as it were, resembling that of chestnut wood. It is a beautiful stone when first worked, but weathers dark and somewhat rusty from the oxydation of its contained iron. Still it is durable, and highly esteemed for architectural purposes.

No conglomerate layers are seen.

Elevation of top of quarry, 1558′.

§ 105. *Glacial scratches* were noticed at this quarry (and again on the State road) running in a southerly direction, corresponding with the trend of the easterly outcrop of the conglomerate.

College Hill quarry, (*Carroll's*.)

§ 106. The most northwesterly outcrop of congloméritic sandstone occupies a narrow ridge, on each side of which a number of openings have been made.

Carroll's quarry lies almost at the extreme point where the rock shows 35′ thick.

Elevation of the top, 1530′.

Here it is a massive, yellowish *coarse-grained sandstone*, somewhat discolored by iron, and irregular in constitution and structure, which causes it to quarry in cuneated masses difficult to work, and entails a large amount of wastage. Still, when the rough blocks are reduced to shape they make a good lasting stone.

Toward the bottom of the ledge are layers and pockets of *conglomerate* which are sometimes little more than beds of closely compacted pebbles, readily dug up with a pick, and utterly worthless for mechanical purposes.

§ 107. About 400′ in a southeasterly direction is another opening, showing 25′ of massive sandstone, the bottom portion of which is a beautiful, white, even-textured and rather fine-grained sandstone, admirably suited to monumental work. Some blocks have *small white pebbles* sparsely scattered through them, but they do not in the least detract from the beauty or value of the stone.

§ 108. Beyond this a few hundred feet and still going southeast, a small opening shows a very different* and quite

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* It will be observed that irregularity of structure, variation in color and rapid changes from conglomerate to sandstone, and *vice versa*—are conspicuously shown by a study of the several quarries upon this ridge, and there can be little doubt but that similar circumstances have conspired, in many places, to produce similar results; in all the sandy members of the carboniferous age. The pebbles in all the conglomerates, here are of the ovoidal type.

inferior rock, it being in some parts only a series of thin, warped plates of *micaceous sandstone* from half an inch to two inches in thickness; and all of the rock exposed here is obliquely or *current bedded* in a very curious manner.

True's quarry.

§ 109. On the southwesterly brow of the summit, overlooking Meadville, and but a few rods north of the State road, a very good and accessible rock is worked.

It is a massive yellowish-white sandstone, sometimes clouded, *almost free from pebbles*, and works easily into any shape desired. The face of the cutting measures 12 feet, but probably the bottom has not been reached.

§ 110. *Water-beds.*—On the lot of Benjamin Newell, across the road from Mr. True's, and at an elevation of 10′ above the top of the quarry, a water-well shows the following section:—Drift clay 8′; coarse *yellow sandstone* 16′.

At a depth of 24′ a horizontal seam was found, beneath a thin conglomerate, containing *loose pebbles* and an abundant supply of good water. As this well is not far from the southwesterly escarpment of the conglomerate, now obscured by drift, it may be presumed that these crevices and *pebble-paved water courses*, owe their origin to a slight displacement and slipping of the rock before its ragged edges were covered.

Meadville section.

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§ 111. A section made at Meadville, descending from Trues quarry by way of the ravine east of Greendale cemetery, reads as follows:

Sandstone, (exposed top, 1526′,)	12 to 1514
Concealed to ravine,	134 to 1380
Shale, bluish-grey,	50 to 1330
Sandstone, thin-bedded,	5 to 1325
Shale, sandy,	5 to 1320
Sandstone, thin-bedded,	10 to 1310
LIMESTONE, sandy, impure, weathering in rectangular blocks with desquamated edges,*	2 to 1308

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* This is probably J. T. Hodge's limestone referred to by Prof. Rogers in Geol. of Penn'a, 1858, Vol. I, page 584. It is Mr. White's *Meadville limestone* of Report QQQ, note p. 61.

Sandstone, blue, in layers 1″ to 2½″ thick,	5 to 1303
Shale, blue, with thin layers of sandstone,	23 to 1230
Concealed,	30 to 1250
Sandstone in thin plates,	5 to 1245
Flags, blue, sandy,	5 to 1210
Shale, blue,	10 to 1230
Concealed to railroad level,	150 to 1080

This section gives a fair exhibition of the *general character* of the strata exposed above water level at Meadville.

In traveling up and down the ravines in the neighborhood, no good and continuous exposures can be seen, but we get glimpses here and there of a few feet of rock in place at various elevations, and may judge of the quality of the intermediate strata by the topography, and the manner in which the erosive agents have worked upon them. The *arenaceous limestone* was not noticed in any other locality than the above, but the measures at this horizon give evidences in many places of containing a greater amount of sandy material than those above or below them.

The *Sub-Garlandyellow sandstone*, which should occupy the interval beneath True's quarry, was not seen in the vicinity of Meadville, unless it may be the rock exposed on Kycenceeder hill west of French creek. A very hasty examination of this point left it in doubt whether the stratum seen there should be correlated with the Garland conglomerate, or with the underlying sandstone.

Citizens' oil well.

§ 112. In 1872 a well was drilled for oil in Meadville, located between North street and Mill run, on a lot belonging to D. Morris, about one mile southwest of True's quarry.

It commenced at an elevation of 1135′ above tide, and was driven down to a depth of 1104′, or to within 31′ of ocean level.

No detailed register was kept, for the reason (as stated by the drillers) that the strata were so homogeneous that there seemed to be nothing noticeable to record; but Mr. Frederick Metzer, one of the owners and managers, confirmed the following particulars obtained from one of the men who worked on the well:

Conductor, 8′.

Water cased off effectually at 108′.

Gas at 450′ in sufficient quantity to fire the boiler during the rest of the drilling.

Well pumped at 1000′, and a good show of oil obtained.

Then drilled to 1104′ and again tested, with no show of oil. Gas considerably weaker on the last test, and not enough to pump the well.

The drilling was "shelly" down to 450′, but no sandstone (more than 4′ thick) was passed through at any point.

"Below 450′ nothing but soft shale and slate—no sandstone—no increase of gas—no oil."

§ 113. *Fossils.*—Mill run cuts down to bed rock, opposite the well, and flows over a blue sandy shale, in some places changing into warped plates of false-bedded, thin-bedded, argillaceous sandstone, traversed by *mud furrows*, thoroughly *ripple-marked*, and containing, in some layers, *fossils in great abundance.*

§ 114. Supplementing the above section at Cemetery run with these facts, obtained from the oil well, we may get a very good general idea of the character of the measures at Meadville extending down 1500′ below the conglomerate.

Meadville reservoir Drift deposits.

§ 115. The surface of the country about Meadville is covered with heavy deposits of *Drift*, even to the tops of the hills, and many rounded and smoothly worn *Erratics* of metamorphic rock, from 2′ to 5′ in diameter, lie scattered at all elevations along the hillsides.

§ 116. The new reservoir is located on one of these drift deposits, on the west face of College hill, on a ridge between French creek and a small stream which rises near the Carroll quarries, and runs in a southwesterly direction into Mill run.

It is said to be 315′ above French creek, or about 1385′ above ocean level.

The excavation was made 20′ deep in a clay drift thickly filled with *gravel* and *bowlders*, the bottom being blue and black *clay*, with occasional small fragments of rocks, angular and unworn, and evidently of local origin, as compared with those in the upper part.

The only bed rock seen was a blue sandy shale, and this was just touched in excavating for the construction of a drain from the bottom of the reservoir into the stream aforesaid.

117. The following notes in relation to the Meadville quarries were made by Mr. H. M. Chance in 1877.

True's quarry 12′ rock exposed, top at		1526′
College Hill quarry, top at		1530′
35′ rock exposed,: contains conglomeritic patches and layers. Mainly composed of massive and coarse, yellow sandstone, to		1495′

Quarry 300′ south of College Hill quarry, top at		1522′
22′ rock exposed, viz:		
Coarse, conglomeritic sandstone,	12′	
Conglomerate,	3′	
Coarse, greyish sandstone,	7′	
	— 22′	to 1500′

Quarry 500′ E. by S. from College Hill quarry, top at		1525′
Sandstone containing layers of conglomerate,	10′	
Coarse, grayish-yellow sandstone,	8′	
	— 18′	to 1507′

The rock here is very massive, but in the northwest end of the quarry the bed underlying the conglomeritic portion is very strongly false-bedded. The false-bedding is at an angle of about 30° to the true bedding, but the false bedded portion is not separated from the bed above by any bed-plate.

Quarry 100′ E. by N. of latter quarry, top of rock,	1533′
25′ rock exposed, to	1508′

In the bottom of this quarry a very white rock was found.

Ellis quarry, top of rock,		1558′
Coarse-grained ferruginous sandstone,	10′	
Tolerably good quarry stone,	7′	
	— 17′	to 1541′

Garland sandstone in College hill,	40′	to 1495′
?	168′	to 1327′
Flaggy, thin bedded sandstone beds, 1″ to 3″ thick,	6′	
Massive but flaggy sandstone,	2′	
?	8′	
Flaggy, gray sandstone,	8′	
	— 24′	to 1303′
?	223′	to 1080′
Railroad level, Meadville, A. and G. W. R. R.,		1080′

CHAPTER V.*

The Sharon coal, Garland conglomerate and under-rocks, southwest of Meadville, through Crawford county, into Ohio.

East Fallowfield township.

§ 118. Southwest of Meadville, the broad erosion of *Conneaut outlet* has left little to note in connection with the conglomerate, until the high ground which forms the easterly water-shed of *Crooked creek* is reached.

§ 119. *Levels.*—To economize time, therefore, we intermitted levels at Meadville and *commenced again at Evansburg station* on the Atlantic and Great Western railway, two miles southeast of *Conneaut lake*, running thence south, for 5½ miles, along the highway passing through nearly the centre of East Fallowfield township; and then, turning west along the road leading directly to *Atlantic station.*

§ 120. *Profile.*—As this interval contains a number of *quarries* and *coal beds* of special importance in studying the characteristics of the lower carboniferous sandstones, we give a profile section, to assist in understanding the notes to follow.—(See Plate 3*A*.)

The profile is drawn on a north and south line which would pass very near to all the quarries and coal beds mentioned, some lying a little to the right and some a little to the left.

Miller's quarry.

§ 121. This is the starting point of the profile, half a mile north of the railway station.

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* Report of the work of 1875.

Elevation of top above ocean 1303′.

Thickness of rock quarried more than 15 feet.

The principal part of the stone used in the old canal constructions at the foot of Conneaut lake was obtained here.

Only a few feet of soil overlies the ledge, which forms a broken escarpment of considerable length, facing the west, and thus the sandstone is very accessible, and easily wrought into blocks of any size.

The rock is rather coarse grained, massive, somewhat irregularly bedded, of a yellowish color, weathering brown, and contains some iron concretions, not only in the bedding and seams, but in the solid sand also.

§ 122. *Fossils.*—Near the top is a stratum a foot thick *rich in fish spines*, *bones* and *teeth*. No carboniferous plants seen and no conglomerate. This seems to be the *Sub-Garland yellow sandstone* stratum.

§ 123. *Coal beds* are noted at three points on the profile—on the Mushrush farm, 1¼ miles southeast of Miller's quarry; —on the McEntire farm 1½ miles south of Mushrush's; and on the Hazen farm 2¾ miles south of McEntire's. At none of these places have excavations been sunk to the base of the sandrock beneath the coal, and its outcrop lower down the hillsides is so obscured by Drift that its thickness cannot be definitely stated.

Mushrush farm.

§ 124. *Coal Pit section*, on the east side of the road nearly opposite the dwelling house.

Top of hill,		1336′
Surface soil,	1′ 6″	
Sandstone,	7′ 0″	
Shale, fawn color, friable,	3′ 6″	to 1324′
Coal, upper part slaty,	3′ 0″	to 1321′
Fireclay, indurated,	2′ 0″	to 1319′
Sandstone, thickness unknown but bottom not reached in a shaft near by at (1336-40,)		1296′

§ 125. *Quarry.*—Many years ago an opening was made a few rods east of the coal-pit, and at about the same level. The rock was found to be not as good as Miller's and much harder to work. It is a white hard sandstone full of contorted masses of *Calamites* and other carboniferous plants.

It is said that thin *coal* beds were found *in* the sandstone sometimes pinching out between two layers and sometimes stopping abruptly as against a wall.

The rock is very uneven in composition, being firm and massive in one place, thin-bedded and broken into small blocks in another, and interlaminated with thin seams of coal, fawn color shale and fireclay.

§ 126. *Boring for coal.*—Twenty or thirty rods south of the quarry, a drill hole was put down in 1845 to a depth of 45′? All that is remembered about it is, that thin seams of coal were passed through in the upper part and that "the lower part was not satisfactory." It commenced at an elevation of 1336′.

§ 127. *A coal shaft*, was also sunk in this immediate vicinity at about the same time and from the same elevation, to the depth of 40 feet and stopped before the base of the sandstone was reached.

"Thin seams of coal from half an inch to one inch in thickness were found at intervals all through the sandstone."

§ 128. The sandrock on Mushrush's hill, where these tests for coal have been made, lies so near the surface in many places that it may be struck by the plough; but to the south, between this ridge and McEntire's, it is cut out below the level of the coal-bearing strata, and covered by from 10 to 15 feet of *drift clay*, as shown by the water wells.

§ 129. *Timber.*—This interval is a wide flat swampy plain occupied in part by very remarkable "timber lots" in which beech, maple, oak, hickory, ash, chestnut, cucumber, white gum and other trees all grow together with equal luxuriance.

McEntire farm.

§ 130. *Coal.*—A number of coal-pits or shafts were opened on the McEntire property as early as 1837, and considerable coal was taken out to supply the surrounding country before the introduction of railroads rendered the business unprofitable. The coal was mined in a very primitive way. A shaft was dug six or eight feet square and the coal picked out under the side walls in all directions as far as it could be safely and conveniently reached, when it was abandoned and a similar one sunk a short distance from it. Several acres are covered with these old pits, long since fallen into disuse, and only the weather-worn fragments of there fuse materials thrown out can now be seen.

The following section of one of these old pits represents as nearly as can now be remembered by the owner a fair average of these old pits.—See Fig. A, page 47:

Elevation at surface above ocean,		1349′
Surface clay,	3′	
Sandstone, soft and broken and easily removed with a pick,	17′	
Coal slate, micaceous,	1′	to 1328′
Coal of good quality,	3′	to 1325′

Sections, Figs. B, C, D and E, on the same page (47) are from pits opened further to the east, where the coal lies nearer the surface.

Section C is from a shaft sunk for a water well near Mr. McEntire's house, in 1874. The hole was about 8′ square. On the south side of the excavation the coal measured 11 feet and on the north side 6 feet. The lower 6 feet being good *block coal,* the upper 5 feet laminated, and somewhat slaty, lying unconformably upon the lower bed as represented in the section.*

§ 131. *Bowlders.*—On the gentle slope to the northeast, and below openings D and E, many large blocks of sandstone lie scattered over the surface, and below them, in the banks of a run emptying into Conneaut outlet, may be seen the outcropping under-shales.

Jackson's quarry.

§ 132. About a mile to the west of these coal beds and belonging to the same horizon of sandstone is Jackson's quarry from which is obtained an excellent stone now being extensively used by the A. and G. W. railway for the engineering work along their road.

Unger's hill.

§ 133. The next rise of ground to the south (elevation

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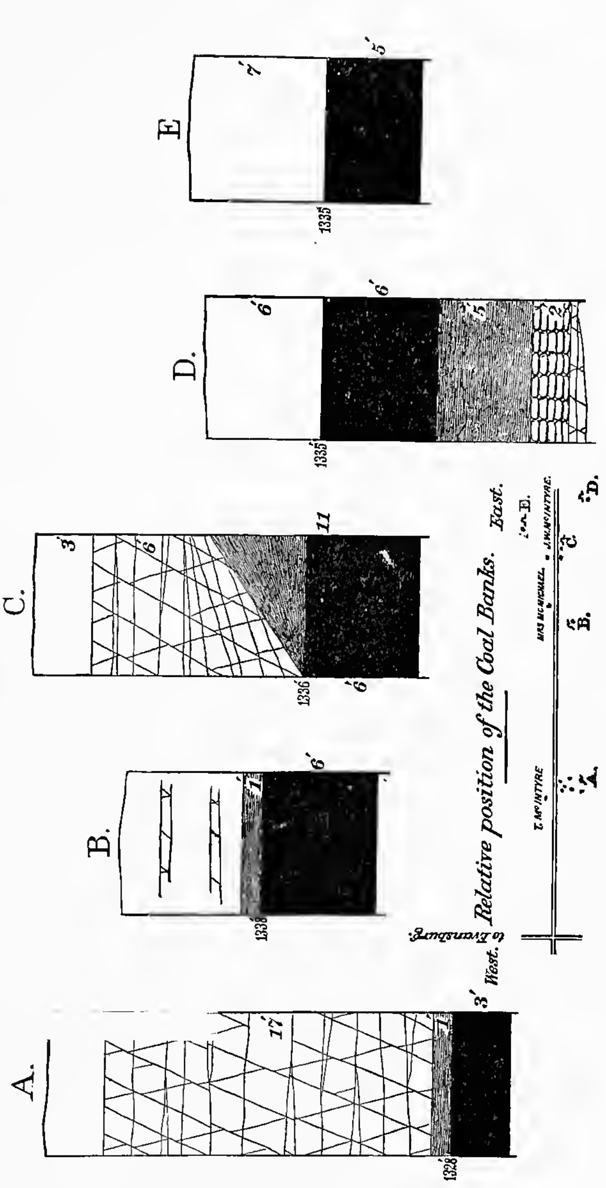
* As none of these pits are now open the sections are necessarily made, not from personal inspection, but from information derived from Mr. McEntire.

§130.

Sections at th Banks on McEntire Hill 5 miles S. of Evansburg, Crawford Co. Penna



Relative position of the Coal Banks.

1348′) is capped with sandstone; white, massive, fine-grained, free from iron, and with a layer of pebbles on top from half an inch to ten inches in thickness. No fossils and no evidences of coal discovered.

§ 134. *Bowlders.*—On the south slope of Unger's hill, and fifty feet below the McEntire coal, lie large blocks of sandstone, with iron balls and stains similar to the Miller quarry stone. These are probably from the *Sub-Garland yellow sandstone* horizon, while the white sandstone on the hilltop represents the *Garland conglomerate.*

§ 135. Along the stream below J. Unger's mill may be seen an outcropping sandrock, ten feet or more in thickness, the base of which lies 70′ below the McEntire coal. This is the lowest band of sandstone in place noted.

§ 136. *Iron ore.*—Fifteen feet beneath this lie thin beds of concretionary iron ore. In the talus of the cliffs and wash of the stream may be found many masses of this ore, having the appearance of fragments of bodies and branches of trees, crooked, gnarled, and forked in a very curious manner. A sample of the ore sent to Greenville furnace several years ago was said to have yielded a large per centage of iron; but the supply, although considerable, is not sufficiently concentrated to make the mining of it profitable.

McLanahan's quarry.

§ 137. This quarry is of the same description as the others along this ridge. It furnishes both white and yellow sandstone which is somewhat irregularly bedded but massive, and contains iron concretions and a few pebbles near the top of the mass.

§ 138. *Glacial striæ.*—On the summit and at the commencement of the southeast slope (elevation 1315′) are a number of plainly marked glacial grooves on the rock, running in directions between S. 37° E. to S. 58° E.

Hazen coal mine.

§ 139. About two miles east of Atlantic station a summit is reached which rises to an altitude of 1413′ above tide, being the *highest point* found in this part of the survey.

§ 140. *Coal.*—This ridge contains a good but uncertain seam of coal which has been exposed on the northerly side in a number of places on the Hazen farm and adjoining Miller farm. Several attempts have been made to mine coal here, since the year 1851, but they all seem to have ended disastrously.

In 1864 or 1865 considerably money was expended at the *Hazen mine*, in laying a tramway, opening a drain at a lower level (which was rendered necessary by the strong southerly dip of the coal) and making the needful preparations for a systematic working of the seam. It was operated for about two years, during which time quite a large amount of coal was taken out, but the enterprise proving unprofitable the mine was abandoned. The drift having since partly fallen in, and the drain being choked, the mine is so full of water that no satisfactory examination can be made.

The *coal* can be seen slowly dipping to the south and running below water level. Its thickness is from 2 feet 6 inches to 3 feet, and it appears to be of good quality. But the deposit partakes of the same character as all the other coals of this horizon. It lies in swamps or beds of uncertain limits and is liable to thin out or terminate abruptly anywhere. But as the mine has been so long in disuse, little reliable information could be obtained concerning it.

It was impossible also to get a complete *section of the rocks* at the mouth of the drift, but the one below will give some idea of the stratification.

Concealed from surface, (1413′,)		38′	to 1375′
Yellow sandstone,	visible for	10′	
Black shale,	visible for	4′	
Concealed to top of coal,		13′	to 1348′
Coal,		3′	to 1345′
Concealed,		7	
White sandstone,	visible for	10′	to 1328′

§ 141. *Bore-holes.*—Many of the land owners in this neighborhood have entertained the idea that a better bed of coal would be found by shafting below the Hazen seam; and to test the matter several bore-holes have been sunk. Mr. O. K. Miller gives, from memory, the following fragmentary facts concerning them.

One bore-hole, 45′ deep, was put down on the farm of T. J. Miller, a little west of the Hazen mine, commencing just below the coal horizon. In this a two feet seam of coal was reported, but at what depth could not be stated. This was in 1848.

In another bore-hole sunk from nearly the same level and to the depth of 85′, an 8-inch seam of coal was said to have been found within three feet of the bottom.

Two other bore-holes were drilled on the south side of the ridge, on land of O. K. Miller, "at about the level of the cross-roads," (which would be 1363′ above tide,) one 45 feet deep, and the other 87 feet. Both passed through thin seams of coal, but at what depth can not now be remembered.

The records of these drillings, kept only in memory, are so imperfect that we did not think it worth while to make further inquiries about them. Such fragmentary accounts of old prospecting ventures are more likely to mislead than instruct.

§ 142.—*Dip rate.*—Referring to the profile, it will be seen that the Hazen coal bed lies 20′ higher than McEntire's, and 24′ higher than Mushrush's, which would imply (if they all belong to one seam) a *dip toward the north* of about six feet per mile. But the Hazen mine dips so strongly to the *south* that the difficulty of drainage was one of the causes of its abandonment. It is an open question, then, whether these several coal beds lie at different horizons in the sand-rock, or whether there may not be a slight anticlinal between the Hazen and the McEntire openings.

Henry's run.

§ 143. Eighty rods south of Atlantic Station, on the Atlantic and Great Western railway, along the banks of a small stream falling into Crooked creek, may be seen a partial exposure of *measures below the Garland conglomerate.* They consist of blue and brown slaty-shale, interstratified with thin plates of false-bedded shaly sandstone, and occasional lines of kidney ore, all remarkably *non-fossiliferous.*

§ 143. *Drift.*—While along the high ground just described very little coarse northern drift is to be seen, *here*, on the contrary, it appears in quantity, as if driven over the comb of the hill, and dropped in the valley. As the stream enters these drift-deposits the bottom-flat widens, and the current sweeps from side to side, cutting in places down to bed-rock, through ten feet or more of Drift, so impregnated with iron that the water-worn material of which it is composed has nearly all of it a rusty cast.

§ 144. Below the railway embankment crossing Henry's run the stream is thickly strewn with thin plates of sandstone, reddish, fine-grained, hard, and having a *metallic ring* when struck with the hammer. These must have come down from the upper part of the shales; for, all of the rocks exposed directly above the creek bed, and along its lower cliffs, are of soft slate or shale, and some of them are so exceedingly fissile that they weather down into thousands of small pieces. These lower shales are also discolored by iron.

Fucoids are found here, with *wave-marks*, on thin sandstones, and long branching cores, cast, evidently, in *mud-grooves* upon the shore.

Adamsville quarry.

§ 145. *Crooked creek section.*—The next exposure of sand-rock to be noted is upon the hill on the west side of *Crooked creek*, about one mile west of Adamsville; descending from which the following section was taken, along a little stream which plunges in a waterfall over the quarry rock, and then makes a rapid descent through a deep-cut ravine into the valley of Crooked creek.

Elevation of top of exposure above ocean, ...		1240
Sandstone, massive, coarse, yellow and white, containing *iron concretions* and clay balls, ...	8 to	1232
Shale, blue, friable, ...	2 to	1230
Sandstone, thin bedded, and dark shale, warped and irregular, in layers half an inch to six inches thick, and containing impressions of *plants*, ...	5 to	1225
Shale, blue, sandy, friable, ...	35 to	1190
Sand plates, thin, with shale partings, ...	10 to	1180
Shale, blue friable, ...	40 to	1140
Sandstone, yellow, thin bedded, ...	5 to	1135

Sandy shale,	20 to 1115
Shale interstratified with thin sand banks,	30 to 1085
Shale, blue, friable, with an occasional thin layer of flaggy sandstone,	35 to 1050
Concealed to water of Crooked creek,	54 to 996

A few fossils were found here, as *Productus*, *Aviculopecten*, *Strophomena*, *Spirifer*, and *Fucoids*.

Snodgrass ore bank.

§ 146. About half a mile west of Adamsville quarry the *summit* of the ridge between Crooked creek and the Shenango is reached at an altitude of 1360′ above ocean, and on the commencement of the western slope, 30′ below the crest, lies the Snodgrass ore bank, on the farm of J. M. and Robt. Snodgrass.

This is a rich deposit of iron ore 1 foot 6 inches in thickness, in basin shape sloping on all sides, but of nearly uniform thickness over quite a large area in the centre.

Extensive operations were carried on here in 1855, and large quantities of ore were taken out and delivered by teams to the furnace at Greenville. It was worked profitably by stripping, being covered by only about 9 feet of *surface clay* and 3 feet of *black bituminous shale;* but the losses incurred by the failure of the parties contracting for the ore caused mining to be suspended. No doubt large quantities of the ore still remain under the hilltop.

§ 147. *Coal.*—In digging a drain from this bank a thin seam of coal is said to have been discovered. Indications of coal are also vaguely reported in several other places on the summit.

Christy's quarry.

§ 147. This quarry lies a mile and a half north of Snodgrass's ore bank and at an elevation which fixes its horizon at the latter place *beneath the ore.*

White, irregularly bedded, coarse-grained sandstone is exposed for 10′, but no doubt it extends down deeper, and the top has evidently suffered some erosion at the quarry. The rock fractures quite irregularly, but works easily when first quarried, and hardens on exposure into a firm and durable stone. Contorted masses of carboniferous *plants* occur in some parts; a few *iron concretions* and numerous clay-ball pockets are seen, but no pebbles.

§ 148. *The knob* containing the sandstone is the highest in the vicinity, and covers an area of perhaps 100 acres.

§ 149. *Glacial scratches.*—On its gentle southwest slope a portion of the top of the rock can be seen, polished and grooved by glacial action in a direction corresponding to the contour of the surface.

§ 150. *The ice conformed to the present topography.*—It may be remarked here in relation to these striated rocks, a number of which have been previously mentioned, that—while the grooves all have a trend pointing plainly to to a general movement of the sculpturing agent toward the south or southwest—they at the same time, as far as my observation goes, *conform universally in detail to the outlines of the present topography* of the country wherever they are found. For example, on the point of a ridge falling on one side to the southeast and on the other to the southwest, the direction of the furrows will vary according to the slope of the surface rock. It would appear then that these groovings are not the inscriptions made by the early glaciers, moving slowly and undeviatingly along their track, but those of more recent and thinner ice-sheets which split upon the resistant headlands and were deflected to the right and left along the valleys, which therefore must have been shaped then substantially as they are at the present day.

Snodgrass quarries.

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§ 151. *Jamestown section.*—On the W. J. Snodgrass farm one mile N. E. of Jamestown and just beyond the northeast angle of the borough limits, the upper part of the following section was taken, and it is connected with Dr. Gibson's oil well record, near the base of the hill, in Jamestown; thus exhibiting the general features of stratification at this point through a vertical distance of 1282′ and down to a level 4′ below the surface of the ocean.

Elevation of top of quarry above ocean,				1278
Snodgrass Upper quarry.	Sandstone, coarse-grained, friable, brownish yellow, containing many *fish* remains,	1	to	1277
	Sandstone, false, bedded, laminated, yellow,	4	to	1273
	Sandstone, blue, flaggy,	5	to	1268
	Sandstone, micaceous, slaty, thinly laminated full of carbonaceous specks and carbonized coal *plants*,	2	to	1266
Partly concealed, irregularly bedded, flaggy, fucoidal sandstones exposed at frequent intervals,		41	to	1225
Snodgrass Lower quarry.	Sandstone, massive, yellow, containing a few iron concretions, and broken fragments of plants,	6	to	1219
	Sandstone. in layers from 1″ to 3″ thick,	6	to	1213
Partly concealed, (see explanation below),		140	to	1073
Christy run and Gibson well mouth quarry.	Sandstone, flaggy, (see below),	12	to	1061
[*Continue down with Dr. Gibson's oil well record, published in I.I., with the No. 1187.*]				
Slate, soapstone, and hard shells,		90	to	971
Sandstone, fine-grained, blue,		20	to	951
Slate, blue,		65	to	886
Sandstone, whiter than the above (thickness estimated,)		25	to	861
Slate, blue,		90	to	771
Sandstone, coarse and pebbly,		18	to	753
Slate and soapstone, soft,		92	to	661
Red rock and hard shale,		100	to	561
Hard sandy slate,		50	to	511
Black slate,		200	to	311
Black slate, no sand,		315	to	—4

§ 152. *On Christy run.*—Following down a small stream (called above Christy run,) which falls over the lower member of Snodgrass quarry and runs in a southerly direction into the Shenango, the measures are not very well exposed; but occasional glimpses caught of them in the side walls of the ravine are sufficient to satisfy one that they are a comparatively homogeneous mass of sandy shale similar to those seen below the Adamsville quarry.

§ 153. *Christy run quarry.*—In this ravine at a vertical distance of 140′ (by barometer) below the Snodgrass Lower quarry another quarry is worked which shows a face of about 12′, and furnishes a bluish-grey, flaggy, sandstone some layers of which are locally from 8 to 10 inches thick.

The same sandy band, but not so well defined may be seen just at the mouth of *Dr. Gibson's oil well* and again along a little run north of the well.

§ 154. *Fossils.*—Mr. J. Dennison who has taken out a large quantity of stone from the exposure in the ravine, states that he found large numbers of fossils, principally *Discina* and *Spirifer*, near the base of the rock; some fine specimens of which he kindly donated to the survey. We did not discover any colonies of fossils at this horizon, but obtained several single specimens.

§ 155. *Gibson's oil well.*—The record of Dr. Gibson's well was, unfortunately, not kept with sufficient care to give us a faithful representation of the strata passed through. The *so-called Third sand* is no doubt correctly located (as to depth) in the section; but the positions of the other sands are somewhat uncertain; and the quality of intermediate strata is very vaguely stated. If this *so-called Third sand* really belongs to the Venango oil group it probably represents not the *Third* but the *First sand* on Oil creek.

The distance from the Snodgrass lower quarry down to it is 442 feet; which agrees, approximately, with the corresponding interval as measured in Venango county. But this of itself is not sufficient to prove its identity with the First Sand of Venango county. It may be a different rock, not at all connected with the Venango group. The question could only be satisfactorily settled by a careful examination of the character of the measures above and below it in the well; but as the sand pumpings were not preserved, this of course cannot be done. I therefore give the section, as above, merely to show the general character of the lower measures in this part of my survey.

J. H. Christy's quarry.

§ 156. *Snodgrass Lower quarry rock.*—About a mile and a half east of Jamestown and one mile south-southeast of the Snodgrass quarry there is a very good exposure of the Snodgrass lower quarry rock. It may be seen in two places just above the forks of a little stream flowing into the Shenango, and about half a mile north of the highway.

The following is the section at that point:

Elevation of top rock above ocean (barometer),	1190
Sandstone, yellow and grey, sometimes massive and in layers from 2′ to 3′ thick; quite coarse-grained, iron-stained, and containing many impressions of carbonized *plants*,	8 to 1182
Sandstone, thin-bedded (plates, 1″ to 8″),	12 to 1170
Shale, blue, visible for	10 to 1160
Concealed,	10 to 1150
Shale, blue,	45 to 1105
Sandstone, flaggy, visible for	10 to 1095

Survey continued.

§ 157. *From Jamestown southwest* our levels were continued to the dividing ridge between the Shenango and Pymatuning, at *Kinney's Corners* (cross roads) in the extreme northeastern corner of Trumbull county, Ohio. The highest point (hill top) in this vicinity, a short distance south of, and 30′ higher than Kinney's cross-roads, has an altitude above tide of 1191′.

§ 158. No sandrock was seen in place here, everything being completely covered with Drift; but the indications are that this little rise in the general level of the crest marks the horizon of the *Snodgrass lower quarry rock.*

§ 159. *Conglomerate.*—Sweeping around at Kinney's Corners from southwest to west no deposit of conglomerate can be reached within a distance of about 30 miles. Every vestage of it has been removed from all the northwestern townships of Trumbull county, Ohio; although it remains in great thickness in the eastern tier of townships of Geauga and Portage townships.

We must look to the south, then, along this Pymatuning-Shenango ridge for the connection of our GARLAND CONGLOMERATE with the OHIO CONGLOMERATE and our *Sub-Garland yellow sandstone* with the *Shenango sandstone.*

§ 160. *Ohio conglomerate.*—The first prominent exposure of Ohio conglomerate is at *Hobart's quarry* in the southeast corner of Kinsman township, about 4 miles south of Kinney's Corners.

Half a mile southeast of this at *Foulke's quarry* in Mercer cer co., Pa. a higher stratum of sandstone is exposed which is probably the one lying above the Orangeville coal beds further south.

Mr. Foulke has drilled here for coal and find a 10′ sandstone 95 feet below the quarry rock which seems to be the *Shenango sandstone.* This sandstone is also exposed in a small stream falling into Booth run about a mile and a half south of Mr. Foulke's.

A mile and a quarter southwest of this point, and two miles north of Orangeville, both the Conglomerate and Shenango sandstone outcrop one above the other in the *cliff* facing the Pymatuning.

About two miles east of these outcrops the Sharon coal is mined quite extensively.

Thus the GARLAND CONGLOMERATE may be traced step by step until it is found coalescing with the OHIO CONGLOMERATE beneath the Sharon or Block coal. It is unnecessary to go further into details in this report of my work of 1875 since Prof. White's systematic survey of Mercer county in 1878 (See Report QQQ, already published) fully confirms and establishes the connection.

CHAPTER VI.*

On the Panama conglomerate.

§ 161. This conglomerate, which takes its name from the place of its best exposure, in the village of Panama, Chautauqua county, N. Y. appears to have a considerable range of exposures in a northeast-southwest direction.

But at right angles to this line of its best development—that is in a southeast direction—it seems to dip rapidly beneath the general level of the country, to lose its conglomeritic character, and by reason of a great acquisition of

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* Report of work done in 1875.

argillaceous material, soon becomes unrecognizable, (even as a well pronounced horizon of sandy shale,) where pierced by borings for oil.

§ 162. The *Panama conglomerate* has often been mentioned by geologists, in the same category with the conglomerates of Ellicottville or Salamanca, Olean, Wellsville, or Genesee, and Quaker-Hill or Garland.

Consequently, it has been represented lying at the base of the coal measures; which conveys an entirely wrong impression of its true age and stratigraphical position.

§ 163. On the other hand also, the Panama conglomerate has been frequently referred to as a Chemung rock; and also as the northerly outcrop of one of the Venango oil sands.

The first classification is unquestionably erronious; and there are grave reasons for doubting whether the latter be absolutely correct.

§ 164. As the rock can only be properly studied along its outcrop, we have been compelled to trespass upon New York territory, and devote some time to an examination of its exposures in Chautauqua county, in order that we might become acquainted with its character and position there, and thus be better qualified to follow it in its southern extension into our own State.

But this examination has not been thorough enough to dispel entirely the obscurity which surrounds the subject, and I am still unable to indicate positively the precise horizon of this interesting deposit in our oil well sections; and chiefly for the reason before stated, viz: that it fines down into shale and is lost before reaching the oil-producing districts.

§ 165. The facts about to be given, however, lead clearly to the following conclusions:—

1. That it is an older rock than the conglomerates of Olean, Garland, &c., and therefore is not of carboniferous age.

2. That although actually of Chemung age, it probably is not the equivalent of any one of the oil-producing sandstones of Venango county, lying much deeper in the series.

Panama rock city.

§ 166. At Panama a north and south ridge, rising on the west of Little Brokenstraw creek, and containing the rock in place, is cut through by a branch heading in the highlands to the northwest.

This branch seems to have formerly plunged over the face of the escarpment of sandstone forming the west wall of the valley of the Little Brokenstraw; but it has now cut back a gorge, half a mile or more long.

At the present head of the gorge the waterfall is quite inconsiderable, except in times of freshets, and the descent over the ledge of pebbly sandstone is made in two leaps, with a sloping cascade between. The bed of the ravine is crooked and obstructed by large blocks of conglomerate dropped from the nearly vertical side walls of the gorge.

It is a picturesque spot, presenting attractive features to the lover of romantic scenery; and it opens to the student of nature instructive pages in the physical history of the globe, both as to the attitude, structure, and constitution of this remarkable deposit of ancient gravel and sand; and as to the fossil forms of life, which are in great abundance, entombed in it, as well as in the shales underneath it.

§ 167. *Level above tide.*—To place its elevation above tide beyond question a spirit-level line was run from grade at Grant station, on the Atlantic and Great Western railway, to the top of the rock, near the "Rock Hotel," Panama. The rise was found to be 234′. This, added to the altitude of Grant station, (1437′, as given in the R. R. levels,) gives 1671′ as the true elevation of the top of the Panama rock above mean ocean level, at this point.

§ 168. *Thickness.*—On the northerly side of the ravine, a short distance from "Rock Hotel," the *base of the conglomerate* is well exposed by a cutting for a mill flume.

Leveling to this point made the rock 69′ thick.

§ 169. *Under-shales.*—Here the rock is seen resting on bluish-green shales, very argillaceous and considerably discolored by iron. About 25′ of these shales are exposed; and beneath them, for 25′ more, (which carries us down to the level of the stream,) may be observed other blue shales, much more sandy than the first, irregularly bedded, and containing several bands richly stored with *fossils.*

§ 170. *The shape of the pebbles.*—The Panama rock may be described as a massive conglomerate composed of quartz pebbles and sand; the proportion of sand to pebbles being much larger than in many of the purely conglomeritic masses of northwestern Pennsylvania. The pebbles whether large or small, are almost always of *lens shape.* They seldom measure an inch in their longest diameter; but one may occasionally be found measuring an inch and a half or even two inches. They are generally of a very pure white quartz, but some are pink; and quite frequently one may be observed of red or slate colored jasper.

One of the first things which attracted my attention while examining the Panama rock, was the marked contrast in form between the pebbles composing it and those of the Pennsylvania conglomerates which I had been studying.

In these last as far as I have observed them, the pebbles are universally of an irregularly *spheroidal shape;* while in the Panama rock the pebbles are as characteristically lentiform; a spheroidal pebble being as much an exception to the general rule at Panama, as a lenticular pebble is at Lottsville or Garland.

Whether this diversity in the shape of the pebbles amounts to positive proof that the rocks belong to different ages or horizons I do not pretend to decide. But it seems quite improbable, to say the least, that two conglomerates so entirely dissimilar in structure and in the shape of the pebbles composing them, as the rock at Lottsville, and the rock at Panama, separated also as they are by a geographical interval of less than ten miles, should be deposited by the same mechanical agents, and at the same time.

Certainly the shape of a pebble must depend not only upon its constitutional structure, but also in great measure upon the manner in which the frictional forces have acted upon it. If it has been constantly subjected to a rotary or rolling motion, it would assume a spheroidal form--if abraded by sliding and alternate movements backward and forward, without rolling, it must take on the lens-shape. But we may ask if these varying conditions prevailed contemporaneously in these two localities so close together, and formed such different kinds of conglomerate in one and the same horizon, why should not similar conditions have occurred and produced as conspicuously varied results in other places? I am not aware that there can be found in the whole range of the Conglomerate series, a single instance where a flat pebble conglomerate of the constitution of the Panama rock is interstratified with the round pebble conglomerates characteristic of the carboniferous age.

It seems quite probable that the original structure of the quartz may have had something to do with the ultimate shape of the pebble;. for in the flat pebble rocks of Chemung and Pocono age the material has a tendency to a lamelate fracture; while the rounded pebbles of the Pottsville period, break up into more approximately cuboidal masses.

I merely call attention here to these facts, for their significance can only be properly understood after the subject has received further investigation.

§ 171. *Alternate layers.*—The rock at Panama is made up from top to bottom of alternating layers of sandstone and conglomerate blending one with the other as the proportions of sand and pebbles varied intermittently during the deposition of the materials composing the rock. Frequently a layer of pebbles consisting of only one course may be seen running horizontally for rods along the face of the cliff. The pebbles lie flat, and the sandstone having weathered away from above and below them, their projecting edges jut out and glisten in the sunlight like a string of beads suspended in front of the sandstone.

In some cases two or three courses of pebbles in immediate contact have been deposited between purely sandy masses, a foot or more in thickness. Several blocks with this structure have fallen from the cliff in such a manner as to split open along the line of pebbles, exposing two plane-surfaces of sandstone beautifully inlaid with a wonderfully regular and uniform stratum of lenticular pebbles. The whole aspect of the rock suggests the story of a gravel heap along an ancient shore reached by occasional storms, the waves of which have washed into the beach, the "back tow" bringing out and distributing the pebbles systematically over a smooth and sandy floor.

§ 172. *Fallen blocks; fissures.*—The disintegration of the soft shales at the base of the conglomerate has undermined it. Long ranges of rock have broken off in the lines of cleavage (which here run about N. 60° W.) and settled away one after the other from the undisturbed portion behind them, leaving a series of fissures from 2 to 10 feet wide separating the several portions one from the other.

These fissures are about 40 feet apart; and the detached projecting portions of rock are traversed by a secondary series of transverse crevices, and thus split up into huge blocks, 70 or 80 feet long. Some of the blocks along the front of the escarpment have slipped down, rolled over, and now lie near the bed of the stream, 50 feet below.

All the *rock cities* of southern New York and northwestern Pennsylvania have been formed in a similar manner. Many of them are situated on the highest hilltops, but they are always composed of rocks *in situ.* They have neither been brought from a distance; nor have they been thrown up to their present position (as popularly imagined) by "convulsions of nature." Their formation has been as slow and quiet as the operations of frost and water amid which we live. They are merely the last remnants of thick and extensive deposits of coarse sandstone that once covered the country, and are now everywhere else removed. Their preservation from the destructive erosion which has been going on constantly for an untold number of ages, removing rock after rock above them, and carving out the valleys hundreds of feet deep below them, must be ascribed to one of two causes, or to both combined: either to their peculiar position in relation to the eroding currents, and to the fact that some great change in the direction and energy of these currents occurred at just the proper time to leave the rocks thus exposed to view; or to the peculiar constitution of the deposit, its superior thickness, coarseness, homogeneousness, and consequent power of resistance, in those parts of it now occupying these positions.

Range of exposures.

Taking Panama now as a central point, let us trace the conglomerate and see what is its probable stratigraphical position in the geological series; in what direction it appears to thicken or thin; how it dips and what changes of constitution or character it undergoes in the several places where it may be examined.

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§ 174. *Blockville* or *Ashville exposure.*—Going to the northeast, the first exposure found is on *Stony ridge*, about a mile and a half north of Blockville and two miles northwest of Ashville.

Here the rock assumes a mixed character. Some parts are masses of pebbles loosely held together in a scanty sandy matrix, easily disintegrated by moisture, frost, and heat on exposure to the atmosphere, and utterly unfit for architectural purposes.

Other positions afford a beautiful white and brownish-grey sandstone suitable for monumental bases, lintels, or any similar work.

The precise *thickness* of the whole stratum was not ascertained, but it can hardly be less than fifty feet.

Elevation (by barometer) of assumed base of rock 1660′.

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§ 175. *Ellory Centre.*—Continuing to the northeast, we cross Chautauqua lake, and find the last traces of the rock (in that direction) in loose pieces, but apparently very nearly *in situ*, on the highest hills around Ellory Centre.

Elevation by barometer 1750′.

Huge erratic *bowlders* of gneissic rock are thickly strewn over the hill slopes (especially the slopes facing the north) to within 40 or 50 feet of the highest summits.

Beyond this in the same northeast direction there are no hills high enough to hold the rock. If it even were deposited there, it has been eroded off.

§ 176. *Williams' quarry*, on the westerly slope of a hill four miles north from Panama, has been worked for more than forty years, furnishing stone for the Mayville courthouse; and from layers which seem to be those at the base of the Panama deposit.

The rock is a fine-grained, free-working, grey sandstone, splitting smoothly and easily; and readily wrought into fence posts, or into square blocks of almost any desired length. The upper pebbly strata are not present at the quarry. The lower compact sandstone layers of the formation underlie a large area covered by only a few feet of surface clay; and the upper rock surface beneath this clay is in many places plainly *glaciated*, the direction of the ice scratches being here nearly north and south.

Elevation (by barometer) of base of quarry 1660′.

On the rise of the hill 30 or 40 feet above the quarry, *conglomerate* precisely similar to Panama rock city may be seen in place.

§ 177. *Lewis quarry.*—Half a mile west of Williams' lies the Lewis quarry; and at many other places in this vicinity the rock could be easily quarried. The character of the stratum is the same throughout, and there can be no doubt of its equivalence to the Panama rock.

§ 178. *Chautauqua quarry.*—Near Panama station on the Buffalo, Corry and Pittsburg railroad, five miles west of Panama village, Messrs. Warren and Hammond of Mayville have opened a quarry calling it by the above name.

It furnishes a fine-grained, compact, bluish-buff sandstone containing minute, evenly disseminated specks of iron; dresses very smoothly; is said to weather without discoloration, and to be very strong and durable.

The stratum worked is about 12 feet thick. Below it are blue clayey shales; above it thin bands of *flat* pebbles loosely held in a sandy matrix and iron-stained. Probably much more conglomerate of a massive character lies above these thin bands since loose blocks are seen on the slopes of the hill.

The bed of the rock dips very strongly in a north northeasterly direction as shown by the water on the bottom of the quarry; but this may be only a local feature which will not continue when the quarry is worked further in.

A branch railroad is laid up to the opening from the B. C. and P. R. R. and they have now every facility for quarrying and shipping an excellent material for monument cutters and builders.

Elevation of base of quarry about 1600′.

Other exposures in Chautauqua county might be mentioned, but as they are all on the same range of rock and these are sufficient for our purpose we now pass on into Pennsylvania.

The Panama rock in Pennsylvania.

§ 179. *Bleaksley quarry.*—Passing the State line and pursuing a southwest course the observer finds the surface of the country heavily covered with northern Drift, and very few attempts have been made to discover the underlying building stone deposits.

On the Bleaksley farm, however, 3 miles south of Wattsburg, Erie county, a quarry has been opened, exposing about 15 feet of sandstone and conglomerate. The conglomerate is of *flat* pebbles, often thinly bedded and splitting in layers from six to twelve inches thick. Some of the more sandy layers are quite massive and work up into good building stone.

§ 180. A *drill hole* for oil was here "kicked down" a hundred feet or more about the year 1864. It commenced in the quarry-opening seven feet below the top of the rock and is said to have gone through 60 feet of sandstone at the top. If this be true there must be a heavy deposit at this point, and the base of the rock would lie at an elevation of about 1340′.

§ 181. *Large blocks.*—Two miles south of Bleaksley's, the same kind of conglomerate and sandstone lie scattered along the foot of the hills skirting the westerly side of Beaver run indicating close proximity to the rock in place.

§ 182. *Another exposure* of the rock occurs about three miles southwest of Bleaksley's on the farm of Mr. Doolittle, where it is laid bare by a small stream falling into the west branch of Le Boeuf creek, showing a thickness of about 15 feet and quite similar in appearance to the quarry last noted. Elevation of base by aneroid 1330′.

§ 183. *Oil well.*—Mr. Doolittle furnishes from memory, the following record of an oil well drilled here in 1860:

Sandstone, (bottom layer of quarry rock), ...	2	to	2
"Soapstone,"	40	to	42
Shelly sandstone, ...	88	to	130
Slate and shale, rather hard drilling, ...	470	to	600

Gas and oil show all through the 88′ of shelly sandstone. Oil of heavy gravity—translucent and very clear "looked like honey."

Between 200′ and 300′ a restricted gas reservoir was tapped which flowed strongly for two hours and then ceased.

The well was drilled wet and abandoned without pumping. Drill hole 4½ inches in diameter.

§ 184. The next quarries of importance are those situated in the southeast corner of Waterford township, Erie county, on the adjoining farms of J. W. Middleton and J. McClelland. They have been worked for many years and are mentioned in Prof. Roger's Final Report of 1858 as being of considerable note when the first geological survey was made.

§ 185. *The Middleton quarry* is now worked principally for its flags. It turns out some very fine slabs of bluish-grey sandstone from 3 to 5 inches thick, which find a ready market as they are well adapted for sidewalks, curbing, &c.

A section of this quarry, from the top down, would be as follows:

Flat pebble conglomerate, irregular, false bedded and containing many *fossils*,	2′
White sandstone quite massive,	2′
Bluish-grey flags in layers from 3 to 5 inches thick,	4′
Flaggy measures said to underlie the band now being worked,	15′ ?

No systematic quarrying has been done to make it absolutely certain that there remains 15 feet more of flags below the 4′ band now worked.

The barometric elevation of the conglomerate is 1275′.

§ 186. *Moravian or Carroll quarry.*—The last ledge of this rock in a southwest direction is at the old Moravian quarry near Le Boeuf. Here some fine building-stone is obtained, and being on the line of the Atlantic and Great Western railway and only a few feet above railroad grade, it is easily shipped to all parts. Consequently the quarry is more extensively worked than any of those previously mentioned, except perhaps the Chautauqua quarry.

The section exposed here is as follows, from top down;

Fossiliferous sandstone, crowded with *spirifers* and *rynchonellas*,	2′
Blue, friable shale,	15′
Flat pebble conglomerate, containing *fossils* and similar to Middletown quarry,	2½′
Barometric elevation of conglomerate,	1220′
Yellowish sandstone, with pebbles in seams and pockets,	2½′
White, massive sandstone,	5′
Yellow, massive sandstone,	6′

Average fall per mile.

§ 187. We have now followed the *Panama conglomerate* for about 35 miles in a southwesterly direction; from its scattered remnants on the highest hilltops in the centre of Chautauqua county, N. Y. to its last appearance, a few feet above the waters of French creek in the southern part of Erie county, Pennsylvania.

The difference in altitude between the points of starting and ending is 1750′—1220′=530′:—an average fall of about 15 feet per mile.

This rate of descent carries it down below the surface to the southwest of Le Boeuf, (if it continues on in that direction,) and we get no further traces of it.

Influence on the topography.

§ 188. It is worthy of passing note that this range of the *Panama conglomerate*, probably the line of its maximum development, crosses Chautauqua lake at the "narrows;" and the peculiar "saddle-bag" outline of the lake, which is said to have suggested its Indian name, Chautauqua, is no doubt due to this fact.

A stratum of massive sandstone interbedded between softer measures and coming up from the south with a very perceptible rate of ascent, could not fail to be influential here in lining out the drainage channels of the *pre-glacial system*, as well as in directing, locally, the flow of the great glaciers themselves.

From Chautauqua lake to Le Boeuf, a high range of hills marks the trend of the *Panama conglomerate* and forms the water shed for streams flowing in opposite directions. One branch of French creek rises to the north of the ridge and within five miles of Chautauqua lake; another branch to the south of it, near the east line of Erie county, Pa.; the two streams running southwesterly, and gradually converging, as the conglomerate sinks in that direction, until they meet near Le Boeuf, where the rock has lost much of its massive character, is thin, and lies not far above the flood plain of the creek.

The southerly water-shed of the ridge, in Chautauqua county, drains quite directly south, through numerous tributaries of the Brokenstraw creeks; but the deeply excavated basin of Chautauqua lake cuts entirely through the range, and receiving the water from several small streams rising on the great divide, within five miles of Lake Erie, outlets toward the east into Conewango creek. The only cuts, therefore, through the ridge are on the southwest, where the *Panama conglomerate* is thin and has sunken nearly to present water level; and on the northeast, where it is coarse and friable and is seen just scaling the tops of the highest hills now remaining in the vicinity of Chautauqua lake.

Quarries in Erie and Crawford.

§ 189. Many quarries have been opened in these counties, to the northwest of the range of the Panama rock as we have traced it. Some of them have been wrought for years, supplying building stone for the villages, and dressed blocks for the old canal locks, so frequently mentioned in the Final Report of the First Geological Survey.

An examination of a large number of these quarries has led to the conclusion that *none of them can certainly be classified with the Panama conglomerate.* They belong to no one constant horizon, but lie at various levels in the softer measures; and are due to comparatively local causes operating during the deposition of the rocks, and resulting in an intermittent and varying supply of fine sandy sediments carried along to be deposited at one time in this place, at another in that.

The variable character of these strata is clearly indicated in the Final Report of 1858, Vol. 2, page 583, where, speaking of the numerous quarries of this section, it says: "The thickest arenaceous beds measure in some places 12 or 15 inches, and where a number of them occur together with only thin partings of shale, the mass is quarried as a building material. * * * It is seldom possible to trace a particular stratum of the sandstone for any considerable distance, for the beds soon thin off, or deteriorate for economical uses, by becoming too argillaceous, and thus they fade into the great body of the formation."

An inspection of the old canal locks, now fallen in decay, and many of them being torn out for the purpose of securing the dressed stone for other uses, shows that some of the material of which those in this section of the country were constructed is not of an enduring quality. A majority of the blocks have weathered badly, some presenting desquamated faces and rounded corners, while other have a tendency to split into thin laminæ, causing them to fall to pieces in removal, and are fit only for rough walls. These characteristics, so entirely dissimilar to those pertaining to more massive formations like the Panama conglomerate, are, aside from other considerations, trustworthy witnesses in favor of the argument that the quarries furnishing the material do not belong to the Panama horizon.

Panama fossils.

§ 190. One of the exceptional features of the Panama rock, as compared with other conglomerates, is the great abundance of fossils found associated with it, and even in the pebble-mass itself. A large number of specimens have been collected from it, embracing—

Euomphalus depressus.
Cypricardia rhombea.
“ *contracta.*
Spirifer disjunctus.
Rhynchonella.
Productus.
Fucoids.

At Williams quarry a small fragment of *fish bone* was found; and at Chautauqua quarry several casts of *plants*, too imperfect to be identified,—one of them two inches in diameter and over two feet long—coated with a thin film of coal containing iron pyrites.

Associated Strata.

§ 191. Let us now look at the associations of the *Panama conglomerate.*

The measures *below* it come up to daylight and spread out over all the belt of country between the line we have followed and the shore of Lake Erie. They have been recognized on all hands as of Devonian age, and those immediately under the conglomerate as a portion of the Chemung group, as indicated by James Hall, in 1843. There can scarcely be a question raised, therefore, in relation to the age of these lower measures.

§ 192. But the equivalence of the measures *above* the Panama rock, by reason of confounding this conglomerate with the conglomerates at the base of the coal measures, has been brought into dispute.

Within three miles of Panama, in going south, southwest, and west, we may pass over and inspect from 125 feet to 225 feet of the softer measures *superincumbent* on the conglomerate. They can be critically examined in many exposures in this locality, and always present the well-known characteristic features of the *Chemung* group—bluish-green, olive, and brown shales, with occasional local acquisitions of sandy matter, resulting in restricted and irregular bands of thin-bedded, flaggy sandstones.

They also contain frequently recurring fossil bands crowded with *Spirifera*, *Rhynchonella*, &c.; forms which seem to be identical with those found in similar fossil bands *below* the conglomerate. There are no massive sandstones; and nothing to indicate that any of the great changes had yet occurred which are so plainly recorded in the character and arrangement of the sediments composing the oil producing rocks of Venango and those above them. There seems to be no good reason, therefore, why these *upper* measures should not be considered as belonging to the same Chemung age as those immediately *below* the conglomerate.

Dip and physical changes in the Panama rock, going south.

§ 193. Little Brokenstraw creek flows in a southerly direction from Panama, crossing the State line about five miles below the village, and continuing on 13 miles further, empties into the Big Brokenstraw at Pittsfield in Warren county, Pennsylvania.

Following down the stream for two or three miles from Panama the presence of the Panama rock is plainly marked in several places on the west side of the valley, by steep bluffs which *indicate unmistakably the position of the stratum* although it is so drift-covered that no exposures are seen.

But at a point a little over three miles (in a direct line) from Panama, the "Eureka oil well," put down in 1869 (?) gives the position of the rock beyond a question.

§ 194. *Eureka well.*—The record can now only be obtained from memory, and the precise depths and thicknesses of the different strata drilled through cannot be stated in detail; but the general facts are these. The drill started on top of the *Panama conglomerate.* It passed through sandstone or sandy measures from 60 to 80 feet thick. Then came an interval of blue, muddy rocks; then a heavy stratum of very *red shale;* then soft drilling, with some thin, fine sand-shells; and finally, quite a coarse massive sandrock 18 feet thick, which seemed to contain considerable *oil.* The drill was sunk in slate 15′ below this sandrock, and stopped at a depth of 456 feet from the surface.

On the test of the well it produced only a "good show" of oil and was abandoned.

One remarkable feature about the well was, that without casing of any kind to keep out the water, it was virtually a *dry hole*—all the water seeping into it from the upper rocks could be bailed out in a few minutes at any time with a sand-pump.

§ 195. In this record we have two important facts to work upon—the top of the conglomerate and the presence of *red rock* beneath it and not far below its base.

As to the conglomerate, there can be no mistake. Its pebble-covered top is visible at the well mouth and in the bed of the little side-hill gully in which the well is located. Lower down in another gully branching to the west, the water is seen coming over sandy layers in water-falls, and the structure can be well observed. The rock is not homogeneous and massive throughout, as at Panama, but consists of quite a massive stratum of pebble-sand on top, then fine greyish sandstones in layers from 6 to 15 inches thick. There appears to be several bands of these thin sandstones, separated by thin, soft, greenish shales, and the total thickness of the whole mass exposed cannot be more than 25′. But there may possibly be sandy shells extending down further, as would seem to be indicated by the well record.

Elevation of well mouth and top of conglomerate 1569′.

Top of same rock at Panama 1671′.

Fall per mile nearly due south about 32′.

§ 196. No further exposure of this rock in place was found south of the well. But on the farm of Mr. E. Bordwell, about one mile south of the State line and on the west side of Little Brokenstraw valley a very interesting exhibition of conglomerate occurs in *loose blocks* covering perhaps 40 or 50 acres of ground at an elevation of about 30′

above the creek bottom. At first sight they have the usual appearance of blocks of this character skirting an outcrop. They lie at proper level to correspond with the dip brought down from Panama through the Eureka oil well, and it cannot be positively asserted that they are not in close proximity to the rock in place.

But here we are met by a difficulty. If the conglomerate be *in place*, it is much more massive and ponderous than anything discovered about the Eureka well, and it is very surprising that no traces of it, even as a thin bedded sandstone, was found in the *Lottsville oil well*, 3 miles down stream ; and that no other outcrop of it is known on either side of the valley south of the State line.

A study of the surrounding country, however, afforded a plausible account of the presence of the *blocks* in this place. They lie on the west side of the stream, at a point where there has evidently been a *moraine*, or Drift-dam, across the valley, in precisely the spot where they would naturally have been deposited if brought down by ice from the hills at the north. The moraine has since been cut through by the stream, leaving a vertical wall of 20′ to 30′ of Drift on its easterly bank, and these conglomerate masses intermixed with erratic bowlders of gneissic rocks on the west.

I am not certain that this is the true solution of the problem, for time and circumstances did not permit of as full an investigation as was desirable to settle the question ; but if the rock be here in place, it adds additional proofs to the strong dip of over 32′ per mile observed between Panama and the Eureka well.

§ 197. *The Lottsville well*, drilled in the autumn of 1877, is five miles from the Eureka well, and its height above tide 1450′.

With a dip of 32′ to the mile (see § 195 above) the top of the *Panama conglomerate* should lie in the Lottsville well, 41′ beneath the surface, *i. e.*

Panama conglomerate at Eureka,	1569′
Dip, 32′ per mile×5 miles=160′,	1409′
Mouth of Lottsville well,	1450′—1409′=41′

But the well-record asserts that for the first 90′ there is nothing but sandy shales; and then, 20′ of soft *red rock.*

As the *red rocks* underlie the Panama conglomerate horizon (see § 195 above) in the country to the north, and as the dip would bring it down into the ninety feet above them here, there is but one conclusion possible, viz., that the *Panama conglomerate* (coming south) has lost its massive character and been converted into *shales* or thin argillaceous sandstones.

The alternative that the rate of dip has been overestimated, and that the Panama horizon overshoots the top of the Lottsville well, is negatived by the fact that, in the bedded rocks exposed in a ravine for a considerable distance *above the oil well*, some greenish-blue flags have been quarried, here containing very curious *fucoidal* impressions on their surfaces; but there is no well-marked horizon of massive sandstone exposed.

Unavoidable inferences.

§ 198. These meagre data are all that have been secured in relation to the Panama rock in this part of the State, and it is a matter of great surprise that a rock exhibiting such massive proportions as this at Panama (and on the range northeast and southwest, containing the quarries above mentioned) should so quickly merge to the south and southeast into the thick masses of sandy shale accompanying it, and become unrecognizable as a distinct stratum in the numerous wells of that section, and in the many cliffs and gorges where a sandstone might reasonably be expected to indicate its presence in the topography at least, although generally so drift-covered as not to be actually in sight.

§ 199. If the Panama rock were one of the *Venango oil-sands*, as has been claimed for it, we should expect to find some geographical sandstone connection between it and the particular oil-sand (whether the 1st, 2d, or 3d) which is supposed to represent it.

Any range of sandrock in Venango county from 20′ to 70′ thick, outcropping as a conglomerate of similar thickness along the Panama range, only 25 miles to the northwest of the oil-belt, would be likely to show unmistakably its horizon in oil wells drilled between the oil-belt and Panama.

But the fact is, over more than one half of this intervening area *we get no reliable expression of either the Panama rock or the Venango oil-sands* even approximating to their normal condition; and in the other half of the area what indications of them we do get only serve to prove that the Panama rock is not stratigraphically identical with either of the three (or more) oil-sands; and that they differ materially also in their respective rates of dip towards the south.

§ 200. Another and collateral proof that the Panama rock is not one of the Venango oil sands is deducible from the abundant evidences presented on all hands of a total dissimilarity in the structure of the oil sands and associate measures *when viewed as a group* from the structure of the strata accompanying and including the Panama rock *when viewed as a group.*

Facts presented in other parts of this report show that the Venango oil-rocks constitute one well-defined and consistent group of sandstones, shales, slates and red rocks; and that the sandy members of this group—whether three in number, as first discovered on Oil creek, or six or seven in number as afterwards developed in Butler county—may all be included between two horizontal planes not more than 350′ (on the average) vertically apart.

If now the Panama rock be one of the oil sands we should reasonably expect to find some of the other members of the group accompanying it. If it be the First sand, then some evidences of the presence of the Second and Third should appear at proper distances below it. If it be the Third sand, then surely some traces of the First and Second should be found above it.

§ 201. *Sub-Panama measures.*—An oil well put down immediately at the base of the conglomerate at Panama to the depth of 1200 feet encountered nothing but soft shales and slate in the whole distance.

Other wells at Clymer, Columbus, Corry, Union and elsewhere near the range of best development of the Panama rock tell the same story.

Neither do the outcrops further north, where the under-measures expose themselves on the surface, bring up to view any sandstone at all comparable with the oil sands.

Therefore the Panama conglomerate cannot be regarded as the *First* oil sand, for none of the associate lower members of the group accompany it.

§ 202. *Super-Panama measures.*—In going over the hill west of Panama to Panama station we can examine 225′ of measures overlying the conglomerate.

In going from Panama south to the Eureka well we can examine 125′ of the same measures.

In the railway cut along Coffee creek valley, 1½ miles southeast of Bear lake station (A. and G. W. R. R.) where the top of the conglomerate is probably 30′ beneath grade, we can examine more than 200′ of the same measures.

Nowhere does a sandstone stratum appear such as should be expected if the conglomerate be the lowest oil-rock.

§ 203. In this *Coffee creek valley* are several cuts, and in the deepest one appear the following rocks:

Drift on top of the point of hill cut through,	10′
Shale, sandy, with thin sandstone layers,	10′
Shale, brown, friable,	20′
Sandstone, one persistent plate, *three inches.*	
Shale, brown,	4′
Sandstone, fine, false-bedded, blue,	4′
Shale, brown,	6′
Total,	54′

§ 204. The bed of *Coffee creek* as it leaves its winding course through the hills and enters the broad valley near Pine creek station lays bare many fine exhibitions of *wave marks.* Numerous *fossil* bands are found here and some in the railway cuts, in which *Spirifer* predominate, some of them being of very large size. *All the fossils have a Chemung aspect* and seem to be identical with those found above the Panama rock in all this section.

§ 205. The Panama conglomerate, then, tried by this test cannot be the Third or lowest oil-sand; for there is plenty of room for the Second sand, at least, if not for the First, to appear above; but nothing of the kind can be seen.

§ 206. It follows as a matter of course, that not being the First, nor the Third, it cannot be the Second oil-sand; and we must conclude that the Panama rock is not any one of the Venango oil-sands; but that it is a *Chemung* rock, of greater age, lying at a greater depth; and that it fines away rapidly going south and southeast; and blending with its associate measures soon becomes untraceable in that direction.

§ 207. It seems superfluous now to attempt to prove that the Panama rock is not the equivalent of the *Garland conglomerate*, with which it has often been confounded; but a single fact bearing on this point may be added here.

On the west side of Little Brokenstraw creek, about half way between Lottsville and Wrightsville and seven miles southerly from the Eureka well, a *rock city* of unmistakable *Garland conglomerate* may be seen on the crown of the ridge.

It is near our line run (over the State road) in 1875, and its top lies about 1950′ above tide. The top of the Panama rock at this point *should be* approximately, 1345.*

Here then we have a vertical interval between the horizons of the two rocks calculated to be more than 600′, and that too without taking into consideration the notable fact that the Panama horizon is apparently dipping south at about double the rate of the Garland horizon.

The Salamanca conglomerate.

§ 208. To the foregoing summary of facts in relation to this rock west and south of Chautauqua lake, we have now to add others east of the lake, pointing to the same general conclusions.

§ 209. A line drawn from Panama to the long famous *Ellicottville* or *Salamanca rock city*, placed upon the ridge between the streams of Little valley and Great valley, 3½ miles north of Salamanca, in Cattaraugus county, N. Y.,

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* At Eureka well 1569′, 7 miles dip at 32′ per mile=224′. 1569—224=1345.

would pass over an area of comparatively low levels, the face of the country having here been subjected to excessive erosion, which has cut down the measures in most places below the horizon of the Panama rock.

This break is so wide (about 40 miles) and the chain of outcrops is so completely interrupted by it, that it cannot easily be decided whether the Panama and Salamanca conglomerates belong to the same horizon or not.

§ 210. *Dennis oil well.*—After making a hasty examination of some of the exposures of the *Salamanca rock*, in southern New York, it was thought advisable to secure a complete record of an oil well on one of the highest hills in the vicinity of Bradford, McKean county, Pa., so that the position of the rock might be definitely fixed at that place, to assist in ascertaining its dip and studying its associations. This section was completed in February, 1878, and is given in a subsequent chapter. It will be seen, however, on reference to the record, that it does not, as was hoped, unravel the knot, but rather complicates the problem by the total absence, in the suite of specimens preserved, of any sandstone corresponding in quality to the *Salamanca rock.*

This absence would be a matter of great surprise, were we not, in a measure, prepared for such a result by the absence of any good representative of the *Panama rock* in the wells holding a similar southerly relation to it, as described above.

We have seen that the *Panama rock* becomes unrecognizable in the *Lottsville well*, ten miles south of a 70′ outcrop of it at Panama.

Just so, now, at Bradford, twelve miles south of Carrollton, where a good exposure of the *Salamanca conglomerate* may be seen, we are unable to fix the horizon of the Salamanca rock in the *Dennis well*, by the lithology of any rock drilled through; for there is nothing like it in the well-section from top to bottom.

§ 211. This similarity in the physical habits of the two rocks (the *Panama* and the *Salamanca*) is suggestive at least of a similar origin and like conditions of deposition;

and it may be noted as one of the facts in support of the argument that they both belong to one formation, although their stratigraphical horizons may not be absolutely or precisely identical.

§ 212. The failure to find the *Salamanca conglomerate* decidedly developed and plainly located in the *Dennis well*, and the discovery of other *rock cities* on the hills bordering the Tunangwant creek, between Carrollton and Bradford, which have not yet been systematically traced, but which apparently lie between the horizons of the *Salamanca rock* and the *Olean* (*Garland*) *conglomerate*, makes it imprudent at present to attempt to fix the precise relative positions of these several strata.

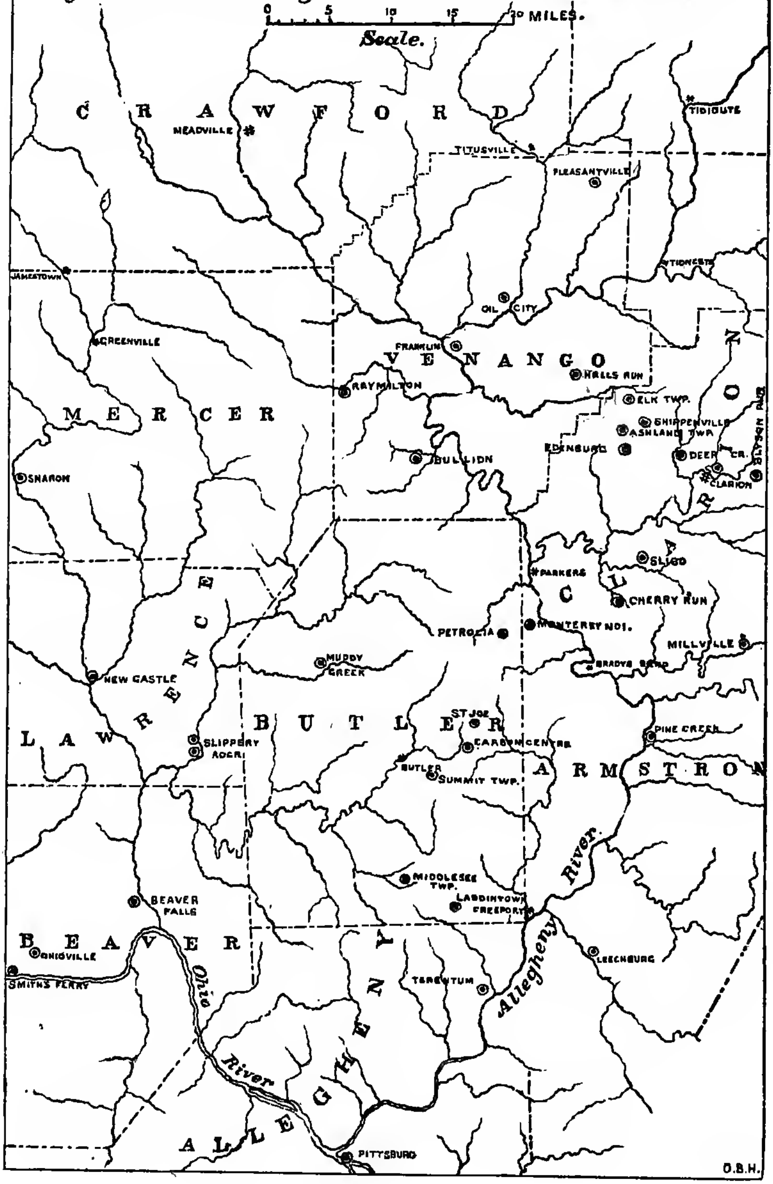
It appears most probable, however, that there are *three ranges of conglomeritic sandstones*, if not more, outcropping along these State line hills—all forming rock cities of similar character, where the conditions are favorable; and that they have all heretofore been regarded as parts of one and the same stratum.

§ 213. If this view of the structure should prove to be correct we shall then have in descending order the following series of sand formations locally conglomeritic:

1. Olean, (=Garland=Sharon=Ohio.)
2. Sub-Olean, (=Sub-Garland=Shenango.
3. Tunangwant.
4. Salamanca.
5. Panama.

But we must await further investigation before the true sequence can be satisfactorily established.

Sketch Map showing the geographical position of Well Sections given on Plates IV. V. VI. VII. XII.



CHAPTER VII.

On the Mountain sand series, and its contrast with the underlying Oil sand group.

[Illustrated by Plate IV, Figs. 5 to 12.]

§ 212. *The Pleasantville section.*—In Report of Progress I, 1874, a typical section made from oil-well records was given, to show the general geological structure of the measures drilled through at Pleasantville in Venango county.

At that time but little field-work had been done and the collection of facts was not adequate for a proper comparison and correlation of the leading members of the formation, except over a very limited area. Subsequent investigations, covering a broader field and affording better opportunities for a correct interpretation of structure, make it evident that some modification should now be made in the section referred to.

§ 213. The designations *First, Second and Third Mountain sands*, used provisionally in 1874, answered very well for the purposes of that local report; but, to adhere to the use of these ordinal numbers still, after the comparison of oil well and surface sections has been extended southwestward to the very borders of the State of Ohio, and northeastward into the southern counties of the State of New York, would only perpetuate confusion in our geological nomenclature. Other rocks than those thus numbered in early oil well borings have been found intruding into the series; and to these additional rocks fixed *geographical* names have been assigned in districts outside of and adjoining the oil regions proper. I propose therefore to adopt in this report such geographical names, and to drop the use of the terms First, Second and Third Oil sands as no longer available.

§ 214. The *The First mountain sand* appears to occupy the horizon of the *Connoquenessing sandstone* of Butler county, and the *Kinzua creek sandstone* of McKean county, and may as well therefore be spoken of when occasion requires under one of those two names.

§ 215. The *Second mountain sand* cannot indeed be robbed entirely of its name for reasons that will make themselves felt in future pages of this report. But whenever it is thus spoken of, the name must be accounted as a mere synonym for the *Garland conglomerate*, and not at all as an index to the numerical position of the rock in relation to other sands in the series. To the oil men it will always be the Second mountain sand; but to the geologist it will sometimes have another number in the series. But it will always be the *Garland-Olean-Sharon-Ohio conglomerate.* The reason for this will appear further on.

§ 216. The *Third mountain sand* will receive in this report a new name, the *Pithole grit.*

This rock was first recognized as a persistent sandstone in the *Pithole oil wells*, being well developed in all that country, and making conspicuous outcrops along the Allegheny river on the south and along Oil creek on the west.

The term *grit* sufficiently designates it as a sandstone; but what is more important, will serve to associate it in the reader's mind with the *Berea grit* of Ohio, which seems to have been a cotemporaneous formation; although the two rocks have not been traced across the country towards each other to a common place of actual meeting.

§ 217. Neglecting for the present the mountain sands as separate members of a small series, and grouping them and their intervals together as a whole, I must now show that they constitute one (and the upper member) of a larger series.

The vertical section of rocks in the oil-belt, as exhibited by the well-records, shows three characteristic subdivisions:

1. *Mountain sands*, so called by the oil well drillers.

2. *Crawford shales*, a group of shales and mud-rocks, in the midst of which lies the *Pithole grit.*

3. *Venango oil sands*, a group of sandstones and shales interleaved.

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

The oil miner's field of operation is large. He has stretched a broad cordon of wells across Pennsylvania from the Ohio to the New York State lines, and furnished from them an amount of information bearing upon the general underground structure that could have been obtained in no other way. But any attempt to work out the complete geological column of the country which he has thus perforated at numberless points, or to define the precise limits of the great Palæozoic formations known in eastern Pennsylvania as Nos. VIII, IX, X, XI, and XII, solely from the data thus obtained, would only result in disappointment and confusion.

In this report I limit myself to the study of the well records strictly as well records; and by comparing one record with another I shall endeavor to establish *the general features of structure throughout the oil district;* leaving the special surveys of adjacent districts to determine how far the several upper Palæozoic formations can here be recognized.

§ 218. *The unity of the Venango oil group*, or rather its uniformity as an oil-producing formation, is the first fact to illustrate.

It is important to state the fact clearly at the outset, that throughout the whole area which has afforded the Venango oil,—that is, along the entire length of the oil producing belt (or belts) of country,—the structure of the *oil-sand-group* is virtually one and the same. On the other hand, the moment we leave the oil-producing-area to the right or left, the internal constitution of the oil-sand-group becomes quite different.

All the wells which pierce the oil producing belts exhibit remarkably the same group of oil-sands. All wells put down outside of these belts exhibit quite a different kind of deposits when they reach the plane of the oil-sands.

§ 219. To make visible this prime fact of the geology of the region I have selected several *series of oil well records*, ranged along certain geographical lines upon the map; some of these lines following the general northeast-southwest direction of the oil belts; others diverging more or less at right angles from it and crossing the barren country.

The locations of the wells chosen for this representation are shown by spots upon a sketch-map, given on page 80 above, which extends from Tidioute in Venango county to Pittsburg. Five wells in Venango county are so marked; 10 in Clarion county; 3 in Armstrong; 7 in Butler; 2 in Allegheny; 3 in Beaver; 3 in Lawrence; and 1 in Mercer.

The vertical sections into which the records have been translated occupy Plates IV, V, VI, VII and XII, accompanying this volume; and they are arranged with the southwesternmost to the left, the northeasternmost to the right of the reader as he sees them on the map.

§ 220. *The first series* to be discussed (see Plate IV, Figs. 5 to 12) is composed of wells stretched along a line of about 80 miles in a southwesterly direction extending from Pleasantville in Venango county to Smith's Ferry, at the Ohio State line, in Beaver county.

Fig. 5. Smith's Ferry, Ohio township, Beaver county, Pa. (Record from Report Q, page 270.)

Fig. 6. Ohioville, Ohio township, Beaver county. (Report Q, p. 271.)

Fig. 7. Beaver Falls, Beaver county, Economy well No. 2. (See Appendix.)

Fig. 8. Iron Bridge, Perry township, Lawrence county, Nesbitt or Chew well. (See Appendix.)

Fig. 9. Cove Hollow, Slippery rock township, Lawrence county, Nesbitt or Shaffer well. (Appendix.)

Fig. 10. Muddy Creek, Brady township, Butler county, John Smith well. (Appendix.)

Fig. 11. Bullion, Clinton township, Venango county, Phillips Bros. well. (Report I.I., No. 1093.)

Fig. 12. Pleasantville, Venango county, Reliance well. (See Appendix.)

§ 221. *Between Pleasantville and Bullion* the essential elements of structure are so uniform and they are so well established by records from the large number of wells drilled in the interval, that there is no need of introducing intermediate sections between these points.

A section made from one of the *valley wells* at Bullion is used, because no detailed record of a *hill-well* could be obtained. The length of column is sufficient, however, for all the purposes of this comparison. It shows the oil group; an interval with red rock above the *First oil sand;* then a 20 foot sandstone with another mass of soft rock above it, and then a heavy sandstone at the top.*

The stratigraphical agreement between the Pleasantville and Bullion sections is so apparent that there can be little risk of error in identifying the sandstones and shales in one well with those lying at the same horizon in the other, and we thus trace a continuance of the Oil creek structure nearly to the southern limits of Venango county.

§ 222. A similar arrangement of strata might be shown to prevail in oil wells at Tidioute and Colorado in Warren county; Church run in Crawford county; and Sugar creek and Raymilton in Venango county.†

§ 223. *Southwest of Bullion.*—In carrying forward our comparison of sections to the southwest of Bullion, the

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*The record gives no intimation of the constitution of this 100′ SS., but it is most probable that it contains shaly layers near the centre as shown at the corresponding horizon in Fig. 10, and is not a massive sandstone from top to bottom as here represented.

† Going still further northward, the outcrop of the Garland conglomerate (with the Pithole grit where the exposures are favorable, appearing at the proper distance beneath it) might be traced in the hills of Warren county at Tidioute, Garland and West Spring Creek; and of Crawford county at Sparta, Meadville, Evansburg and Jamestown. But these details need not be repeated here as they have been sufficiently described in preceding chapters of this report.

Ferriferous limestone (the "key-rock" of the Butler county driller) becomes an important auxilliary and guide. It is well to note, therefore, that its place in the Bullion Run section would be about 870 feet above the *First oil sand;* which fact is ascertained thus:

At Clintonville, 3½ miles southwesterly from Bullion run, the *Ferriferous limestone* is found in the hilltops, and wells drilled near its outcrop show an interval of about 870′.

On the highest hill immediately south of Bullion the limestone and underlying shales cannot be found. They have been eroded off. The erosion seems to have been checked by the *Homewood sandstone*, which usually lies from 30′ to 50′ below the limestone.

Wells on this hill find *First sand* at 830 to 840 feet; which would make the interval between the *Ferriferous limestone* and *First sand*, at this point, agree substantially with that observed at Clintonville.

§ 224. *John Smith well.*—We may now pass on to Fig. 10, which is made from the register of the John Smith well, put down in 1877, by Messrs. Phillips Bros., in Brady township, Butler county, southwest (and about sixteen miles in advance) of the termination of the Bullion Run development, and twenty miles from the location of Fig. 11.

The section is so remarkably in accord with the two already compared, that it might be viewed with suspicion as having been made up from some established formula, in conformity to the views of those who always find the rocks "regular" no matter where they drill, did it not present in itself many strong evidences of its fidelity to truth, and were we not assured by the owners of the well that it was carefully watched and measured by themselves while being drilled.

The record need not be accepted, however, on its own merits alone. From the *Ferriferous limestone* down to the *red rocks* and *First oil sand* it is confirmed in a remarkable manner by wells not far distant from it—on Wolf and Slippery Rock creeks—wells put down by other parties, and whose records have probably never before been brought into comparison with this well.

Below the red rock there is a marked disagreement between the Smith well record and the others; but this is not at all surprising; it is, in fact, in keeping with observed facts in well developed territory, where the oil group changes materially in structure, or fades out quickly, in directions transverse to the trend of the deposit.

§ 225. If then the *Smith well section* may be relied upon there need be no hesitation in concluding that the general structure shown in the oil wells of Venango county prevails here also; and we may now take this well as a *pivotal point* from which to carry forward the further identification of these measures to the northwestward, to the westward, and to the southward.

§ 226. *Southwest of the Smith well.*—Continuing our course in the same direction, then, we may now compare the *Slippery Rock* well, Figs. 9 and 8; the *Beaver Falls* well, Fig. 7, and those near the *Ohio line*, Figs. 6 and 5.

§ 227. The *Ferriferous limestone* is not seen in any of these sections, as it lies above their tops.* But since it is seen outcropping above the well mouths, on the hillsides along Slippery Rock creek and the Beaver river, its place over each section is readily ascertained; and the sections are adjusted mutually by reference to the horizon of the limestone.†

§ 228. *The Mountain sands unreliable guides.*—The variableness of the several members of the sandy deposits belonging to the *Mountain Sand series* is well illustrated in these figures; as indeed it is in every case where well sections are placed side by side for comparison.

It is quite evident from a study of these sandy deposits, that no one of them, however locally thickened or largely developed in this or that particular locality, can be trusted as a sure guide to the geology (whether in an oil well, or in a surface section where the rocks are exposed to view) any further than it can be actually traced without break from

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* Only the *Ohioville well* is high enough to catch it, and in the record of this well it is wanting, the deposit being either absent, or so thin and poor as to be overlooked by the driller.

† This is shown by the addition to the Beaver Falls well of a portion of Prof. White's surface section, given in Report QQ.

place to place. When a sandstone is once lost sight of it is very hazardous to attempt to take it up again in a distant place without other proofs of identity than an apparent similarity of composition and structure; for it is plain to see that the Carboniferous measures are full of these varying strata, and one band of them often imitates so closely another in all its characteristics that no dependence can be placed on any one of them unless its identity is well assured by collateral evidence.

§ 229. *Reliability of well records when properly grouped.*—I have said a great deal in other places about the unreliability of well records. It is quite true that in most cases they are faulty in detail, and particularly so in their upper parts; but whenever a number of them are available for comparison in the same locality the *general* structure can be made out almost to a certainty. The Slippery Rock wells furnish an instance.

The record Fig. 8 exhibits the sandstone producing heavy oil, which must have been wanting (or very poorly developed) in record Fig. 9; for it is not probable that the drillers *overlooked* it, since it is one of the oil horizons which they were searching for, and the place of which they were well acquainted with.

Again, a combination of the two sections Fig. 8 and Fig. 9 taken thus as a type of the stratification in that locality harmonizes well with section Fig. 10.

So, too, a combination of Figs. 5 and 6 confirms the structure of Fig. 7.

But if we had merely Figs. 6 and 7,—or merely Figs. 5 and 9,—and no more definite horizon than the sandstones themselves to guide us, a mistake might easily be made in attempting to identify any particular stratum in one well with that in another.

§ 230. These sections on Plate IV are given, it must be remembered, for the purpose of correlating the geology of Venango and Butler counties, along a geographical interval of about fifty miles. And they are amply sufficient for the purpose; seeing that they are confirmed by scores of other wells along the line.

The uniform thickness of the *Crawford shales* between the Mountain sands and the Pithole grit,—the persistency of the *Pithole grit*,—the interval of shales always to be seen below it, carrying the characteristic *red rock* of this horizon,—and the well-sustained integrity of the *Oil group* at nearly every point, clearly establish the identifications here claimed.

§ 231. The *red rocks* grow thin in a southwest direction from the Smith well to Slippery rock creek.

The *Venango oil sands* as a group not only thin away, but disappear and are wanting in the Slippery Rock country.

Both these guides to the mutual adjustment of the well sections are therefore lost, as we proceed southwestward.

But on the other hand, the *Ferriferous limestone* in the hillsides above the derricks becomes a good guide horizon.

From the *Ferriferous limestone down to the Red rocks* the section type on Slippery rock is very much the same as that on Muddy creek.

From the *Red rocks down to the Oil sands* there is great variation, as just observed. But the variation is confined to this interval. Whatever may have been the cause preventing the deposit of the *Oil sand group* in the Slippery rock vicinity, it evidently operated only up to the time of the deposit of the *Red rocks.* After that time uniform deposits were spread over both districts, and the well sections become generally alike, up to the *Ferriferous limestone.*

§ 232. *Southwest of Slippery rock.*—At Beaver Falls and Ohioville the *Ferriferous limestone* is the key rock.

In this part of the country the cause which prevented the oil group deposits on Slippery Rock creek seems to have lasted longer. Its effects are observable in higher strata; above the *red rocks.* Not only is the *Oil group* cut out, and also the *red rock* over it, but the sandstone deposit occupying the horizon of the *Pithole grit* is enlarged; the shaly interval above the sandstone becomes sandy; and thus the true base of the *Mountain sand series* becomes somewhat obscure.

§ 233. The *Homewood* and *Connoquenessing sandstones*, fortunately, can now be added to the Ferriferous limestone as guides.

These constitute two well marked horizons, quite reliable as bases of measurement for adjusting our well sections:—the *Homewood sandstone* at Beaver falls and Smith's ferry—the *Connoquenessing* sandstone (seen lower down in the sections Figs. 5 to 10) containing in some places thin beds of shale, but recorded variously as 84′, 40′, 50′, 67′, 75′ and 100′ thick.

§ 234. *Pithole grit.*—The general harmony of structure being thus well established, there can be little doubt that the *Eighty foot sandstone* at Beaver Falls is the equivalent of the *Pithole grit*, which we have therefore now traced through from Pleasantville in Venango county to the Ohio State line.

§ 235. The *Amber oil and Heavy-oil horizons.*—It follows from this study of our sections that the Ohioville *amber oil* must be derived from the horizon of the *Pithole grit*, which also furnishes *amber oil* in small quantities on Slippery Rock creek.

It follows as logically, also, that the Slippery rock *heavy oil* is found in one of the lower members of the Mountain sand series, an horizon which also produces *heavy oil* in many wells at Smith's ferry.

CHAPTER VIII.

On the identity of the Pithole grit with the Berea grit.

[Illustrated by Plate IV, Figs. 1 to 4.]

§ 236. The *Pithole grit* forms one of the most prominent features in the sections referred to in the foregoing chapter. It appears to be more constant in its horizon, and to preserve its identity more unmistakably than any of the other sandstones along the line where the wells are located. We know, however, that in some parts of Clarion county and Butler county it is very inconstant, and is frequently unrecognizable.

It may be well then to examine somewhat into its northern and western extension with a view of ascertaining its character in that direction, and seeing what the probabilities are of its being the equivalent of the *Berea grit* in Ohio, the oil-bearing rock of the Mecca oil district.

§ 237. *Four well sections* are added to those described above, on plate IV, to assist in this investigation.*

Fig. 1. The upper portion of the *deep well at New Castle* in Lawrence county; continued upwards as a generalized section of the surface rocks, after Mr. Chance's survey along the Shenango river valley, in 1875. See Report of Progress V, page 228, Fig. 151.

Fig. 2. The *John Smith well* in Brady township, Butler county. Its rocks have been identified in the description of Fig. 10. See § 224 above.

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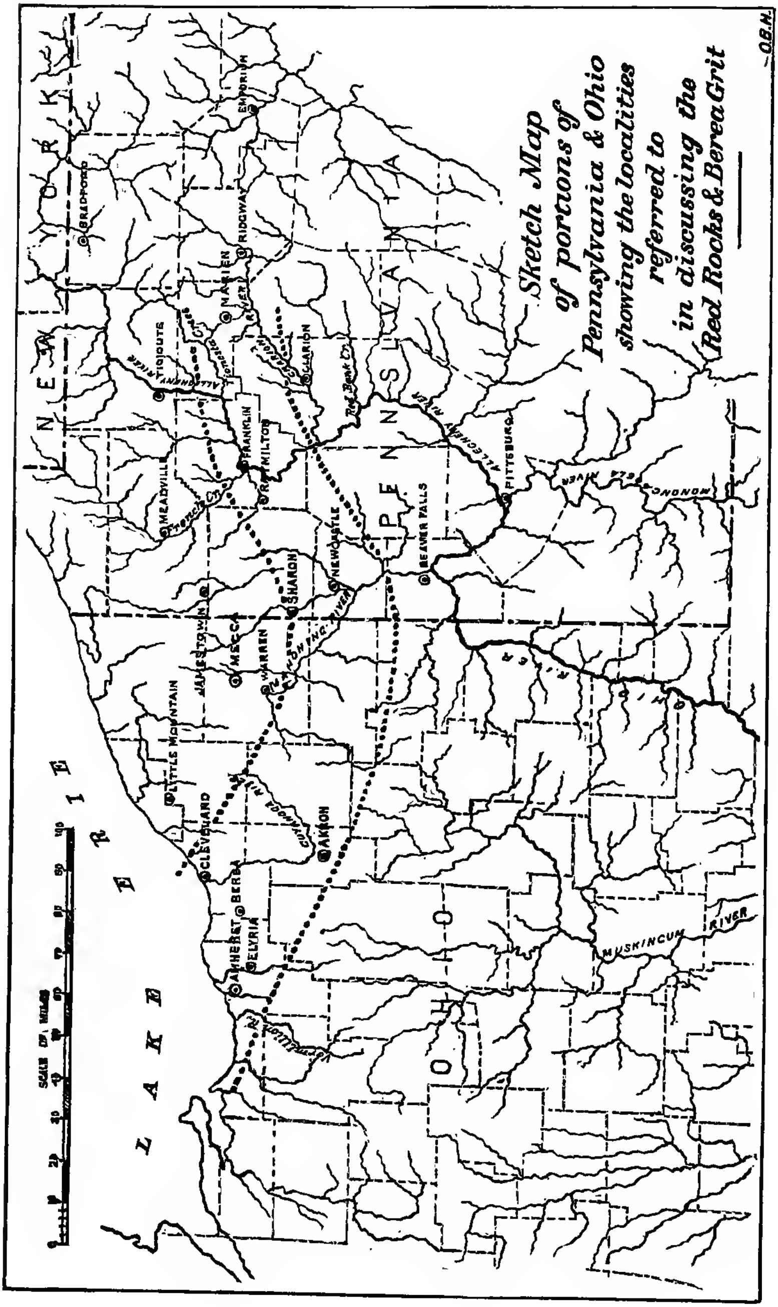
* For full records of these wells, see Appendix.



Sketch Map of portions of Pennsylvania & Ohio showing the localities referred to in discussing the Red Rocks & Berea Grit

Fig. 3. The upper portion of the *deep well at Sharon* in Mercer county; continued upwards by the addition of Mr. Chance's section of the surface rocks.

Fig. 4. The *Raymond well, No. 6*, at Raymilton in Venango county; continued upwards so as to include the Mercer coal group outcrops, in the hillsides above the well mouth.

§ 238. In studying sections made from the records of wells drilled outside of the oil producing areas, where the *Oil sand group* is not found in its integrity, and the surface rocks belong to the *Mountain sand series*, errors of identification may readily be made if one is compelled to to depend on the well records alone.

In all cases where it can be done, then, it is advisable to lengthen the well section upwards as high as to the outcrop of the Ferriferous limestone on the hill slopes. With this key rock in the sections comparisons can be confidently made with other wells situated in any direction. This plan has been adopted in Figs. 1, 2, 3, and 4; which are all four adjusted to a horizontal line above the well-mouths representing the position of the *Ferriferous limestone.*

§ 239. The horizontal coincidence of the horizons of *limestone*, *coal* and *red rocks* in these sections leaves little room to doubt that the *Pithole grit* is represented lying at a depth of 382′ in the New Castle well by the *78′ sandstone*, and of 185′ in the Sharon well by the *75′ sandstone.*

§ 240. The *Mecca oil field* in Trumbull county, in Ohio, lies about eighteen miles northwest of Sharon.

The geologists who have surveyed the State of Ohio assert that the oil-bearing rock of that district is the *Bera grit*, named from the famous quarries worked at Berea, Independence, Amherst, and other places in that State.

If, then, the 75 foot sandstone in the Sharon well could be shown to be the equivalent of the Mecca oil-rock, the propriety of identifying the Pithole grit of Pennsylvania with the Berea grit of Ohio could hardly be questioned. But as no well sections offer themselves for comparison across this interval of eighteen miles, we are compelled to resort to a calculation of dips, and a consideration of collateral evidence.*

§ 241. The following figures, taken from the Ohio Geological Reports, show *the relation of the Berea grit to ocean level* at the places named. *See map, page 92 above.*

	Above tide.	
Near the mouth of Vermillion river, ...	base 673′	top 733
Amherst, ...	“ 714	“ 774
Elyria, ...	“ 638	“ 698
Berea, ... (80′ thick,)	“ 713	“ 793
Cuyahoga Valley, N. line of Summit Co., . . .	“ 748	“ 808
Little Mountain, ...		“ 1081

Where the base of the rock is given in the Report, I have added a constant 60′ to get the top elevation, which may not be absolutely correct in every instance.

The levels of places further east, determined by our survey, are as follows:

		Above tide.
Powers Corners, oil-bearing rock, (Berea Grit,) Mecca town, O., ...		top 915*
Jamestown, Mercer Co., Pa., . . .	(Berea?)	“ 1095
Sharon, Mercer Co., Pa., ...	(Pithole grit,) . . .	“ 715
New Castle, Lawrence Co., Pa., . .	“ “ . . .	“ 428
Meadville, Crawford Co., Pa., . . .	“ “ . . .	“ 1303
Raymilton, Venango Co., Pa., . . .	“ “ . . .	“ 846
Fresh-Water rock, at Warren, Ohio,	(Berea?)	“ 765

§ 242. *The calculated average dip per mile of the Berea grit* is then as follows, (in feet:)

A. From Little Mountain, Geauga Co., O.

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* It is not to be supposed, nor is it here or anywhere else in this report intended to be asserted, that this stratum of sandstone (or any other in fact) lies in an uniform plane, susceptible of accurate and indisputable tracing in this or that direction, by the extension of the slopes which are known to obtain in one locality, into an undeveloped district miles in advance. Undoubtedly there are slight undulations and warpings in the most undisturbed of strata; but it is nevertheless evident from experience in similar cases that the general gradual southwestward and southward sinking of the formations, relative to ocean level will plainly manifest itself when a considerable distance intervenes between the points of comparison, whatever local irregularities may exist. The figures given in the text, therefore, are not intended to represent the *exact* slopes of the Berea grit, or of the Pithole grit; for in some cases, no doubt, the formations run across slightly disturbed areas; but they show the position of the rocks approximately; and they thus indicate the horizon at which one may reasonably look for them in sections.

* By barometer observation.

1.	Southwest	to Berea,	8′
2.	South	to Cuyahoga Valley,	9′
3.	Southeast	to Warren, Trumbull county, O.,	8′
4.	Southeast	to Powers Corners, (Mecca,)	5′

B. From Jamestown, Mercer county, Pa.:

1.	West-southwest	to Powers Corners, Ohio,	9.5′
2.	Southwest	to Warren, Ohio,	12′
3.	South	to Sharon, Pa.,	22′
4.	South	to New Castle, Pa.,	15′

C. From Meadville, Crawford county, Pa.:

1.	Southwest	to Jamestown, Pa.,	11′
2.	South-southwest	to Sharon, Pa.,	18′
3.	South by west	to Newcastle, Pa.,	20′
4.	South by east	to Raymilton, Pa.,	20′

D. From Powers Corners, (Mecca,) Ohio:

1.	South by west	to Warren, Ohio,	14′
2.	Southeast	to Sharon, Pa.,	12′
3.	Southeast	to Newcastle, Pa.,	14′

E. From Warren, Trumbull county, Ohio:

1.	East by south	to Sharon, Pa.,	3′
2.	East-southeast	to Newcastle, Pa.,	10.5

F. From Sharon, Pa.:

1.	South-southeast	to Newcastle, Pa.,	15′

§ 243. Of course, the concordance of these various calculations, even were it perfect, would not *prove* the rock at all these points one and the same, *i. e.*, Berea grit=Pithole grit; but it lends an additional reasonable coloring to the hypothesis. For, in a country so little disturbed by crust-warpings as this confessedly is, some reliable conclusions may be drawn from a study of the slopes of the strata when extended over considerable areas.

§ 244. The remarkably uniform declension of the *Oil rocks* towards the southwest, shown in the large diagram Plate VIII, is merely a parallel fact, illustrative as well as confirmatory of the general slope of the (higher lying) Pithole-Berea grit in that direction.

§ 245. The *red rocks* offer another open line of evidence to the above presumed identity of the Pithole grit with the Berea grit further west.

The probabilities of the correctness of the identification are greatly strengthened by the fact that a thick and persistent band of *red shale* is known to underlie the Pithole grit, all the way from the south line of Warren county to the John Smith well (Fig. 10) in Butler county, a distance of about 55 miles,—that it appears in proper place at New Castle, 17 miles in advance to the southwest,—and that the geologists of Ohio state that in their northeastern counties the only *red rock* known to them in this part of the geological column is the *red member of the Bedford shale*, which comes in immediately below the Berea grit.*

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* "Beneath the Berea grit, in northern Ohio, we find 70′ to 75′ of argillaceous shale, of which the upper portion is generally of a marked *red color*, while the lower portion is dark bluish grey. These shales are very variable in their relative thickness, sometimes one or the other filling the entire interval between the Berea grit above and the black Cleveland shale below, sometimes that interval being equally divided between them, and sometimes again one or the other greatly preponderating, while both are present. In the section exposed at Bedford the red shale is scarcely visible; while it is met with at Newburg, five miles distant, and in the hills east of Cleveland fills the larger part of the interval that separates the Berea grit from the black shale which underlies the East Cleveland quarries. At Berea and Elyria both shales are visible; while on the Vermilion—which takes its name from this circumstance—the *red shale* is much more largely developed and attains a thickness of something like sixty feet."—*Geology of Ohio, vol. 2, page 90.*

"Below the Berea grit comes in the Bedford shale, and this is exposed in all places where the sandstone is cut through. In Lorain county the upper part of the Bedford shale is generally red, and this will serve as a convenient guide in future explorations made in search of the Berea grit, it being understood that the only red shale in the county lies immediately beneath the sandstone. This red shale is well shown at the village of French Creek, in the gorge of Black river, at Elyria, in the railroad cut between Elyria and Amherst, in the quarries at Amherst and in the cliffs bordering the Vermilion in Brownhelm."—(*Vol. 2, page 212.*)

"In some localities [in Summit county] the Bedford shale is more or less red, and has been here, as elsewhere, used as a mineral paint."—*Geo. Ohio, vol. 1, p. 209.*

"Section of the rocks in the valley of Black River:

1. Berea grit, thickness,		40′ to 70′
2. *Red shale*, thickness,	Bedford shale,	30′ to 60′
3. Grey shale, thickness,		10′
4. Grey limestone, thickness,		5″ to 0′ 8″
5. Calcareous shale, thickness,		1′
6. Black bituminous shale,	Cleveland shale,	27′
7. Gray shale,		7′
8. Black shale, like No. 6,		50′
9. Grey shale to water-level—Erie Shale,		40′ "

(*Geol. Ohio, vol. 2, p. 215.*)

§ 246. *The Red Shale belt.*—In Pennsylvania this particular stratum of *red shale* seems to have been deposited in a long irregular and comparatively narrow belt,* seldom more than 12 or 15 miles in width. It is well developed at New Castle, which is probably near the center of the deposit; but only traces of it show at Sharon, on the north, and none is seen at Beaver Falls, on the south.

In Ohio, red shales are noted at various places between East Cleveland and the Vermilion river, and the limiting lines of the formation may therefore be traced approximately as shown on page 92 above. The continuity and constancy of this *red band* over such a stretch of country can hardly be without some important significance in a study of the structure where the deposit is found.

CHAPTER IX.

The two oil belts.

[*Illustrated by Plates V, VI, VII; and diagrams, on pages 99, 101, 103.*]

§ 247. No direct connection has yet been discovered between the Upper or Tidioute-Bullion oil belt, and the Lower or Clarion-Butler Oil belt.†

§ 248. *The Upper belt.*—The present southern termination of the line of productive wells on the Upper belt, is

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* The supposed limits of this belt are marked by dotted lines upon the little map on page 92, above.

† The popular names *Upper* and *Lower* Oil belts have no *geological* value, the rocks being the same. They do not mean two oil formations one lying *over* the over; but two parallel strips of oil-producing territory one further *up country from Pittsburg* than the other. It is a purely geographical distinction and has its convenience in being understood and used habitually by all oil men. The two names arose naturally out of the fact that the *Upper Belt* was first developed, far north, and high up the valley of the Allegheny river; while the later developed *Lower Belt* lies to the south and east of the other, and crosses the river valley as low down on the Allegheny river as Parker in Armstrong county.

near Clintonville in Venango county. This is about 12 miles northwest of Columbia Hill in Butler county, which is the nearest point of development on the Lower belt.

§ 249. *The Lower belt* is known to extend south-southwesterly from Columbia Hill into Summit township, Butler county, some 20 miles; and northeasterly into Elk township, Clarion county, some 15 miles. (See Map and Section, Plate IX.)

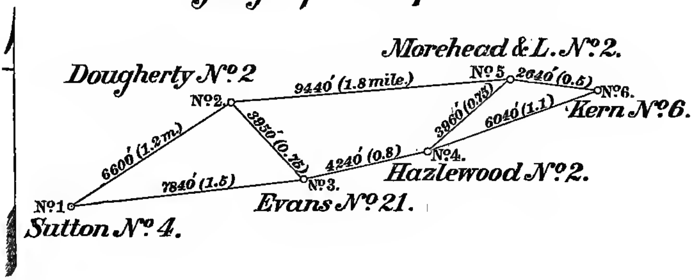
§ 250. *The interval between the belts.*—The area of country separating the two belts (say 12 miles between Clintonville and Columbia Hill, and 17 miles between Oil City and Shippenville) has been tested in hundreds of places with results in most cases quite unsatisfactory. Nevertheless, several good pools of oil have been discovered, one on Slate run and one at Gas City, both in Cranberry township, Venango county; and subsequently one at Six-Points, near Crawford's Corners, on the Venango-Butler county line, about 3 miles west of Emlenton, the development of which is now progressing. These however do not establish a connection between the belts; for the stratification is somewhat irregular throughout all this district, as far as known, and the continuity of the oil-producing rocks seems to be here interrupted.

We cannot therefore speak of the *Upper* belt as being directly connected by a line of paying wells with the *Lower;* yet the main structural features of the group in the Upper belt are observable across the interval, and the rocks themselves reappear with their characteristic aspect as soon as the Lower belt is reached.

§ 251. *The two belts are of the same age.*—That the deposits of the *Lower belt* have been subjected to more vicissitudes of water level than those of the *Upper belt,* resulting in a greater number of alternating bands of sandstone and shale within the vertical limits of the group, seems evident: yet it cannot be doubted that the deposits in the two belts were being laid down at one and the same time. They occupy the same geological horizon; they are associated with similar strata; and they exhibit a like parallelism of structure. Geologcally, therefore, the two belts may

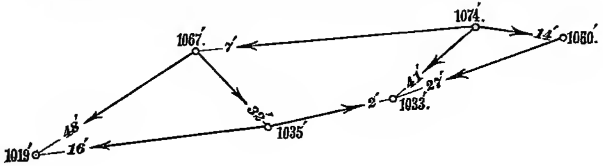
The Six Petrolia wells.

1. Their geographical positions.



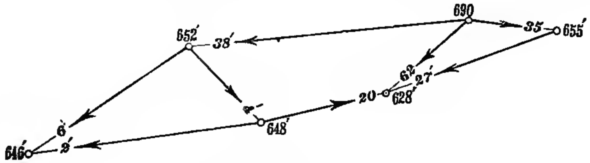
2. The basal plane of the Ferriferous limestone.

Its height above tide, and amount of slope in feet.



3. The basal plane of the Mountain sand group

Its height above tide, and amount of slope in feet.



Scale 6400' = 1 Inch.

be viewed as one and may be studied and described accordingly.

§ 252. The *Ferriferous limestone* is the drillers' key-rock in Butler county and in some parts of Clarion. In all places where it is found he knows very nearly the depth to which his well should be sunk. The interval between the limestone and the Oil Sands varies indeed somewhat in different places; but the rate of the variation, in any given direction is soon ascertained as development advances, and the well-sinker seldom makes a mistake in his calculations.

§ 253. *From the Ferriferous limestone down to the Oil sand group* the distance is astonishingly constant, as will be seen from the following tables:

DISTANCE FROM BASE OF FERRIFEROUS LIMESTONE TO TOP OF	1st SS.	3d SS.	4th SS.
In the Upper Belt.			
At Bullion,	870±	. . . .	1170
In the Lower Belt.			
Edenburg (McGrew No. 4),	823	1105	1152
Columbia Hill (Columbia No. 4),	847	1100	1152
Parker (Sheasley),	860	1075	1155
Sheakley Station (Ed. Bennet),	898	1140	1214
Petrolia (Hazelwood No. 21),	942	1147	1217
Karns (Matteson & McDonald),	980	1205	1285
Millerstown,	. . . .	1205	1275
St. Joe (Mead well),	905	1190	1270
Carbon Centre (Thompson),	947	1226	1308
Across the Lower Belt; E. & W.			
Greece (Morrison),	910	1189	1234
Modoc (Sweepstakes),	882	1182	1249
Fairview (Sutton No. 4),	919	1129	1189
Between Petrolia and Karns (Evans No. 21),	916	1155	1228
Frederick (Kern No. 6),	933	1165	
Crisswell (Boss Well),	902	1185	1270
" Cummings No. 1,	950	1173	1266

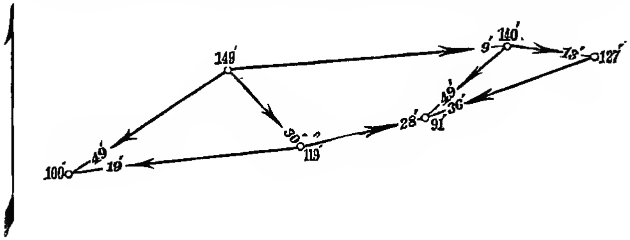
§ 254. *The variability of the distance* in different localities, observable in the above table is certainly less than might be looked for under the circumstances. For the limestone itself is slightly undulating; the *sandrocks*, also are locally irregular; and the drillers measurements are always subject to unavoidable accidental inaccuracies.

§ 255. *The maximum of interval* appears, curiously enough, to lie vertically underneath the maximum of lime-

The Six Petrolia wells.

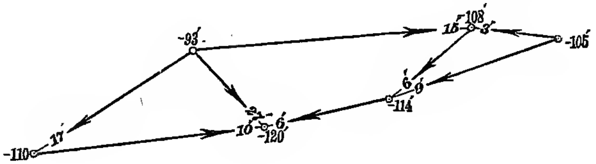
4. The plane of the top of the Oil sand group.

Its height above tide, and amount of slope in feet.



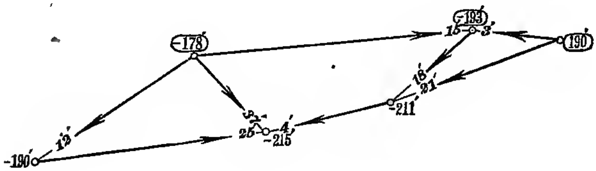
5. The plane of the top of the Third Oil sand.

Its height above tide, and amount of slope in feet.



6. The basal plane of the Oil sand group.

Its height above tide. and amount of slope in feet.



Scale 6400′ = 1 Inch.

stone; that is in the central portion of the great water-basin in which the limestone was deposited. Now, if this be anything more than an accidental coincidence, it suggests the probability that the interval does not keep on increasing southwestward, southward and southeastward from Butler, where both it and the limestone have reached their maxima of thickness; but that it will be less at Beaver Falls, Pittsburgh, Tarentum and Millville, where the limestone is comparatively thin. The sections to be given presently support this view of the case.

§ 256. *Local variability of the oil sands.*—To illustrate the local variations which occur in so-called parallel strata, not only in one locality and at one horizon, but everywhere and in all sedimentary rocks, we give below an analytical study of the six wells measured carefully for the survey, while being bored, near Petrolia, in six little diagrams and two vertical profile-sections, showing the undulations of limestone and sandrock over a small area.* A glance at these sections will suffice to impress upon the mind the radical contrast between the rude symmetry of nature and the absolute parallelism of human art.

§ 257. Sufficient data may be found in the chapter on the Venango Oil group,—in the diagram showing the dip of the Oil Sands (Plate VIII),—and in other parts of this Report, to prove that the Venango and Butler oil-rocks were cotemporaneous deposits and have a similar *general* structure throughout the oil producing districts. But in looking for a geographical extension of the *Oil Sand group* from the Butler oil field towards the southwest, south and southeast, very important and significant stratigraphical changes are noticeable; so that any proposed identification of the Butler rocks in wells at Pittsburgh, at Tarentum, or at places further round toward the east, must demand careful consideration.

To illustrate these changes, and the numerous obstacles they place in the way of such identifications, I have presented on Plates V, VI and VII, four series of grouped well sections, selected along lines starting from the oil belt where all the features of its stratification are well known,

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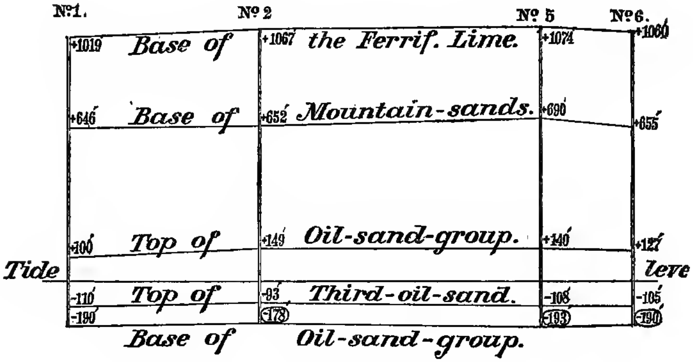
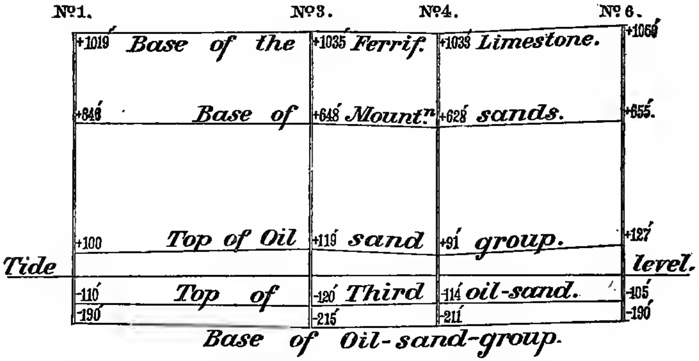
* Plates XXIV, XXV, XXVI.

The Six Petrolia wells.

1. Northern line of the polygon.



2. Southern line of the polygon.



Vertical scale 800′ : 1″.

Note. Figures in ovals (-178) &c. are calculated.

and running out in different directions into this unknown territory thus :—

Series 1. A line from the *Mead well*, near St. Joe in Donegal township, Butler county, to Tarentum in Allegheny county. (Plate V, Figs. 13, 14, 15, 16, 17, 18.)

Series 2. From *Petrolia* in Fairview township, Butler county, to the Cherry Run well in Toby township, Clarion county. (Plate V, Figs. 19, 20, 21.)

Series 3. From *Oil City* and *Franklin* in Venango county, to Clarion in Clarion county. (Plate VI, Figs. 22, 23, 24, 25, 26, 27, 28, 29, 30.)

Series 4. A cross line connecting the ends of the other three, from *Pittsburg* to Tarentum, Cherry run, Clarion and the James well, 7 miles northeast of Clarion. (Plate VII, Figs. 31, 32, 33, 34, 35, 36, 37, 38, 39.)

These four series of selected well-records will be discussed in the following chapters.

CHAPTER X.

Series No. 1, Plate V. From St. Joe to Tarentum.
Series No. 2, Plate V. From Petrolia to Cherry run.

§ 258. *Fig. 13. Mead well* near St. Joe, in Donegal township, Butler county (I.I. No. 1173). This record was made from memory by the owner and the driller, who both asserted that it was as accurate as any written record could be. It makes the interval between the *Ferriferous limestone* and the oil group less than is given in other wells in that vicinity. The well produced a large quantity of oil.

Fig. 14. Thompson well at Carbon Centre, Summit township, Butler county (I.I. No. 1175). This well produced oil from the 3d sand and was afterwards sunk to the 4th, where a flow of gas was obtained sufficient to fire 20 boilers at the neighboring wells, without any further increase of oil. Supposed to be a reliable record.

§ 259. *Fig. 15. Summit well* near Herman Station, Summit township, Butler county, (Appendix.) A fragmentary record but good as far as it goes. This well was but a small producer of oil being apparently near the southwestern termination of the Butler productive oil belt.

§ 260. *Fig. 16.* Harvey gas well at Larden's Mills, Clinton township, Butler county (I.I. No. 1181). The first great gas well from which pipes were laid to Sharpsburg, for the purpose of utilizing the gas as fuel in the manufacture of iron. (See Natural Gas in Iron working, Report L.) Record from memory but said to be correct.

§ 261. *Fig. 17. Mahan well,* Middlesex township Butler county (I.I. No. 1182 and Q. page 81). This well produced a little amber colored oil from the "1st SS." and black oil at a lower horizon, but both in unremunerative quantities. Two versions of the record are given by the owners, but they do not differ in material points.

§ 262. *Fig. 18. Graff, Bennett & Co.'s well* at Tarentum, Allegheny county, (Appendix.) No oil was found in this well. It produced only gas and salt water. The record was carefully kept and the measures passed through at this point appear to contain an unusual amount of fine sandy sediment.

§ 263. *Three horizontal lines across Plate V* will be noticed by the reader.

The upper line is intended to show the approximate place of the *Ferriferous limestone.*

The middle line indicates the approximate base of the sandy measures belonging to the Mountain Sand series.

The lower line limits approximately the top of the Venango group of oil-bearing rocks. These lines will guide the eye across the plate, and enable one to make comparisons more readily.

§ 264. The *Ferriferous limestone* is shown in all the sections except in that of the Mahan well; and here its horizon is plainly indicated by the coal beds which accompany it, which are placed at 290 feet, and 640 feet, (round numbers.) The upper coal bed, underlaid by a limestone, (whose thickness, 20 feet, is no doubt exaggerated,) must be the Freeport Upper coal. The lower one must be either the Clarion or the Brookville coal. The horizon of the *Ferriferous limestone*, then, may be considered as well established in all the sections.

§ 265. But *the base of the sandstones* beneath the Ferriferous limestone seems ill-defined; partly by reason of the incompleteness of the records; and partly because our line of study is not geographically coincident with the trend of deposition. In addition to this, it passes over the Brady's Bend synclinal and anticlinal, and well down into the fifth coal basin.*

§ 266. *Crawford Shales.*—Wherever the normal type of

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*On the theory generally accepted that the anticlinal and synclinal structure of the country was accomplished as a whole, after the close of the carboniferous era, any reference to the Brady's Bend anticlinal and synclinal in this discussion is unnecessary, since they did not exist when the Oil group and Conglomerate rocks were deposited; but there is a feeling with some geologists that the beginnings of the crust movements may have taken place early in the coal era; and been only consummated at its close.

stratification observed along the Oil belt does not obtain, there the structure becomes obscure. The shaly interval between the Mountain sands and the Oil sands, (the Crawford shales,) referred to more particularly in Chapter VIII, when not found with its characteristic Pithole grit near the center, may contain other sands in its upper or its lower part; and such sandy deposits might easily be mistaken for members of the Mountain Sand group above, or of the Oil Sand group below. For example—

§ 267. A *Shaly Sandstone close over the First Oil-sand* is noted in the well-records of some localities.

This shaly sandstone, if we were not so well acquainted with the constitution of the Oil group, might be considered a part of it. But, after ascertaining the normal structure by the examination of hundreds of well-sections, we can say without hesitation, in cases where the integrity of the oilsand group is best preserved without it, that this sandy stratum must be merely a local interpolation of coarser material in the muddy measures above the Oil-sands.

There is a great deal of sandy matter all through the *Crawford shale* in some localities, and there can be little doubt that occasional and *local beds of sand* were being spread over parts of its area during the whole time of its deposition. Changes of current and material undoubtedly took place.

We have a striking proof of this in the fact that in one district *red shale* was deposited immediately upon the First Oil sand, at the commencement of the Crawford shale formation.

In another place a few feet of *blue shale* was deposited first and then the *red shale;* and in another place blue shale first and then sand. Why not then in other places sand upon sand; that is, a Crawford shale-sandstone upon the First Oil sand?

The line of division, then, separating the Oil sand group from the Crawford shale group, would be locally an arbitrary one, and could only be drawn in agreement with the harmony of structure above and below it, rather than from any evidence furnished by the sand and shaly-sand deposits themselves.

These remarks apply with equal force to the junction plane between the *top of the Crawford shale* group and the sandstone group above it.

§ 268. The *three geological divisions* which have been adopted, (Oil group, Crawford shale, and Mountain sands,) appear in fact to blend together in such a way that no absolute planes of separation can be discovered between them in the oil well sections, except in certain localities, where the conditions have been most favorable for marking in a sharp and decisive manner the principal changes of deposit.*

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*In eastern Pennsylvania, the measures between Chemung rocks and Seral Conglomerate (No. XII) are of great thickness and the sediments seem to be easily divisible into the three groups, named by Prof. Rogers, Umbral, Vespertine and Ponent, and in the Reports of the Second Survey, Mauch Chunk red shale, Pocono gray sandstone and Catskill red sandstone.

At Broadtop City, Huntingdon County, Mr. Ashburner gives their several thicknesses as follows. (See Report F.)

Mauch Chunk red shale (Umbral),	1100′
Pocono sandstone (Vespertine),	2133′
Catskill red shale (Ponent,)	2680′
Total	5913′

At Lockhaven, Clinton County, Mr. Chance gives the following section of them: in Report F.

Mauch Chunk red shale (Umbral),	100′
Pocono sandstone (Vespertine),	1175′
Catskill red sandstone and shale (Ponent),	2106′
Total,	3381′

In Venango county the total mass of all three formations has evidently thinned down to 800′ or 900′, and with this diminution of volume there appears a corresponding alteration in the distinguishing lithological characteristics of the several groups, and their characteristic fossils seem to be promiscuously intermixed, so that the palæontological planes of distinction seem to disappear. In one place Chemung and Catskill rocks cannot be distinguished apart by their fossil contents. At another place the Catskill cannot be separated from the Pocono. At another place the Pocono sandstone group (Vespertine) apparently merges into the Pottsville conglomerate group (Seral); and the intermediate Mauch Phunk, (Umbral) seems to have disappeared entirely, or if present cannot be recognized by color, constitution or fossils.

Any single section of the rocks, as at Tarentum for instance, would furnish a very deceptive identification with strata of the same age in Eastern and Middle Pennsylvania.

§ 269. The *three horizontal lines* across the sections on Plate V, while agreeing approximately with the vertical intervals assigned to these measures in generalized section Plate XI, must not be considered to represent absolute planes of division between established geological formations. They merely accentuate to the eye of the reader the prominent groups of sandstone and shale strata penetrated by the oil wells; and render unmistakably visible their really distinct characters and their succession in the order of time.

The structure of the sections under review being thus analysed; we reach the following results, viz:

§ 270. 1. *The sandy measures* shown in the Tarentum well (Fig. 18,) from 1218 feet to 1362 feet, seem to mark the upper part of the Butler Oil-group.*

§ 271. 2. The *Gas-sand* of the Harvey well (Fig. 16) is seen to lie *above* the Oil group.

The structure of the Crawford shale mass here seems to be quite the reverse of what it is along the Venango belt; shales occupy the middle portion, and sandy measures the top and bottom; in other words, the *Pithole grit* is absent.

The Mahan well, Fig. 17, exhibits similar features; and many other wells of the same class might be mentioned.

§ 272. 3. *The (so called) First sand* of the Butler county driller, lying near the bottom (or in the lower part) of the Crawford shale, is (as shown in Chapter XII) *not* the First sand of Venango county, but a higher rock. The *Second sand* of Butler is undoubtedly the First sand of Venango.

This (so called) *First sand* of Butler is quite variable in both position and thickness, and is frequently absent altogether; as may be seen in records published in Report I.I.

In the Harvey well (Fig. 16) it lies 65′ above the top horizon-plane of the Oil-group, as shown by the records of other wells in the neighborhood.

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* I have two specimens of sand pumpings, one from 1220′; the other from 1287′. The former might properly be called a dark micaceous sandy shale; the latter is a clean, fine-grained, white sandstone. The top of the *First Oil sand* probably lies somewhere between the two points from whence these specimens came.

In the Mead well (Fig. 13) it is marked at 110′ above the oil group.

In fact well-records of different sections are so incongruous in their location of this so-called Butler "First Sand," that it is clearly not a continuous sand sheet, but a series of comparatively local beds deposited at various levels in the lower part of the (Crawford) shaly interval coming in above the Oil group.

§ 273. *Gas well horizons.*—But whatever this "*First sand*" of Butler may be, it is frequently a gas-producing rock; and so notably in some localities as to receive from the drillers the name of "*gas-sand.*" Many wells however pass through it without obtaining gas.

Prof. White says (Report Q page 84) "Just east from this [The Harvey or Lardintown well], one fourth of a mile, a well was commenced at a surface level of 125 feet above the Lardintown well and bored to the depth of 1772′. It struck no gas of any importance until the bottom was reached, when a very large supply was obtained. It was not so strong as the Lardintown well however."

At this locality the rocks are rising rather rapidly to the northwest, and I have no means of ascertaining the precise geological relations of the two well mouths; but it is evident that the deep well above referred to obtained its gas from a rock lying about 500′ below the Harvey well gas-sand; and a reference to the Thompson well-section (Fig. 14) shows that this rock must be the "*Fourth sand,*" the same stratum which furnished the large flow of gas in that well, and which also, further to the north, produced the celebrated gas-wells known as the Burns and the Delemater, near St. Joe.

§ 274. But attention should be called to the fact that the production of gas is not confined to any one particular stratum of our oil measures.

We have powerful gas wells in McKean county from Chemung rocks 1000′ or more below the Venango oil group.

The gas at Fredonia, N. Y., and Erie on the lake shore comes from still lower strata.

As to our Venango oil-group—gas is in the Fourth sand, in the Third, in the Second, in the First, and in sands higher still in the series, above the oil-group, as we have just seen.

At all these horizons heavy gas-wells have been obtained, in different places, at one time or another. It appears to be an universal product, confined to no particular horizon or locality; but *why* it is found in this place in one rock, in that in another, is as much a matter of speculation as are the questions concerning its origin and the sources of its supply.

Series No. 2, Plate V. From Petrolia to Cherry run.

§ 275. This series consists of only three wells, as follows:

Fig. 19. Evans well No. 21 (I.I. No. 1201) four fifths of a mile southwest of Petrolia, measured for the survey by John H. Carll, and specimens of sand pumpings preserved.

Fig. 20. Binkard well No. 1 (I.I. No. 1163) Perry township, Armstrong county.

Fig. 21. Cherry run well, Plyer farm, near the centre of Toby township, Clarion county (Appendix).

These sections are all reliable and the structure is so plain that no comment is necessary.

CHAPTER XI.

Series No. 3, Plate VI. From Oil City to Clarion.

§ 276. This series consists of nine borings, full records of which may be found either in Report I.I., or in the Appendix to this volume.

Fig. 22. *Hains well*, on Halliday run, Oil City, Venango county.

Fig. 23. *Washington well*, near P. T. and B. Ry. station, Franklin.

Fig. 24. *McGrew well* (I.I. No. 1059) near Halls run, Cranberry townspip, Venango county.

Fig. 25. *Oelschlager well No. 1* (I.I. No. 1116) Ashland township, Clarion co.

Fig. 26. *Schreiber well,* Strotman farm, Elk township, Clarion co.

Fig. 27. *Columbia Oil Co. well No. 19,* H. Keiser farm, near Edenburg, Wheatland township, Clarion co.

Fig. 28. *Hope well* (I.I. No. 1117) 1 m. N. W. of Shippenville, Elk township, Clarion co.

Fig. 29. *Rohrer well No. 2,* on a branch of Deer creek, 1½ m. south of Shippenville, Elk tp., Clarion co.

Fig. 30. *Griswold well,* Rattlesnake Gulch, near Clarion, Clarion co.

§ 277. Scattered over quite a wide area these well-sections afford an excellent opportunity for comparing the oil-rocks of the old Venango district with those of Clarion county, and a short study of them must convince any one that *the lower line* drawn across the plate approximately *represents the top plane of the Venango Oil-group* in all the wells.

§ 278. None of the sections commence high enough to catch the *Ferriferous limestone;* but its position has been calculated at the Washington well from one of its most northerly outcrops in Cranberry township; and it is seen near Columbia well, No. 19, lying only 2′ above the level of the well-mouth. These are the only places where we have the data for locating it; but a line drawn across the sections through these two points will indicate very nearly its horizon at all of the other wells.

§ 279. The *Mountain sands* are not shown in Figs. 22, 24, 26 and 29, simply because the drillers omitted to note them in the records.

The *bottom member* of the Mountain-sand group, in Fig. 23, is supplied from quarries opened in the hillside above the well-mouth, and also in several places at Franklin.

§ 280. The *Pithole grit* is also supplied, in Fig. 23, from other wells in the vicinity; but it appears of diminished size in the wells to the southeast of section, Fig. 24; not only thin, but graduating into shale.

§ 281. The Rohrer well, No. 2, section, (Fig. 29,) is quite imperfect in the upper part; and it is only given because it goes down to an unusual depth. The following notes accompany the record, and suggest what must be inserted in order to make it complete.

"The regular strata of first, second and third sands were passed through, but we kept no record of the first and second sands." "Water was cased off at 260 feet." No doubt just below the Mountain sands, as is usually the case. We thus get the approximate place of the base of these sands.

"The first red rock was struck at 660 feet." As there is no red rock above the first sand in this region, the first sand must have already been passed. We may fairly presume, also, as they were evidently drilling without noting details in this part of the well, that the red rocks above the "Big red" were overestimated for the Second Oil sand should come in here.

With these additions and corrections (and they are evidently called for) the section will be similar to the very reliable one furnished by the Hope well (Fig. 28).

§ 282. *Red shale above the Oil Sand group.*—One of the most noticeable features in this group of sections is the manner in which the red rocks vary.

In Fig. 23, 115′ of *red shale* is seen *above the First sand;* in Fig. 24 only streaks of red mixed with grey; and in Fig. 25 it has disappeared entirely.

This is the red band traced in chap. 8 all along the Venango belt and thence to New Castle and so on into Ohio; but it is not, to my knowledge, found above the Oil group in any part of the Clarion or Butler districts.

§ 283 *Red shale in the Oil Sand group.*—The main red rock of the Clarion field is the "big red" or "blood rock;" a stratum of dark-red shale, (as its name implies,) from 30′ to 45′ thick, lying *between the Second and Third sands.*

§ 284. *Red shale below the Oil Sand group.*—There are also other red rocks interstratified at various levels with the oil sands, and extending down two or three hundred feet below them, in some localities to the southeast of the oil-producing belt.

If one had in hand for comparison merely the sections Figs. 23 and 30 he might very naturally fall into the error of identifying the 115 foot red rock in Fig. 23 with the 90 foot red rock in Fig. 30; in which case he would suppose that the measures between the Red rock and the *Ferriferous limestone* thickened toward the southeast.

But with the whole group of sections before him, the reader cannot make this mistake. The red shales are plainly seen to be *local and variable deposits*, occupying intervals in one well, which are filled with grey shales in another well only a short distance from it. Evidently these red deposits are not to be depended upon as horizons to work from, except over restricted areas, and in certain directions.

Going toward the southeast the red bands become more numerous and occupy lower levels successively in the oil group. The general parallelism of the whole series, however, being preserved, it is evident that the red rocks seen low down in the oil group at the southeast can have no connection with those seen higher up in the group at the northwest; and that those found to the southeast of the producing belt, below the place of the oil group, can have no connection with those of the oil group itself.

CHAPTER XII.

Series No. 4, Plate VII. From Pittsburg to Clarion county.

§ 285. This group of well sections extending, from Pittsburg to Blyson run in Mill Creek township, Clarion county, 7 miles northeast of the town of Clarion, is composed of nine, all (except 33, 37 and 39) to be found recorded in the Appendix to this volume.

Fig. 31. *Boyd Hill well* in the city of Pittsburgh.

Fig. 32. *Graff, Bennett and Co.'s well* at Tarentum, East Brady township, Allegheny county (Fig. 18 in group No. 1).

Fig 33. *Leechburg gas well* (I.I. No. 1191) at Leechburg Allegheny township, Westmoreland county.

Fig. 34. *Pine creek well*, on the Allegheny river flat near the mouth of Pine creek, Pine Valley township, Armstrong county.

Fig. 35. *Midland well No. 1*, at Millville on Red Bank creek, Red Bank twp., Clarion county.

Fig. 36. *Cherry Run well*, on Cherry run a tributary of Clarion river, near the centre of Toby township Clarion county. (Fig. 21 in group No. 2).

Fig. 37. *Sligo well* (I.I. No. 1121) on Licking Creek, a tributary of Clarion river, Piney twp., Clarion county.

Fig. 38. *Griswold well No. 1*, Rattlesnake Gulch, near the town of Clarion. (Fig. 30, in group No. 3).

Fig. 39. *James Well* (I.I. No. 1120) Blyson run, Mill Creek township, 7 miles N. E. of Clarion.

Boyd's Hill, Pittsburgh well.

§ 286. The section of the Pittsburgh or Boyd Hill well (Fig. 31,) as here given, differs somewhat from that published and commented upon in Appendix E to Report L.

When Prof. Lesley examined the specimens of drillings in Pittsburgh they were packed, layer upon layer, in large glass jars, in the order in which they came out of the well;

and consequently only the top layer of each jar could be critically examined. In that shape, (like glass tubes similarly packed, which many esteem so highly) they were of very little use in studying the character of the sediments.

The drillers had passed through the *Ferriferous limestone* without noticing it, as it was thin and lay nearer the surface than they calculated and, mistaking another limestone for it, had given it a place in the record 220′ below its proper position.

As the specimens were packed, the drillings from the interval where the *Ferriferous limestone* ought to have been found, and also of the interval said to contain limestone, were both covered by other layers, and none of the material could be taken out for a chemical test. All this cast a shadow of uncertainty over the whole record.

§ 287. On one of my visits to Pittsburgh, since the publication of Report L, the owners of the well kindly made a donation of the whole collection of sand pumpings to the survey. I carefully dipped the materials from the jars, layer after layer, keeping only the central portion of each layer, and throwing away the top and bottom where any intermixture of material occurred. Assisted by Dr. Hunter with his drilling record in hand, I put the specimens in paper bags, marked them in agreement with the record, and shipped the whole to Pleasantville. I have since filled a set of bottles and labeled them so that each specimen may be examined separately and compared with any other in the large collection prepared in the same manner for the State Museum.

The section as given on Plate VII, agrees with the specimens as thus arranged; and there now appear to be but two or three points in the record open to question; and these are quite immaterial in a study of the general structure.

§ 288. Where the *Ferriferous limestone* should be looked for (taking the coal beds and sandstones of the record for guide) I found small pieces of limestone, intermingled with the dark bluish-gray sandy shale drillings. But as only one specimen of drillings through 15 feet of well had been preserved, the thickness of the limerock and the part of the 15 feet interval which it occupies must of course remain unknown. I judge that had it been, say, more than 5 feet thick, it would have compelled the attention of the drillers, even although they were looking for it at another horizon.

§ 289. *Limestone* is plainly to be distinguished also in the drillings from 879′ to 914′, where the drillers *supposed* the Ferriferous limestone to lie; but the geological significance of this we need not stop to consider here.

§ 290. A "*White lime*" is marked below the *Ferriferous limestone* in the Harvey and the Mahan well records (Figs. 16 and 17); but there is no way of finding out whether it is really a limestone or only a driller's name.

Doubtless *local deposits* of limy strata would frequently be found at various horizons in the oil wells if the sand-pumpings were carefully tested; but no attention is given to such strata, except when some test-well is being put down where the position of the *Ferriferous limestone* is not known, and it becomes necessary to watch for it with unusual care. Traces of limestone are sometimes thus brought into notice which otherwise would have been overlooked, and which are seldom heard of again in subsequent adjacent wells, after once the proper position of the *Ferriferous limestone* has been ascertained.

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§ 291. *The extent of country* over which these sections are distributed may be seen from the following rough measurement of distances:

From Mead well (Fig. 13) to Pittsburgh (Fig. 31), in a direct line, 35 miles.

From Evans well No. 21 (Fig. 19) to Millville well (Fig. 35), 22 miles.

From Franklin (Fig. 23) to Clarion (Fig. 38), 25 miles.

From Pittsburgh (Fig. 31) to James well (Fig. 39), 67 miles.

§ 292. In comparing sections over so wide a range of territory, it is not to be expected that they should agree in detail. Indeed, it would be contrary to every known law of sedimentary deposition if they did. From the very nature of the mechanical agents employed and the materials wrought upon, local irregularities of structural constitution should be looked for, among the subordinate members of a group, even where a marked parallelism might be seen to exist between the general division-planes hypothetically adopted as separating one characteristic series of rocks from the next above or below it. We shall be well satisfied, for the present, if we be able to trace approximately these primary divisions; the subordinate ones are of secondary importance.

§ 293. *Leechburg gas-sand in the Pittsburg well.*—If we have correctly traced the first oil sand in groups Nos. 1, 2 and 3 (Plates V and VI) down from the producing oil belt to the wells at Tarentum, Cherry run and Clarion, it seems probable from the arrangement of sections in Group No. 4 (Plate VI) that the sandstone in the Pittsburg well at 1590′. represents the top of the oil group. It is also evident that the Leechburg gas-sand belongs to the same horizon.

§ 294. The *James' well record* as published in report I.I. needs some modification. It there appears as if the first 435′ from the surface was all sandstone, which is not the case. This part of the record seems to have been rather vaguely kept. The facts given in a note accompanying the record are as follows and the accompanying section is made accordingly.

"Conductor 25 ft. to a rotten sandstone."

"White mountain sand struck at 278 feet."

Leaving 253 feet to be represented by rotten sandstone and unknown strata: next

"Fresh water cased off at 314 ft. in a *grey sand.*"

Consequently the "white mountain sand" must have been less than 36′. We have called it 30′.

"Struck a 90 ft. grey sand at 435 ft.. Oil in this rock at 445′ and 518′—it rose in the hole from 60′ to 80′ in a few minutes."

We have then from 308′ to 435′=127′ to represent the grey sand and unknown measures below it; and, in all probability, the "90′ grey sand" was rather a series of sand shells than a solid sandstone. Below this the record is very precise, no point being left open for question.

§ 295. One other matter should be mentioned in connection with this well. From 2063′ to 2112′ the record gives "49 ft. of olive shale with brown shells." Mr. James' description of this is as follows—"49 ft. of olive shale and sand shells—a light-brown colored sand alternating with the shale, each sand showing oil and gas. The sand is greasy to the touch and smells of oil. These streaks of sand run one to eight feet thick. A description which would apply equally well to some of the Chemung oil-rocks of McKean county to which series this deposit undoubtedly belongs.

§ 296. It only remains, now, to note the contrast between the rocks of the oil group as shown along the oil producing belt, and those at the same horizon as seen in the last group of sections; and to offer if possible some plausible hypothesis to account for it. This is done in the next chapter.

CHAPTER XIII.

Contrast between the producing and non-producing areas of the oil-sand group.

§ 297. Previous to our present survey, the Venango oil-sands were universally regarded as of *Chemung age.*

In the summer of 1875 evidences began to accumulate pointing strongly toward the probability that they were of more recent date; but the idea seemed then so heterodox, and the facts to support it were at first so meagre and questionable, that no definite conclusion on the subject could be immediately arrived at.

Even now, their relative place in the Palæozoic column of eastern Pennsylvania cannot be precisely and positively indicated. We can only say there are reasonable grounds for inferring that they *do not belong* to the *Chemung* formation, as represented in New York State and in eastern Pennsylvania.

§ 298. That *the close of the Chemung period* was accompanied by movements of the earth-crust of at least sufficient importance to interrupt the uniform conditions of deposition previously prevailing over a large portion of western Pennsylvania, cannot be questioned; for, bands of coarse conglomeritic sandstone, indicative of such movements, make their appearance near the top of the formation, in marked contrast to the homogeneous deposits of shale and slate below them.

§ 299. We may infer that these coarse sediments which lie as a group of *transition strata* between the deposits of the *Chemung* age and the deposits of the next following *Catskill age*, represent a considerable interval of time.

During this interval-age changes in the general relations of land to sea must have been going on. These changes would affect the character of the deposits in some districts and not in others; and thus the nonconformity was established between the present vertical section of western Pennsylvania with that of eastern Pennsylvania and New York.

I can imagine that a vertical movement of sea bottom to the extent of say one hundred feet would have an effect upon the subsequent deposits, varying according to the depth of water; scarcely perceptible where the sea was deep, and where the same class of deposits would go on if the same kind of material were furnished; but where the water was shallow, sufficient to materially alter the nature of the deposits, and even to change the bottom into dry land, or *vice versa.*

Thus, the deposits in one area of the State may be very uniform; while in another area, deposits of that same age, and laid down in the same sea basin, may be quite heterogeneous.

§ 300. Furthermore, while such movements left the general system of *currents carrying along the materials for deposit* practically unchanged in force and direction, it might and probably would happen that the *character of the materials carried* would suffer some and perhaps a notable change. The shore lines being shifted by the shifted sea level, new sources of material would be exposed and utilized; a different range or country of rocks in place would be eroded; consequently a different kind of sediments would be laid down.

Where the water was deep, there the red sands of the Catskill would immediately cover the brown and olive muds of the Chemung, and the change would be sudden and distinctly marked. But in the shallower parts of the sea-basin an irregular series of the two would be in process of deposition at the time; alternations of red Catskill and olive-brown Chemung strata would be made; and thus a transition series would take the place of a sharply defined plane of distinction.

§ 301. A corresponding change in the animal life of the period would take place; and while in one area the change from Chemung fossils to Catskill fossils would be at once and complete, in another area forms characteristic of the Chemung age would be mixed with or alternate with characteristic forms of the Catskill age next succeeding it.

§ 302. A comparison of the structure and depth of sediment belonging to the Catskill, the Pocono, and the Mauch Chunk periods in eastern Pennsylvania with those of the same ages in western Pennsylvania leaves little room to doubt that the former represent deposits in a much broader and deeper sea than the latter—a sea perhaps whose bottom was undergoing a steady depression in the east while it was alternating between depression and elevation, and gradually shallowing, in the west.

An elevation of ocean bottom near the close of the Chemung period seems to me to have thrown off the waters from a large portion of its former bed in the west, leaving submerged in that direction only a narrow arm of the sea, representing perhaps some old sub-marine valley. This comparatively contracted and shallow basin must necessarily, from the very nature of the case, have been the repository of immense deposits of *re-worked Chemung sediments*, rapidly brought into it from the newly emerged mud-land, to be interbedded with the *Catskill reds* which were intermittently swept in from the east to greater or less distances as circumstances directed.

We might then expect to find in this basin precisely what the drill discloses—alternations of *Catskill red* and *Chemung grey* argillaceous shales, occupying the deepest part of it; and more sandy deposits lying around its edges.

§ 303. It is not surprising then to find that the representation of the *Oil-sand group* (in Plate VII) by records of wells in the barren country, differs materially from that of Plates IV, V and VI constructed from well records along the oil producing belt.

The rocks in Plate VII evidently lie in a deeper part of the basin. *Red shales* appear more abundantly and at lower levels. The *sands* are finer; of more uniform texture; and more micaceous. They look like sediments deposited over areas where the transporting currents, having just motion enough to hold this kind of matter in suspension, met dead-water and dropped the burden. In such situations deposits take place rapidly, as we know from forming sand bars at the present time; and in this fact we have a sufficient explanation of the additional thickness of the measures which I consider to be of the same age as that of the Oil-sand group.

§ 304. But although the Oil-sand group appears to be thicker in some of the sections along this line (Plate VII) than along the oil-producing belt, it is nevertheless unproductive of oil as far as yet developed. Whether this may be owing to a lack of the material required for the formation of oil, to a poorer quality of sand rock, to the universal intermixture of a large amount of argillaceous matter throughout the whole mass, to the quality and conditions of the measures below, or of the cap rock above the sands, to the depth at which the oil sand lies below surface and sea level, or to one or all of these conditions combined with unknown causes—who can say? The facts have been presented, let each investigator decide for himself.*

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*The relationship of the Devonian rocks of Western Pennsylvania to those of the Middle and Eastern districts and to the mass of the Catskills may possibly be illustrated by Prof. Geikie's correlation of the Lower Old Red Sandstone south of the Ord, with the upper portion of the great Caithness flagstone series, in the last paragraph of his memoir "On the Old Red Sandstone of Western Europe," published as No. XVI of the Transactions of the Royal Society of Edinburgh, Vol. XXVIII, page 345 to 448, and read April 1, 1878.

Resumé.

§ 305. It may not be amiss now to glance hastily over the *general structural features* of the whole district as summarized from the facts advanced in other parts of this report. If it be found that the superincumbent rocks exhibit similar peculiarities of structure to those claimed above for the Oil-sand group,—if they all seem to indicate by the quality of their sediments and the manner of their strewing that there was open water to the southeast and dry land to the northwest,—the probabilities of the correctness of our conclusions in relation to the Oil-sand group will be greatly augmented.

§ 306. *The Panama Conglomerate.*—We may commence with the Panama rock, the lowest conglomerate, geologically, in the measures we are speaking of. Its best exposure is in Chautauqua county, New York, where it attains a thickness of 70 feet. Going southeast it sinks gradually,

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He explains his views thus: The southern margin of Lake Orcadie (the Devonian sea) did not extend beyond the Ord, during the greater part of its history. All south of that granitic ridge was land. Scotland extended then much further northward than now. The depression went on to the north. Late in the flagstone age the depression began to allow the land south of the Ord to be overflowed. The Devonian waters slowly crept southward, filling up the hollows leading up into the Grampians and penetrating to the heart of the mountain country. Gravel banks were formed along the new shores at successive levels, especially in such recesses as that of Cawdor. Northern fish found their way southward, but when they died were buried in a calcareous silt, and around their bones nodules were formed. These silts represented intervals of changed conditions, not frequently recurring. As a rule sand and gravel were deposited on the lake bottom, and in these scarcely any fish are found.

An analogous state of things in Pennsylvania might be thus expressed: The depression went on through the Chemung age unequally, the greatest sinking being through Middle Pennsylvania. By the time the first Catskill deposits were being deposited in still deep water there, the Chemung basin had shoaled up westward toward Ohio and southward in Virginia, and low mud flats appeared, by an arrest of sinking, or by a slow elevation further west. This action limited the red Catskill deposits (IX) to the eastern area. Afterwards the general depression permitted the western area also to receive soft deposits, corresponding therefore then to the Gray Pocono deposits (X) in the eastern area. But the western deposits were in shallow water, and at intervals were charged with iron, and so constitute now the red bands of X, the reds of the Oil region, &c. This was followed by the great deposit of Mauch Chunk red shales of XI in the east, represented by gray shales in the west and limestones and coal beds in the south.—J. P. L.

and finally disappears beneath water level in the southern part of Erie county, Penna. Where last seen it has lost much of its conglomeritic character and become greatly reduced in thickness. If traced transversely to this line, that is towards the south and southeast, it soon passes into sandy shale, loses its individuality, and becomes unrecognizable as a sandstone.

§ 307. The *Salamanca Conglomerate* or Ellicottville rock, another conglomerate very similar in aspect to the Panama, is best exposed in Cattaraugus county, New York. Its geological horizon is apparently from 200′ to 300′ higher than the Panama rock, which in its trend, slope and physical characteristics it closely imitates.

These two conglomerates by their positions and fossils and by the fossils of their associate strata, are evidently of Chemung age; and, from their ascertained dips toward the southeast, and all the traces that can be obtained of them in well borings on the interval between their outcrops and the productive oil belt, the inference is that they are narrow ranges of pebbly sandstones trending in a northeast southwest direction and that they soon merge into shale when traced toward the south or southeast.

§ 308. *The Oil-sand group.*—Ascending the geological scale, the Venango oil sands come next in order. Whether these rocks be Upper Chemung, Catskill or Lower Pocono need not be discussed here, as it is the *geographical range* of the formations and the *manner in which the sediments have been laid down*, and not the *age* of the strata, that we are now considering. Wherever this group is found in its integrity it is always deeply buried from sight. Like the conglomerates mentioned above, it also trends in a northeast southwest direction, and the several sandy members become more argillaceous when traced toward the southeast. The range of its maximum development lies some 25 miles southeast of the range of the Panama rock.

§ 309. *The red belt.*—Above the Oil group comes in the persistent band of red shale before referred to; sometimes 125′ or more in thickness, and spreading out over many square miles of the Venango Oil belt; but nowhere in Pennsylvania showing an outcrop to the north or northwest although its horizon is in many places above water level.

§ 310. The *Pithole grit*, lying still higher, is a massive sandstone, well defined along the Venango Oil belt as we have seen above, and traceable in frequent outcrops at the north and northwest of it, but scarcely recognizable in the oil wells of Clarion county and Eastern Butler.

§ 311. *The Garland* (*Sharon*, *Olean*) *conglomerate.*—Then the remnant outliers of the *Second Mountain sand* (the conglomerate of Olean, Garland, &c.) may be seen sweeping around to the southeast of the before mentioned conglomerates of Salamanca and Panama. This rock too fines down in composition and frequently thins out or becomes interstratified with shale as it spreads toward the southeast.

§ 312. The *Sharon coal group.*—Investigating still further, we find the lowest or oldest coal beds coming in a short distance to the southeast and south of the outcropping conglomerates in Ohio, and in Crawford, Venango, Warren and McKean counties in Pennsylvania.

These coals are not discovered in any of the drill holes over the central parts of the basin. They lie in detached, irregular and restricted areas, as if accumulated in landlocked bays, and swamps, at the dawn of that luxuriant era of vegetation which in a later day spread the thicker and more persistent Lower and Upper Productive coal-measure beds over the central portions of the great water area filled by this nearly to sea level.*

§ 313. *The Berea grit* in Ohio is said to gradually pass from the coarse and sometimes conglomeritic sandstone, seen in its northern and western outcrops, into flags and sandy shale as it is traced towards the south and east. The conglomerate underlying the coal measures fines down or thins out in the same directions, and the lower coal beds fol-

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*In Ohio, however, the preparatory conditions for large continuous coal beds were accomplished earlier than in Pennsylvania; so that, what are scattered patches of thin poor coal (Sharon and Mercer) in Pennsylvania, are in Ohio regular and continuous large coal beds; and therefore the Lower *Productive* coal series of the Ohio geologists does not terminate downwards at bed A of the Clarion series of the Pennsylvania reports.—J. P. L.

lowing the trend of the conglomerate are lost in passing transversely to it, toward the great central coal basin.

There is nothing in all these facts to conflict with the views advanced above in relation to the deposition of the oil sands; but on the contrary, they appear to furnish confirmative evidence of their probability.

CHAPTER XIV.

The Venango oil group.

§ 314. The "*Group of the three oil Sands*" was referred to in Report I, and a number of sections of its oil rocks were given, made from well records obtained in Venango county. Continuing in this report the same line of research, I will now give some additional similar sections, for the purpose of illustrating the extension of the group *south-south-westward*, into the counties of Clarion, Armstrong and Butler, where it is as plainly recognizable by its structure, position and general characteristics as it is in Venango county.

§ 315. *Four plates* occupying pages 129, 131, 133 and 135, each plate containing seven sections, drawn to a common scale, and representing (in diagram) records of wells located in different parts of the district, are designed to exhibit the varying positions and thicknesses of the several sandy members of the group.

The well-sections on each plate are numbered from left to right, to correspond with the southwest-northeast arrangement of the first three, and the northwest-southeast arrangement of the fourth.

Series—Figs. 40 to 46—extends from Bullion in Venango county, to Tidioute in Warren county.*

Series—Figs. 47 to 53—extends from Carbon Centre in Butler county, to Parker City in Armstrong county.†

Series—Figs. 54 to 60—extends from Columbia Hill,

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* See note *a*, Chapter XV.

† I am compelled to leave Fig. 49 blank, for the reason that no detailed record of the oil group could be secured at or near Millerstown, although special efforts were made to get one. The depths to *Ferriferous limestone* and "3d sand" were all the measurements that could be obtained—another illustration of the indifference of the well driller to anything but his "key rock" and the oil sand.

near Parker City, in Butler county, to Shippenville in Clarion county.

Series—Figs. 61 to 67—extends from Greece City in Butler county, to Criswell City in Armstrong county; along the "*Cross Belt*" or "*Fourth Sand Belt*" of Butler county.

The integrity of the *Venango Oil-sand group* must be kept in clear view if the value of these sections is to be fully appreciated.

It is a group in the strictest sense of the term. It has a well-defined top and a well-defined bottom.

It is *overlaid* by several hundred feet of measures—the Crawford shales—which have a plainly different character.

It is *underlaid* in like manner by hundreds of feet of measures—Chemung—which (whether belonging to the same epoch or not) have as plainly different a character.

§ 316. *Over the Oil-sand group*, everywhere along the Oil-belts, lie from 400′ to 500′ of soft rocks, unmistakably separating it from the Mountain-sands above.

This great soft formation outcrops in a broad belt through Warren, and covers a great part of Crawford county,* beneath the northern Drift.

Along the Venango Oil belt it is split by the *Pithole grit* into two divisions, of nearly equal thickness.†

Its *upper* division (above the Pithole grit) may be called 195′ thick; but there is often a considerable difficulty in fixing its top, on account of occasional or local massive sandstone layers, similar in all respects to those of the Mountain-sand series above it.

Its *lower* division (under the Pithole grit) is much more easily measured, averaging 185′ in thickness, and so homogeneous that the drill makes more rapid progress in passing

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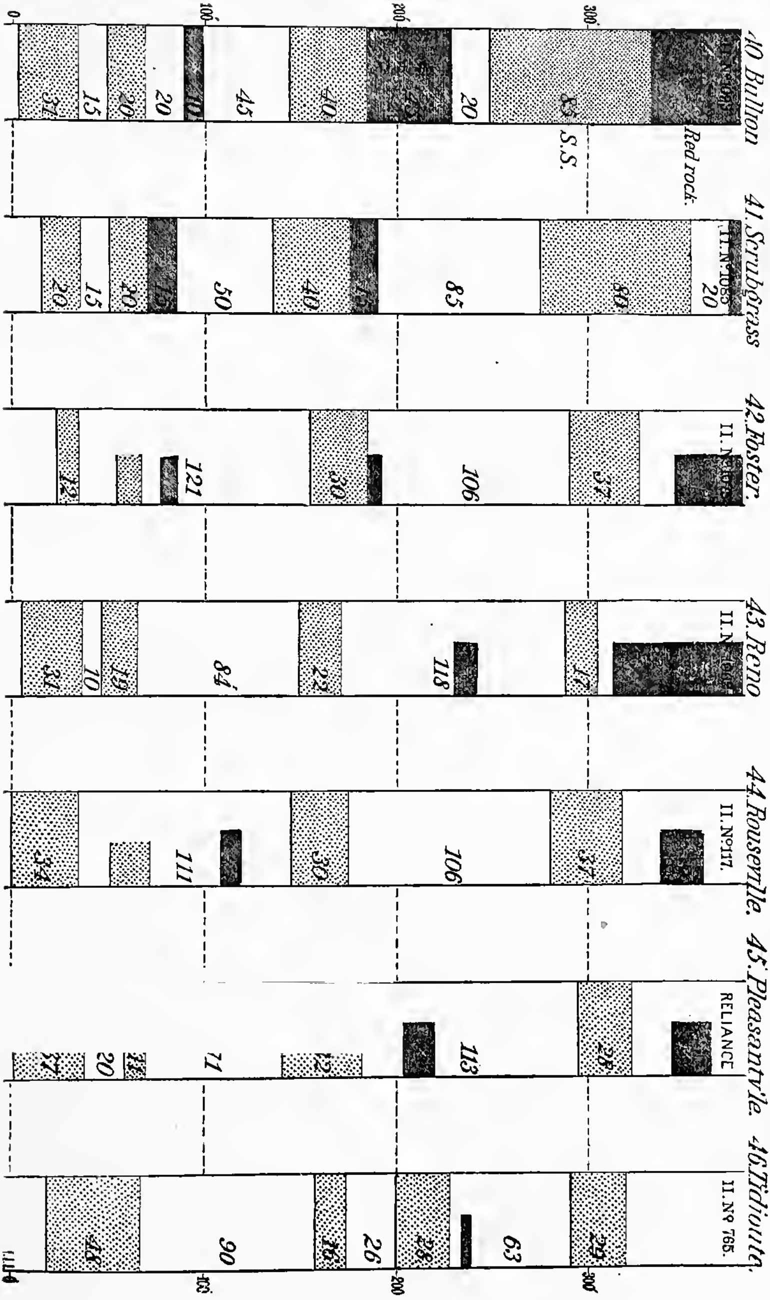
*Hence its provisional name of *Crawford Shales*, adopted by the State Geologist to avoid complications with the Ohio column, pending the final settlement of the harmony between it and the Pennsylvania column.

† See plate IV.


40. Bullion
II. No 1082
Red rock.
S.S.
31
15
20
20
10
45
40
45
20
83
41. Scrubgrass
II. No 1085
20
15
20
15
50
40
15
85
80
20
42. Foster.
12
121
30
106
37
43. Reno
34
10
19
84
22
118
17
44. Rouseville.
II. No 117.
34
111
30
106
37
45. Pleasantv'le.
RELIANCE
37
20
11
71
12
113
28
46. Tidioute.
II. No 765.
44
90
16
26
28
63
29
0
100
200
300

down through it than in any other section of the wells of equal volume.

Taking the Pithole grit at say 20 feet, the whole Crawford Shale formation may be said then to measure about 400 feet, along the Venango oil-belt.

§ 317. Where the Pithole grit does not split it into two main divisions, *i. e.*, in parts of Butler, Armstrong, and Clarion counties (where the horizon of the *Pithole grit* is obscure, and the Crawford Shale is not so homogenous a formation) there are nevertheless always to be found above the Oil-sand group from 300′ to 400′ of soft measures, through which the drills go faster than anywhere else; a visible evidence of which fact is presented in the curious diagram of the *Relative rates of drilling in the six Petrolia wells*, Plate XVII.*

§ 318. The sandy layers at the top of the Crawford shale are of no moment in the present discussion. The sole fact here insisted on is this:—

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

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

§ 319. The name adopted, therefore,—*Venango Oil-sand group*—is not an arbitrary designation, suggested merely by the fact that petroleum was first discovered in them in Venango county,—nor by the fact that our oil surveys commenced with them in Venango county,—but a designation

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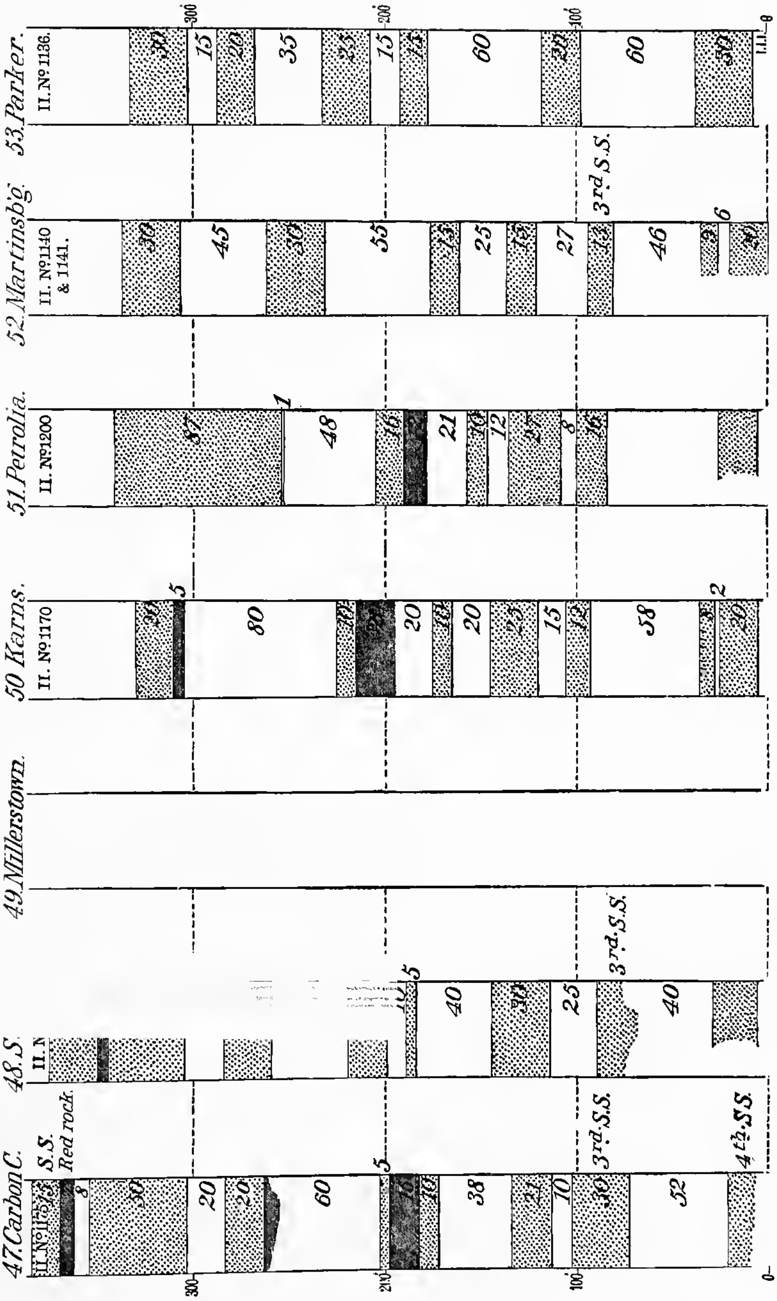
* See also photographs of the cabinet arrangement of the specimen drillings from these wells.

Plate XXVIII.



based upon a sound geological generalization of all the facts obtained thus far in our surveys of the whole oil field between Pittsburg and Lake Erie, confirming the integrity of the group as a group, its type being in Venango county.

The Warren oil sands are quite a different older and lower group; and the Bradford oil sands also.

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§ 320. *Under the* Oil-sand group, again lies a perfectly well marked different formation.

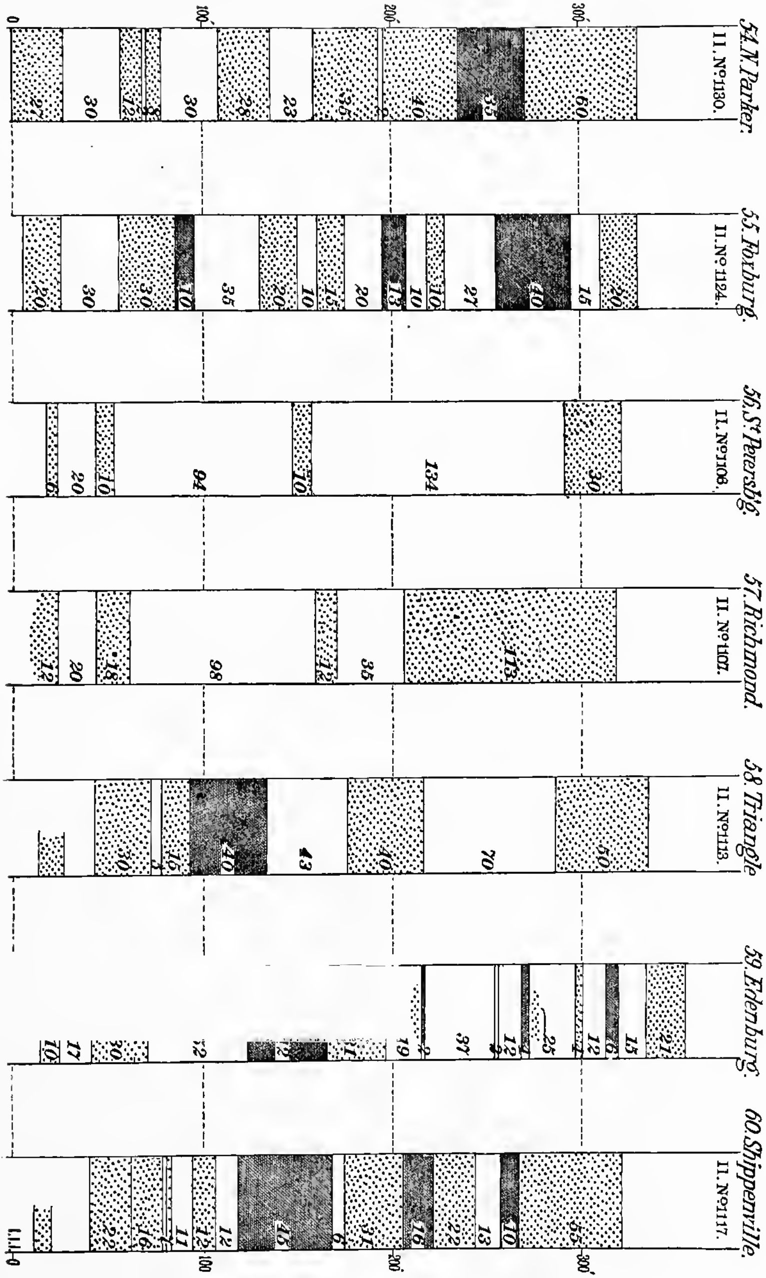
The driller having gone through the Venango Oil-sands and their separating shales, and reached the base of the group, suddenly, by as abrupt a transition as that which he encountered at its top, enters a different set of rocks. Wherever the group is normally developed, the drill passes at once from sandstone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

A large majority of oil wells were never drilled below the Third sand, or base of the group; for experience had convinced operators that it was useless to expect another sand layer below that horizon, along the whole line of the Venango and Butler belts.

Several hundred wells, however, *were* put down to depths of 100′ to 500′ beneath the lowest Venango Oil-sand. Their numbers and the extent of ground over which they lie scattered, afford conclusive evidence that the measures beneath the Oil-sand group have everywhere the same clay character. The universal testimony of their records is—*soft drilling and no coarse massive sandrock after leaving the Productive oil measures.*

Occasionally, indeed, a "sand" has been reported; and some fine-grain sandstone layers were to be expected, for they are not unknown in the Chemung series; but it is now conceded that such layers never resembled the Oil-sands, and that they occurred so rarely, and the reports of them are so vague and questionable, that we are warranted in treating them as mere local variations of some of the beds of the Chemung shales.

Plate XXIX.


0
100
200
300
54. N. Parker.
II. No 1130.
27
30
12
8
30
28
23
35
2
40
35
60
55. Foxburg.
II. No 1124.
20
30
30
10
35
20
10
15
20
13
10
10
27
40
15
20
56. St Petersb'g.
II. No 1106.
6
20
10
94
10
134
30
57. Richmond.
II. No 1107.
12
20
18
98
12
35
113
58 Triangle
II. No 1113.
30
5
15
40
43
40
70
50
59. Edenburg.
10
17
30
52
2
21
19
2
37
2
12
2
25
2
12
6
15
21
60. Shippenville.
II. No 1117.
10
22
16
7
11
12
12
45
6
31
16
22
13
10
55

The whole experience of deep drilling proves that under the Oil-sands lies a mass of rather soft shale, sometimes pure argillaceous shale (red or blue), sometimes "shelly," but always a quiet deep water deposit,—totally unlike the oil-sands, with their shore-deposit aspect.

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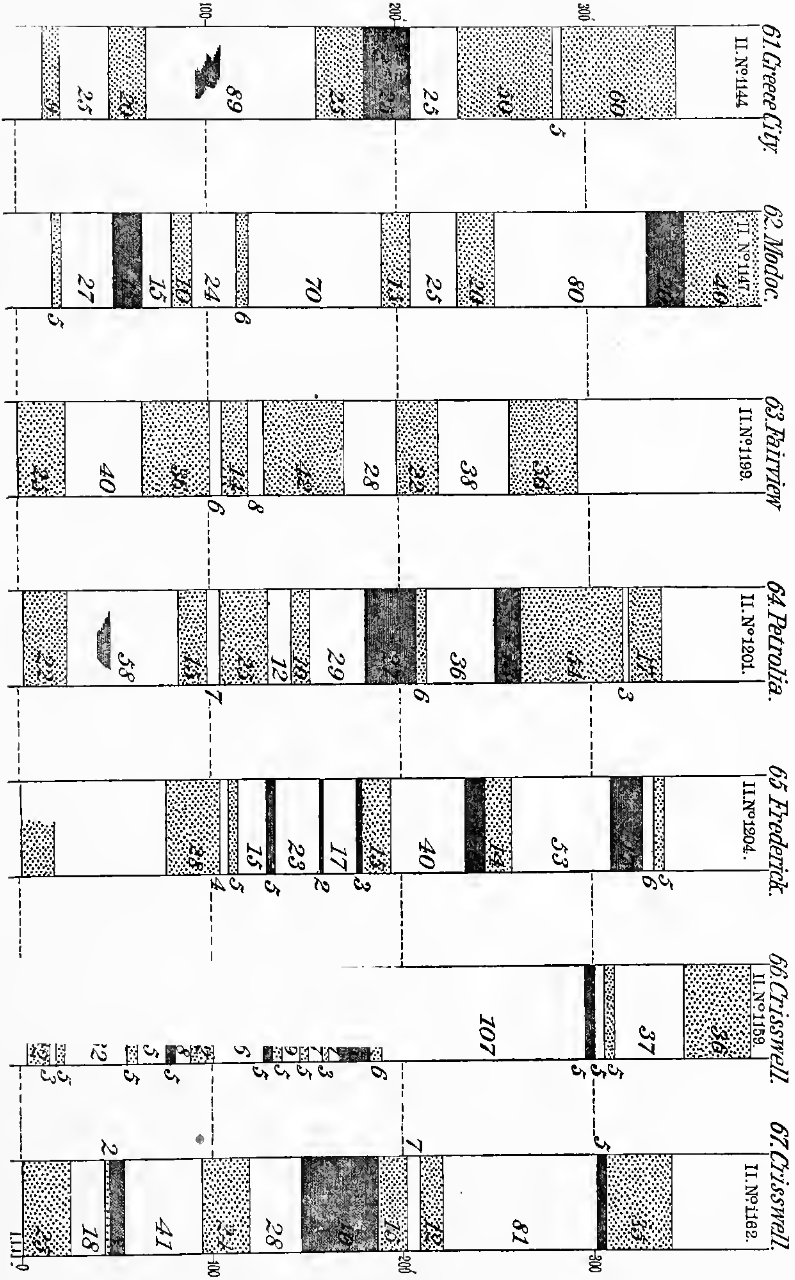
§ 321. *The Venango Oil-sand Group*, itself, is seen in the sections to be a mass of sandstone deposits, from 300′ to 380′ thick, with layers of pebbles, and many local partings of shale and slate.

As a whole, it is a well-defined group of sandstones lying between the two shale formations above and below it described above; so sharply separated from them, so persistent, so characteristic, and so uniform in structure and thickness, that it deserves the special name which it receives.

§ 322. *Its thickness*, as measured in different parts of the district is seen in the sections, thus:

Fig. Well.		*Feet.*
At Tidioute,		300
" Pleasantville,		322
" Rouseville,		318
" Reno,		301
" Fosters,		306
" Scrubgrass,		340
" Bullion,		331
" Shippenville,	(278′, 3d SS.+30′±to 4th=)	308±
" Edenburg,		339+
" Pickwick,	(293′, 3d SS.+30′±=)	323±
" Keating,		308+
" Ritts, between St. Petersburg and Emlenton,		304
" Foxburg,		325
" Reddick farm ("Columbia Hill"),		332
" Parker's Landing,		325
" Sheakley Station,	(255′+81′=)	336
" Petrolia,	(258′+80′± Dougherty No. 2=)	338±
" Karns,		325+
" Millerstown,		?
" St. Joe,	(265′+75′=340; or 265′+75′+30′=)	370±
" Carbon Centre,	(351′; or 351′+30′=)	381+
" Greece,		333+
" Modoc,		372+
" Fairview, Sutton No. 4,	(295′+86′±=)	381±
" Fairview, Evans No. 21,		334
" Frederick,	(260′+75′±=)	335±
" Criswell,		380+
" Criswell,		341


61. Greece City.
II. N° 1144.
62. Modoc.
II. N° 1147.
63. Fairview
II. N° 1199.
64. Petrolia.
II. N° 1201.
65 Frederick.
II. N° 1204.
66. Criswell.
II. N° 1159.
67. Criswell.
II. N° 1162.
0
100
200
300
9
25
20
89
25
21
25
30
5
60
5
27
15
10
24
6
70
11
25
20
80
40
25
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30
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14
8
42
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22
38
36
22
58
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27
6
36
54
3
17
28
4
5
15
5
23
2
17
3
15
40
14
53
6
5
107
37
36
6
3
5
5
5
5
5
5
7
2
5
2
7
5
25
18
41
24
28
40
15
12
81
35

§ 323. These figures may be varied somewhat by taking other well records; but it will be found, as a general rule, that a thickness of 350 feet, as claimed in Report I, will in nearly every case embrace *all the sands* belonging to the Venango group—even the *Fourth*, *Fifth* and *Sixth* sands, as the lower members of the group, in some localities have been called.

§ 324. That the confessedly variable thickness of its individual members should vary the dimensions of the group as such, might be expected. It is wonderful therefore how the group maintains its total thickness with such uniformity for a distance of 62 miles in a straight line, from Tidioute in Warren county to Herman station in Butler county. The top sand is sometimes 10′ thick and sometimes 85′; the bottom sand may be 5′ thick or it may be 120′; and so, either one of these members may individually vary in thickness about as much as the whole group is found to vary.

§ 325. *Shape of the Oil-sand deposits.*—It has sometimes been asserted that the *top* of a sandrock is always uniform, and that any irregularity of thickness necessarily implies an uneven *base*. But facts do not seem to warrant the acceptance of any such law of structure as universally prevalent. The commencement of sandy deposits upon soft ones would no doubt, under certain circumstances, be attended by some unevenness of bottom. Strong currents bearing course materials might excavate first to a certain extent, and then deposit; while sluggish waters would lay down finer sand on the original floor undisturbed. And this has sometimes happened; for we not infrequently discover by actual levels and measurements, that where a thin fine sandrock swells into a thick pebbly one, there is *a more uniform level at the top* of the stratum than at the bottom. Still, where the conditions of deposition were so variable and uncertain as these must have been, it would be unsafe to formulate any fixed rules for universal guidance in these particulars.

§ 326. *The importance of viewing the oil-rocks as a group by itself*, and of studying them individually, always with a view to their natural association as members of such a group, cannot be too earnestly impressed upon oil producers. It is the true key to a correct understanding of the structure of the oil regions,—the only one indeed which unlocks the complications and involutions of the drillers oil sand nomenclature, some specimens of which are given in Chap. XIX.

If for example the pioneer operators in Butler county had only always kept in mind the fact—which they very well knew—*that above the first oil sand they had always found a mass of soft rock about 400 feet thick*, and if they had always noted the relative positions of *all* the sandy members of the oil-sand group, instead of confining their scrutiny to that one of them from which the oil came, they would have soon remarked that what the driller called *Second sand* in Butler county was really nothing else but the *First* sand of Venango county.

§ 327. If, at Petrolia, the oil drillers had observed carefully when and where they struck the top of the Oil-sand group, they would have noticed in going deeper that *their so called Third sand* lay only 250 feet beneath it, and therefore could not be the *Oil creek Third sand;* for they would have inferred that the group had been only two thirds pierced, and that there must be other sands still below them.

The result in some cases was disastrous enough. There were men in the Petrolia district who, relying on their own judgment, and ability to indentify the *Third sand* anywhere, and knowing by experience that no oil was to be expected under the *Third sand of Oil creek*,—stopped their borings at the first rock that yielded oil, *calling it the Third sand*, and then, getting little or no oil from it, sold out at a loss, without an effort to go deeper. The *name* of Third sand stopped them. It is easy to imagine their surprise and chagrin when new owners suspecting the right application of the name, or for other reasons, carried down their holes to the bottom rock of the group and got hundreds of barrels of oil per day. Territory which the first owners had condemned and sacrificed through the mistake of a name, came to rank in second hands among the most valuable in the country.

§ 328. I could cite several cases where the knowledge of the simple fact, *that all the oil-sands lie in one group and that* *this group has a well defined soft top and a well defined soft bottom*, would have saved the operator more money than the whole expense of the geological survey of the oil region.

But this fact—simple as it is—became known, and could only become known, by a strictly geological method of observation. Yet the average oil producers sees no utility in a geological investigation ; shifts his tools from place to place ; puts down his wells ; and decides for himself, by *surface* levelings in reference to some *assumed dip* of the oil-rock, where his *Third sand* will be, stamping a character, productive or unproductive, on the territory, which the geologist can easily show to be unmerited.

CHAPTER XV.

The dip of the Venango oil sand group.
Plate VIII, (with a map, Plate IX.)

§ 329. The unity of the group having been exhibited, and its identity proved both in the Venango and the Butler-Clarion belts, it remains to show how it lies in reference to sea level; how it dips southwestward,

Plate VIII, and the tables below, tell the whole story without more words.

It is to be regretted that the exhibition in the Clarion county part is not fuller; but although the oil developments have there spread out much wider than is shown on Plate VIII, or on the large map Plate IX, I have limited myself to facts in hand; omitting several interesting calculations for which my data were still insufficient. The map however is complete enough for the purpose intended; and others may place upon their copies of it additional facts as they get them, and so extend the calculations.

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[a] It was intimated in Report I (page 30) that there were reasonable grounds for supposing that the Stray and 3d sand had coalesced and united into one in the Tidioute and Triumph district. Additional facts since obtained leave little doubt that such is the case. Accordingly, in the arrangement of the sections on Plate p. 129, the top of the Tidioute and Colorado sands have been placed to correspond with the top of the Stray in other localities. This view of the order of stratification would require a reduction of the elevations of the Tidioute and Colorado sands of about 45', in order that they may agree with the top of the Oil Creek 3d sand, (which lies about 45' below the top of the Stray,) this being the horizon used in all the other elevations given on the northern belt, from Tidioute to Clintonville.

The Tidioute Third sand horizon will then be . . 1008—45=963'
The Colorado Third sand horizon will then be . . . 853—45=808'

The dips in Table A² will be changed as follows:

Tidioute to Fagundus, ...	from	30.9	per mile to	20.0
Tidioute to Church Run, ...	from	11.9	per mile to	9.6
Church Run to Colorado, ...	from	0	per mile to	6.8
Colorado to Pleasantville, ...	from	20.2	per mile to	10.0
Fagundus to Colorado, .	from	5	per mile to	14.0

§ 330. *Table A*[1]*;* giving the *Elevation of the Top of the Third oil sand above sea level*, at the points along the belt, *in Warren and Venango* counties (designated on Plate VII) from Tidioute to Clintonville; as follows:

Table A.[1] *Warren and Venango counties.*
Tidioute to Clintonville.

Height of top of Third sand above ocean level.	*See Plate VII.*
Tidioute†,	*1008′
Fagundus,	*878
Colorado,	*853
Church Run,	*853
Titusville (Watsons Flats),	*793
Pleasantville,	*768
Shamburg,	*723
Pithole,	*683
Cashup,	*708
Petroleum Centre,	*653
Rouseville,	*558
Clapp Farm,	550
Siverly Farm,	528
Reno,	472
Milton Farm,	455
Franklin, near A. V. RR. Depot,	421
Raymilton, Raymond estate,	360
Fosters,	363
Scrubgrass,	340
Bulion run, Gealy Farm,	345
Clintonville, Cross Farm,	230
Emlenton, near town,	130±

Table A[2]*. Warren and Venango counties.*
Tidioute to Clintonville.
Dip of top of Third sand, in feet, per mile.

	Miles.	Bearing.	Elevation above ocean in feet.	Fall in feet.	Rate in feet.
From Tidioute to					
Church run,	13	S. 84° W.	1008 to 853	155	11.9
Colorado,	6¾	S. 72° W.	1008 to 853	155	22.8
Fagundus,	4⅕	S. 27° W.	1008 to 878	130	30.9

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* These points were used on a diagram in Report I, 1874, but the elevations as there given are all now raised 13′ to cause them to conform to ocean level, as explained in Report II, 1877.

† See note *a* previous page.

From Fagundus to					
Colorado,	5	N. 71° W.	878 to 853	25	5.0
Pleasantville,	7½	S. 77° W.	878 to 768	110	14.7
Cashup,	8	S. 41° W.	878 to 708	170	21.0
From Colorado to					
Church run,	6½	N. 82° W.	853 to 853	0	0.0
Pleasantville,	4⅕	S. 39° W.	853 to 768	85	20.2
From Church run to					
Titusville (Watson flats)	2½	S. 5° E.	853 to 793	60	24.0
Pleasantville,	5½	S. 42° E.	853 to 768	85	15.5
From Titusville to					
Petroleum Centre,	7	S. 12° W.	793 to 653	140	20.0
Shamburg,	4 3/10	S. 20° E.	793 to 723	70	16.3
Pleasantville,	3 9/10	S. 65° E.	793 to 768	25	6.4
From Pleasantville to					
Shamburg,	3⅕	S. 40° W.	768 to 723	45	14.1
Pithole,	5⅙	S. 4° E.	768 to 683	85	16.3
Cashup,	5	S. 25° E.	768 to 708	60	12.0
From Cashup to					
Pithole,	1⅚	S. 68° W.	708 to 683	25	13.6
From Shamburg to					
Petroleum Centre,	4	S. 47° W.	723 to 653	70	17.5
Rouseville,	7 3/10	S. 30° W.	723 to 558	165	22.6
Pithole,	3 7/10	S. 42° E.	723 to 683	40	10.8
From Petroleum Centre to					
Rouseville,	3 7/10	S. 9° W.	653 to 558	95	25.7
From Pithole to					
Rouseville,	7 1/10	S. 59° W.	683 to 558	125	17.6
Clapp farm,	7⅔	S. 47° W.	683 to 550	133	17.3
Siverly farm,	9¼	S. 38° W.	683 to 528	155	16.8
From Rouseville to					
Clapp,	1⅓	S. 12° E.	558 to 550	8	6.0
Reno,	5¼	S. 40° W.	558 to 472	86	16.4
From Clapp farm to					
Siverly farm,	2	S. 3° W.	550 to 528	22	11.0
Reno,	4½	S. 53° W.	550 to 472	78	17.3
From Siverly farm to					
Reno,	3½	S. 78° W.	528 to 472	56	16.0
Milton farm,	4⅓	S. 63° W.	528 to 455	73	16.8
Foster's,	8	S. 41° W.	528 to 363	165	20.6
From Reno to					
Milton farm,	1½	S. 20° W.	472 to 455	17	11.3
Franklin,	3¼	S. 63° W.	472 to 421	51	15.7
From Milton farm to					
Foster's,	4⅔	S. 21° W.	455 to 363	92	19.7
Franklin,	2½	West.	455 to 421	34	13.6
From Franklin to					
Foster's,	4⅓	S. 10° E.	421 to 363	58	13.4
Raymilton,	9¼	S. 68° W.	421 to 360	61	6.6
From Foster's to					
Raymilton,	9⅔	N. 85° W.	363 to 360	3	0.3
Scrubgrass,	4½	S. 22° W.	363 to 340	23	5.1
Bullion run,	6	S. 36° W.	363 to 345	18	3.0
From Raymilton to					
Bullion run,	8½	S. 48° E.	360 to 345	15	1.8
Clintonville,	10	S. 30° E.	360 to 230	130	13.0
From Scrubgrass to					
Clintonville,	5	S. 37° W.	340 to 230	110	22.0
From Bullion run to					
Clintonville,	3⅜	S. 18° W.	345 to 230	115	34.1
Scrubgrass,	2	N. 68° E.	345 to 340	5	2.5

Table B¹. Clarion county.
Shippenville to Foxburg.

Height of top of Third sand above ocean level. See Plate VIII.

Foxburg.

Shippenville,	1 m. N. E. of town,	370′
Edenburg,	½ m. S. E. of town,	325′
Beaver City,	½ m. S. W. of town,	255′
Dogtown,	½ m. west of town,	230′
Turkey City.		220′
Foxburg,		100′

Table B² Clarion county.
Shippenville to Foxburg.
Dip of the Third sand in feet per mile.

Shippenville to Edenburg,	3¼	S. 45° W.	370–325	45	14′
Edenburg to Beaver City,	1¾	S. 77° W.	325–255	70	40′
Beaver to Dogtown,	2⅔	S. 46° W.	255–230	25	9′
Dogtown to Turkey City,	1	S. 60° W.	230–220	10	10′
Turkey to Foxburg,	4¾	S. 44° W.	220–100	120	25′
Foxburg to Parker (Island],	1½	South,	100–60	40	27′
Foxburg to Columbia Hill,	2½	S. 48° W.	100–100	0	0′

Table C¹. Armstrong and Butler counties.
Parker's to Herman's Station.

Height of top of Oil-Sands above ocean level. See Plate VIII.

	3rd SS.	*4th SS.*
Columbia Hill, Reddick farm,	+100	
Parker Island, at mouth of Clarion,	+ 60	
Farrentown, near oil tanks,	+ 10	
Stonehouse, in valley, near R'y station,	— 8	
Frousinger farm, 1 m. E. of Martinsburg,	— 20	
Martinsburg, Say farm, S. E. of town,	— 30	
Argyle, near the pump station,	— 70	
Petrolia, near the post-office,	—100	
Frederick, Mortimer farm,	—108	
Criswell, vicinity of Boss well,	—105	—190
Brady's Bend, at furnaces,	(—130 ?)*	—215
Fairview, McCleary farm,	— 90	—175
Modoc, near town,	(—120 ?)	—200
Greece, near town,	(—220 ?)	—300
Karns City, McClyman's farm,	—160	—250
Millerstown, (4th SS. on eastern belt ?),	—245	—320
St. Joe, J. Now farm,	—260	(—335 ?)
Carbon Centre, R. Thompson farm,	—294	—376
Humes,	(—375 ?)	—457
Herman station,	(—418 ?)	—500

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* The figures given in brackets have been supplied for the purpose of keeping the horizons of 3d and 4th sands separate. To preserve uniformity and avoid confusion, the dips are calculated throughout for the "3d sand," and where its exact position was not noted at the points designated, because it was imperfect and not oil-bearing, we have located it from 80 to 85 feet above the "4th SS." The 3d and 4th sands appear to lie very nearly parallel in this section, therefore the dips here given may be considered as representing the slopes of both sands, one lying about 80 feet below the other.

Table C². Rate of dip in feet per mile.

Table C².	*Miles.*	*Bearing.*	*Ocean level.*	*Fall.*	*Rate.*
Columbia Hill to					
Parker (Island),	1¾	N. 85° E.	+100′ to + 60′	40′	23′
Farrentown,	2½	S. 35° E.	" " + 10	90	36′
Stonehouse,	2¾	S. 11° W.	" " − 8	108	39′
Parker (Island) to					
Farrentown,	2⅓	S. 13° W.	+ 60 to + 10	50	21′
Farrentown to					
Stonehouse,	2	S. 66° W.	+ 10 to − 8	18	9′
Fronsinger Farm,	2	S. 25° W.	" " − 20	30	15′
Stonehouse to					
Fronsinger Farm,	1½	S. 35° E.	− 8 to − 20	12	8′
Martinsburg,	1⅛	S. 20° W.	" " − 30	22	20′
Fronsinger Farm to					
Martinsburg,	1¼	N. 83° W.	− 20 to − 30	10	8′
Argyle,	2	S. 24° W.	" " − 70	50	25′
Frederick,	2¾	S. 1° W.	" " −108	88	32′
Criswell,	3½	S. 19° E.	" " −105	85	24′
Brady's Bend,	5½	S. 43° E.	" " −130	110	20′
Martinsburg to					
Modoc,	6½	S. 40° W.	− 30 to −120	90	14′
Fairview,	3	S. 12° W.	" " − 90	60	20′
Argyle,	2	S. 12° E.	" " − 70	40	20′
Argyle to					
Fairview,	1½	S. 47° W.	− 70 to − 90	20	13′
Petrolia,	1	S. 15° W.	" " −100	30	30′
Frederick,	1¼	S. 40° E.	" " −108	38	30′
Petrolia to					
Frederick,	1	S. 88° E.	−100 to −108	8	8′
Karns,	1¾	S. 21° W.	" " −160	60	34
Fairview to					
Petrolia,	1	N. 80° E.	− 90 to −100	10	10′
Karns,	1½	S. 12° E.	" " −160	70	47′
Modoc,	4¼	S. 60° W.	" " −120	30	7′
Frederick to					
Karns,	2¼	S. 42° W.	−108 to −160	52	23′
Karns to					
Millerstown,	3¼	S. 15° W.	−160 to −245	85	26′
Millerstown to					
St. Joe,	3½	S. 35° W.	−245 to −260	15	4′
St. Joe to					
Carbon Centre,	2	S. 11° W.	−260 to −294	34	17′
Carbon Centre to					
Humes,	2	S. 25° E.	−294 to −375	81	40′
Herman Station,	3¾	S. 24° W.	" " −418	124	33′
Humes to					
Herman Station,	2¾	S. 55° W.	−375 to −418	43	15
Modoc to					
Karns,	4	N. 82° E.	−120 to −160	40	10′
Millerstown,	4	S. 51° E.	" " −245	125	31′
Greece,	2	S. 51° W.	" " −220	100	50′
Greece to					
Millerstown,	4⅔	S. 73° E.	−220 to −245	25	5′
St. Joe,	4⅔	S. 34° E.	" " −260	40	8½′
Herman Station,	9¼	S. 5° E.	" " −418	198	21′
Criswell to					
Frederick,	1½	N. 63° W.	−105 to −108	3	2′
Karns,	3	S. 73° W.	" " −160	55	18′
Millerstown,	5½	S. 43° W.	" " −245	140	25′
Brady's Bend,	2½	S. 76° E.	" " −130	25	10′
Brady's Bend to					
Millerstown,	7	S. 62° W.	−130 to −245	115	16′

Table D¹, Along the axis of development. Northern (Venango) belt.

Tide.	*Top of Third Sand at*			*Fall.*	*Miles.*	*Rate.*
1008	Tidioute	to	Colorado,	155	6.75	22.8′
853	Colorado	to	Pleasantville,	85	4.20	20.2′
768	Pleasantville	to	Shamburg,	45	3.20	14.1′
723	Shamburg	to	Rouseville,	165	7.30	22.6′
558	Rouseville	to	Reno,	86	5.25	16.4′
472	Reno	to	Milton Farm,	17	1.50	11.3′
455	Milton Farm	to	Fosters,	92	4.66	19.7′
363	Fosters	to	Bullion Run,	18	6.00	3.0′
345	Bullion Run	to	(230) Clintonville,	115	3.37	34.1′
	Tidioute	*to*	*Clintonville—total,*	778	42.23	18.42
	Tidioute	*to*	*Clintonville*, bee line, S. 39° W.,	. . .	39.5	19.70

Table D², Along the axis of development. Southern (Butler-Clarion) belt.

230	Dogtown*	to	Turkey City,	10′	1.00	10′
220	Turkey City	to	Foxburg,	120	4.75	25′
100	Foxburg	to	Parker,	40	1.50	27′
60	Parker	to	Farrentown,	50	2.33	21′
10	Farrentown	to	Fronsinger Farm,	30	2.00	15′
— 20	Fronsinger Farm	to	Argyle,	50	2.00	25′
— 70	Argyle	to	Petrolia,	30	1.00	30′
—100	Petrolia	to	Karns,	60	1.75	34′
—160	Karns	to	Millerstown,	85	3.25	26′
—245	Millerstown	to	St. Joe,	15	3.50	4′
—260	St. Joe	to	Carbon Centre,	34	2.00	17′
—294	Carbon Centre	to	Humes Farm,	81	2.00	40′
—375	Humes Farm	to	Herman Station, (418′,)	43	2.75	15′
	Dogtown to Herman Station—Total,			648	29.83	21.72
	Dogtown to Herman Station, bee line, S. 27° W.,			.	28.25	22.93

Table E.

Tidioute to Clintonville, as above,	778	42.23	18.42
Clintonville to Dogtown, (Strike,)	0	. .	0
Dogtown to Herman Station,	648	29.83	21.72
Tidioute to Herman, along development,	1426	72.06	19.80
Tidioute to Herman, bee line, S. 21° W.,	. . .	62.00	23.00

Table F.

Tidioute to Dogtown,	S. 19° W.,	778	34.0	22.88
Dogtown to Herman Station,	S. 27° W.,	648	28.25	22.93
Tidioute to Herman Station,	S. 21° W.,	1426	62.00	23.00

Table G.

Tidionte (1008′) to Shippenville (370′),	S. 8° W.,	638	29.	22′
Pithole (683′+45′=728′) to Turkey City (220′),	S. 7° W.,	508	22	23
Foster (363) to Modoc (200),	S. 5° W.,	563	24	23

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* Same level as Clintonville in last table.

CHAPTER XVI.

The Butler-Clarion Oil belt map.—The Oil-production of the belt.—The Cross or Fourth sand belt.

(*Illustrated by Plate IX.*)

§ 331. *The map* of the Butler, Armstrong and Clarion Oil fields, in two sheets forming Plate IX, was partly drawn in the winter of 1875 by Messrs. F. A. Hatch and Arthur Hale while working up the notes of the previous season's field work.

§ 332. This map was originally intended to serve as a skeleton base for details to be obtained by subsequent surveys.* Our principal *base lines* at that time extended from Parker City to St. Joe; from Petrolia to Greece City; and from Foxburg to Shippenville.

Nothing more was done toward collecting material for the map until late in 1876, when Mr. H. Martyn Chance and Mr. Hale prolonged the line from St. Joe to Herman Station and also lined across from Petrolia to Brady's Bend. In the winter following Mr. Chance drafted the map anew, enlarged it from the notes of his own surveys, and added the profile section at the bottom.

§ 333. It was found that, while the surveys made and the data collected, sufficed for the study of the *general features* of structure underground, they would not serve the purpose of settling difficult local geological questions with an extension of the survey. For these questions accurate and complete well records were needful; and it was utterly impossible to obtain such, except by employing a number of assistants to watch and measure wells as they were bored, and preserve the sand-pumpings for study. As this could not be done over such a field, except at great expense, it

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*No opportunity has since been afforded for doing additional field work of this kind in either of these counties, and consequently the map is not filled out in detail as was originally intended.

was obviously a waste of time to make spirit level surveys simply to locate oil wells and get their heights above ocean level, when nothing could be learned of their geological record, except the one fact of the depth of the oil-producing sand beneath the mouth of the well.

§ 334. The systematic detailed surveys, made by Prof. White in southern Butler, and by Mr. Chance in northern Butler and Clarion, diminished still further the necessity for completing the map in the mode originally intended.

§ 335. The map is therefore published as drawn, to show the geographical extent of Butler-Clarion oil district; and to indicate the trend of the central or main developement along the "Third Sand Belt," from the northeastern extremity of productive territory in Clarion county, to its southwestern termination in Butler county. The new districts which have been opened up since then, to the right or left, can easily be located by those who desire to study the subject in detail.

Production.

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

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

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

§ 338. In 1874, the maximum development of the district was reached, during the great Fourth sand or "*cross belt*" *excitement.*

The average production for the month of July in that year, was 28,424 barrels per day ;* or an average of $17\frac{765}{1000}$ bbls. per day to each of the 1,600 wells then at work.

From this date (1874), although the wells constantly increased in numbers, the production gradually declined until—

§ 339. In 1877 extensive new developments, principally in Clarion county, added very largely to the daily out-put, as the following figures based on Mr. Stowell's reports will show.

During	*Average No. of Wells.*	*Average Production daily.*	*Average Production per well.*
1875	1696	20,060 bbls.	11.828 bbls.
1876	2346	14,490 "	8.308 "
1877	3889	22,787 "	5.859 "
1878	4650	18,730 "	4.028 "
1879	4315	11,840 "	2.744 "

The second column showing the average number of wells *at work* in the district during the year.

The Profile section.

§ 340. *The general structure of the oil group along the central line of operations on the Butler-Clarion belt* is shown in the profile section on Plate IX ; where dotted lines indicate the horizons of the *Butler Third* and *Fourth sands* and explain why no "Fourth sand" was found at Parkers Landing.

Here (at Parkers Landing) the oil came from the lowest member of the Oil group—the representative of the *Oil-Creek Third sand,* and so the rock was very properly called, not the Fourth sand, but the Third.

In Clarion county, however, and likewise in Butler, the oil *first* obtained came from a rock higher in the series. But the drillers of the early wells did not notice the change from one horizon to another; and consequently supposed that they were still getting the oil from the Parker Third sand.

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*According to Stowell's Petroleum Reporter.

After the development had reached Modoc and Petrolia, it began to be suspected that there might be *two oil horizons* instead of only one, and then commenced the experiment of deeper drilling at Petrolia, and elsewhere, which finally resulted in the development of the "Cross Belt," which was also called the "Fourth sand belt."

The profile shows *how the "Third" and "Fourth" sands* of Butler and Clarion must unite to form the *Third sand* at Parkers, if the drillers nomenclature of the oil sands be followed.

CHAPTER XVII.

1. A profile section from lake Erie to West Virginia.
2. A vertical section of known oil producing formations.

(Illustrated by plates X and XI.)

§ 341. A grave misapprehension exists in the minds of many oil producers regarding the true relationship of the oil rocks of one locality to those of another. Because it can be shown on a map that nearly all of the oil producing areas of Pennsylvania, Ohio and West Virginia are included within the limits of a comparatively narrow general belt of country, stretching from northeast to southwest, it is taken for granted by those who do not stop to reason much about it, that the oils of different localities along this general belt are all produced from one and the same series of rocks.

This erroneous idea has given occasion to a great deal of injudicious drilling along lines run merely to connect a district producing oil from one horizon, with another district producing oil from a higher or lower rock.

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

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

§ 344. *The profile section* on Plate X, and the *vertical section* on Plate XI, have been prepared for the purpose of exhibiting the fallacy of such views; and to enable the reader to see at a glance, what some of the fundamental features of the sedimentary structure, of the oil region especially, are.

§ 345. *The profile-section* Plate X, follows a line upon the map drawn from Black Rock on the Niagara river, in Erie county New York, to Pittsburgh and thence to Dunkard creek oil-field in Dunkard township, Greene county, close to the West Virginia State line.

From Black Rock to Pittsburgh the bearing of this line is S. 20° W.—distance about 175 miles.

From Pittsburgh to Dunkard creek, its bearing is S. 3° E. —distance 50 miles.

§ 346. *Places on the line of profile, Plate X.*—Starting at *Black Rock* the line crosses the foot of *lake Erie* and strikes the southeasterly shore at Lakeview, in Erie county N. Y.

Thence it runs through, or very near to, the following places:—*Jamestown*, N. Y.; *Youngsville*, on Big Brokenstraw creek, in Warren county, Pa.; *Tidioute* on the Allegheny river, in Warren county; *President* on the Allegheny river, in Venango county; *Foxburg* on the Allegheny, in Clarion county; *Parkers Landing*, on the Allegheny, in Armstrong county; and *Petrolia*, *Millerstown* and *Great Belt city*, (or *Summit*) in Butler county.

Thus it may be said to follow the Butler oil belt very nearly along its line of best development.

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

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

§ 349. Now it is a remarkable and important fact, that in no boring in Pennsylvania has the *Warren group of oil rocks* (unmistakably developed) been seen directly beneath the *Venango group.*

It is equally a fact, that in no boring has the *Bradford "Third" sand* been seen directly below the *Warren group.*

In other words, we have not a single direct oil well measurement between these several groups; and therefore we must trust to some pretty nice and difficult calculations, when we try to determine the thicknesses of these intervals—that is, when we attempt to place the Warren and the Bradford oil rocks in their proper places in our profile section.

But whatever inaccuracies of detail may thus creep into the section, it will still suffice to show the *relative* positions of such oil horizons as have been profitably worked in different parts of the country.

It will certainly demonstrate the folly of drilling on so-called belt lines, run from one producing district to another, regardless of the age or equivalence of the rocks to be connected.*

§ 350. *The Vertical Section, Plate XI*, is intended to show that oil has been produced from ten or twelve different geological horizons in the earth's crust, ranging through a thickness of about 4,500 feet of sedimentary strata. And the most skillful oil producer, the most expert geologist,

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*It must never be forgotten that a "line well" may prove remunerative by discovering a local oil horizon not before known; but, in that case its success as an oil well will have nothing to do with the theory on which it was located; or, in plainer terms, the line run to locate it can have nothing to do with the existence of the local horizon of oil which may be thus fortunately explored.

cannot tell how many *other* oil horizons may exist at intermediate depths beneath the surface, (*i. e.* in the scale of the formations) but which, being good only within certain geographical limits, have as yet escaped the oil miner's drill.

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

This rock can be unmistakably identified at Black Rock in New York; and therefore Black Rock has been selected as the northern end of our *profile section*, Plate X.

§ 352. The next and only other point at which the elevation of the *Corniferous limestone* can be fixed, is in the Coburn gas well at *Fredonia*, Chautauqua county, N. Y.,

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*Oil has been found or struck at lower horizons yet, but in insufficient quantities.

† "The color of the *Corniferous limestone* varies from a light greyish blue, to dark blue or black, and it is sometimes even of a light gray or drab color. It contains numerous nodules of hornstone, and the strata are sometimes separated by irregular layers of the same. In other localities these layers of hornstone increase in number and thickness to the almost entire exclusion of calcareous matter, and they then present a very harsh outline." * * "At the eastern end of the district the hornstone is intermingled and interstratified with the calcareous strata, the whole very dark colored. The same character prevails at the western extremity of the district, where the rock outcroping on the Niagara has, from its black color, given name to the village of Black Rock."

"It will be observed, that in all cases where this rock is highly developed, the Onondaga limestone, the next rock below, is but meagerly so. For all practical purposes, in the Fourth district, the two masses may be considered as one. They are intimately connected, forming together the limestone terrace, and there are few good localities where both are not to be seen. In lithological character, there is scarcely more difference between the Onondaga and the Corniferous, than in different parts and different localities of the latter rock."

"It forms a slight barrier at the outlet of Lake Erie, at Black Rock, producing a rapid current with considerable descent, and presenting a small island just above the water which is all that now remains to show that the rock was once continuous from the two shores."

"The point of greatest thickness actually measured is on Allen's creek [near LeRoy, Genesee co.] where it is seventy-one and a half feet. At the eastern extremity of the district, the thickness cannot be more than half this, and at some points I have estimated it at thirty feet. At Black Rock there is about twenty-five feet laid open to view; but the higher part of the rock is not visible, and from the deep alluvion covering it further east, it cannot be correctly estimated." (Geol. of New York, 1843, Part IV, pp. 161 et seq. by Jas. Hall.)

for in our own State, as far as known, it has never been reached by the deepest borings.*

§ 353. *The average pitch of the Corniferous limestone towards the southwest* can be calculated from its elevation at Black Rock and Fredonia, allowing us to judge approximately of the thickness of the measures between it and the Venango oil group.

At Black Rock, as shown by the quotations below, the exact thickness of the rock is not known. We have assumed the top to lie about 52 ft. above the surface of Lake Erie, or 625 ft. above ocean level, which cannot be far wrong.

In the Coburn well at Fredonia it is said to have been struck at a depth of 1050 ft. which, (the elevation of the well mouth being 735′) puts it 315 ft. below ocean level at that place.

The distance from Black Rock to Fredonia is about 38 miles in a direction S. 35° W. and this gives an average slope or dip of about 25 ft. per mile.

But along our section line (S. 20° W.) the average dip of the limestone ought to be stronger than 25′ per mile, because the line runs more nearly in the direction of the line of greatest dip as calculated from other strata which admit of more accurate tracing. And this inference is strengthened

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*As the thickness of limestone reported in the Coburn well is rather surprising, it may be well to state here a few facts in relation to the well, as given by Mr. Coburn himself who has several specimens of the sand pumpings still preserved in his office.

In digging the conductor to the rock some gas appeared. After the drill was introduced the gas increased all the way down to 700 ft. below which point no further increase was obtained.

The limestone was struck at 1,050 ft. and continued until the drill was stoped at 1,207 ft. It was "hard and flinty" and produced neither oil or gas.

The well is tubed at 700 ft. The lower part of the hole fills up to the tubing with salt water. The pump is put in motion about once a year, but there seems to be no accumulation of water above the bottom of the tubing.

The flow of gas is 4,000 cubic feet per day by measurement. Pressure 19 lbs. per square inch. The well was drilled in 1871 or 1872 and is apparently delivering as much gas now (Oct. 1877) as when first struck.

Mr. Colburn kindly gave me some specimens of limestone, one of which, coming from a depth of 1,200′, contains a well preserved fossil shell, readily recognized as the Atrypa prisca, figured in geology of N. Y. Vol. IV page 175.

by the fact that no limestone is reported in Jonathan Watson's deep well near Titusville.*

§ 354. *The distance from Black Rock to Watson's well* is about 100 miles. Direction S. 26° W. Elevation of well mouth 1290 ft. above ocean. Depth of well 3553 ft.

On an average slope of 25′ per mile the limestone should have been found at 1875 ft. below ocean level, or 3165′ from the surface. But as no limestone was seen in the well, we must conclude either that it is absent in that locality (which is hardly probable) or that it has a greater average dip slope than 25′ per mile in that direction.

As the well stopped at 2263′ below ocean level, an average of 29′ per mile would put the limestone at 2275′ or 12 feet beneath the well. A greater dip would of course put it still deeper.

§ 355. A number of other deep wells are shown on the

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*Owing to a combination of unfortunate circumstances the record of this important well cannot be given.

In an exceptional and expensive experiment of deep drilling, such as this was, it could not be expected that the owner of a well would allow it to be watched and measured as an ordinary well might be, or that he would give to the public facts which his money paid for until satisfied that his own interests no longer demanded secrecy. Prudential considerations suggested that the daily revelations of the drill should be known only by those connected with the well, but Mr. Watson instructed his drillers to keep a good record, and to preserve sand pumpings whenever a change of rock occured, so that a satisfactory history of the well might be given to the survey when the proper time should come. This was all that could be asked and probably shortly after the work stopped a very good record could have been obtained. But Mr. Watson did not yet feel willing to make the details public because he intended soon to put up heavier machinery and sink the well deeper

Thus the matter lay for a couple of years, and then when an attempt was made to get at the facts it was found the record had been mislaid or lost, and that the specimens had suffered the usual fate of all such collections in an oil producers office—some of the bottles had been emptied because they were wanted for other purposes and others had lost their labels and were worthless. But three reliable specimens remained. One of these is of considerable importance as it shows the character of a 15 foot band of black slate at a depth of 2.600 ft. This was one of the most noticeable strata in the well and possibly may represent the Genesee slate of N. Y. Bluish slaty shales with occasional hard "shells" were found below this with very little change in the character of the drilling, all the way to the bottom and Mr. Watson is positive that no limestone was passed through. A hard rock was reported however just as the utmost limit of drilling cable forced a suspension of the work at a depth of 3,553 feet from the surface.

profile; but it will be seen that none of them have gone deep enough to reach the *Corniferous limestone*. The Watson well is not only the *deepest boring* ever made in Western Pennsylvania, but it is also *deeper geologically* than any other. It is greatly to be regretted therefore that so little can be known of its history.

§ 356. *Localization of the oil horizons to certain areas.*—A person unacquainted with the laws of sedimentary deposition and with the methods of preparing a profile-section, might inadvertantly be led to suppose from an examination of the profile section plate X, that the different strata represented there spread out continuously and universally in every direction under the oil regions; that a well failing to produce oil in the Venango group, might be put down four or five hundred feet deeper and pump oil from the Warren group, and then five hundred feet deeper and renew itself in the Bradford "Third" sand.

But such has not been the experience of oil producers. The several groups of oil producing rocks are locally well defined under certain areas; but they have their geographical as well as their geological limits, and as far as at present known, *the geographical limit of one group never overlaps that of another.*

If we take a map and outline upon it the limits of the Smith's Ferry and Slippery Rock oil-producing district—and then the Butler, Clarion and Venango—and then the Warren—and then the Bradford—we shall see that each has its own particular locus; and that the different districts are separated from one another by areas (of greater or less extent) which have been pretty thoroughly tested by the drill and proven to be unproductive.

§ 357. *Structural variations, Plate X.*—Theoretically the structure represented in this section is correct. The horizons of the various strata of limestone, shale, and sandstone, do lie superimposed one upon the other in regular order as there delineated.

But the physical constitution of these sedimentary rocks is in fact very variable. It must have been true in all ages, that every deposit of sandstone in one locality must have been represented by cotemporaneous deposits of shales in other localities. Hence it happens that, in tracing rocks long distances, the sandstones disappear and shales come in at the same geological horizon.

It may not then be presumed that each particular sandstone, or its oil, will be found in every locality where its horizon can be pierced by the drill, or that a measured section of the rocks in one place can be precisely duplicated in detail in another.

Vertical Section.

§ 358. *Summary sketch of the formations exhibited in the Vertical Section, Plate XI.* This generalized section extends from the surface rocks in the Upper Barren Coal series of Greene county, Pa., down to the Corniferous limestone, the Canadian oil rock, and will enable any one to distinguish and locate the several oil horizons thus far discovered and profitably worked in these measures. It is in fact an enlarged representation of the features presented in the Profile Section Plate X.

GROUP No. 1.

Upper Barren Coal Measures, B.—"Greene county group." Thickness 600′.

Vertical Range.—From surface to top of Washington Upper limestone.

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

Exposures.—The high lands of central and southwestern Greene county, Pa.

Authority.—Prof. J. J. Stevenson, Report K, p. 35, and White and Fontaine, Report PP.

Upper Barren Coal Measures, A.—"Washington county group." Thickness 350′.

Vertical Range.—From top of Washington Upper limestone to top of Waynesburg sandstone.

Composition.—Shales, sandstones, limestones and thin beds of coal; but carrying also the "Washington coal bed" from 7′ to 10′ thick. In Washington county 6 beds of limestone compose about one-third of the mass, but in Greene, the limestones are thin and less frequent.

Exposures.—In the highlands of Washington and Greene counties. See Report K, p. 44.

GROUP NO. 2.

Upper Productive Coal Measures.—Thickness 475′

Vertical Range.—From top of Waynesburg sandstone to base of Pittsburgh coal.

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

Exposures.—Throughout Washington, Greene and Allegheny counties. See detailed section in Prof. Stevenson's Report K, page 57.

GROUP NO. 3.

Lower Barren Coal Measures.—Thickness 500′.

Vertical Range.—From base of Pittsburgh coal to top of Mahoning sandstone.

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

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

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* Prof. Stevenson gives the section referred to above as a typical one of the Lower Barrens in Beaver county, and it will also probably hold good in a general way in Allegheny, Washington and Greene, where the exposures were so imperfect that a complete detailed section could not be obtained. But in the Dunkard creek oil wells he says "the interval between the Pittsburgh coal and Mahoning SS. is not far from 425 feet; but this interval increases northward and northwestward until in Beaver county, according to Mr. White it is from 530′ to 540′."

He adds on page 77 (and this is quoted to show the similarity of structure pervading all deposits of interstratified sandstones and shales, whether in the Barrens of the Carboniferous or in the Venango oil group—and in confirmation of opinions to that effect expressed in other parts of this report) "So great and so frequent are the changes in the sandstones and shales of this series, that a detailed discussion of the whole would be intelligible only by a comparison of a large number of sections; but for the most part the rocks are of so little interest or importance that such a comparison would be only a waste of time and space, edifying to neither the author nor the reader."

GROUP NO. 4.

Lower Productive Coal Measures.—Thickness 400′.

Vertical Range.—From top of Mahoning SS. to top of Conglomerate No. XII.

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

Exposures.—This series is exposed over a large extent of country in Butler, Armstrong, Clarion, Beaver, Lawrence and Venango counties. See Mr. Chance's detailed section, Report V, page 16.

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

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

GROUP NO. 5.

Mountain sand series, including the *Pottsville conglomerate* No. XII, and probably in some localities, some of the sandstones belonging to the upper Pocono sandstone No. X, (No. XI being either thin, or wanting.) Thickness from 350 to 425′ ft.—say 375 feet.

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

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

Exposures.—In the highlands of Mercer, southern Crawford, Venango, Forest, Warren and McKean counties.

The lower members of this group produce heavy oil at Smith's Ferry, in Beaver county, and on Slippery Rock creek, in Lawrence county and the upper conglomerate is said to be the source of some oil in Kentucky.

GROUP No. 6.

Crawford shales, thickness 400′ to 500′—say 450′.

Vertical Range.—From the base of the Mountain sand series to the top of the Venango oil group.

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

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

The horizon of the *Pithole grit* appears to furnish the light gravity amber oil at Smith's Ferry and Ohioville in Beaver county, with traces of the same on Slippery Rock creek in Lawrence county. It also probably yields the heavy, lubricating oil of the Mecca district in Trumbull county, Ohio. (See Chap. 8.)

GROUP No. 7.

Venango Oil Group.—Thickness 300′ to 375′. Say 350′

Vertical Range.—From the top of the *First Oil sand* (the "Second sand" of the driller in Butler county) to the bottom of the *Third Oil sand* (called the "Fourth sand" in Butler, Armstrong and Clarion, and the "Fifth sand" in some parts of Venango county.)

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

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

At Tidioute, the deep gorges of Dennis run and the Allegheny river expose the *First and Second Oil sands*, and as far up as Warren it is quite probable that we see the upper portion of the group exposed in the river hills. These are the only localities where a portion of the group in even an approximately normal condition may be seen above water level. Its horizon is cut through by many of the ravines of McKean county, but it has there become so changed in its physical aspects, that it disappears or becomes unrecognizable when the proper range for its outcrop is reached.

These are the oil sands of Tidioute and Colorado, Warren county; Fagundus, Forest county; Church Run and Titusville, Crawford county; and of all the well known oil centres in Venango, Clarion, Armstrong, and Butler counties.

They produce oil in different localities from the different members of the group ranging from 30° to 52° in gravity and varying greatly in color—Green oil from the *Third sand*, on Oil creek; black oil from the Stray sand at Pleasantville; amber oil from the *Second sand* in many places; and dark heavy gravity oil from the *First sand* at Franklin. There are also occasional local deposits of oil, shading from a light straw color to almost a jet black.

GROUP No. 8.

Interval between the Venango oil group and the Warren oil group.—Thickness 300′±.

Vertical Range.—From the base of the *Venango Third oil sand* to the top of the Warren oil group.

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

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

GROUP NO. 9.

Warren Oil group.—Thickness about 300 ft.

Vertical Range, and Composition.—This group may be viewed as including the so-called *Second, Third*, and *Fourth sands of Warren*; but its composition is so variable in different parts of the district that it does not afford any persistent bands of sandstone, by which to define either its upper or its lower limit.

At north Warren the upper part is shaly, and the largest wells, it is claimed, flowed from these shales, while others got their oil from the "Third sand." At Warren the Second sand" is fairly developed, but the oil generally comes in the Third sand." At Stoneham a lower sand, the "Fourth" produces the oil. Thus the North Warren shales are represented at Stoneham by more sandy measures which contain no oil, and the Stoneham "Fourth sand" is poorly developed at North Warren, and unproductive. The group then may be said to extend from the top of the North Warren shales to the bottom of the *Stoneham sandstone*, covering an interval, as nearly as may be calculated, of about 300 ft.

GROUP NO. 10.

Interval between the Warren Oil group and the Bradford "Third sand."—Thickness from 400′ to 450′—say 400 ft.

Vertical Range.—From the *Stoneham oil sand* to the *Bradford oil sand* ("Third").

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

Similar difficulties are encountered in estimating the thickness of this group to those mentioned in No. 8. A large number of wells have been sunk between Bradford and Warren, but the rocks are so variable in composition and the well records have been so imperfectly kept, that no completely satisfactory identification of the rocks of the Warren oil group with their equivalents at Bradford, or of the *Bradford* "*Third sand*" with its corresponding stratum at Warren, can yet be made. The interval between the two oil horizons, however, appears to be in the neighborhood of 400 ft. as above given.

This interval holds the *Bradford* "*Second sand*" which has yielded oil in many of the McKean county wells and also the sandy-shale horizon producing "slush oil" along the Tuna Valley.

GROUP No. 11.

"*Bradford Third sand.*" Thickness from 20 to 80 feet.

Composition.—A fine-grained, light to dark-brown sandstone, containing pebbles the size of pin heads in some localities, while in others it is little more than a sandy-shale. It appears to be rather thin and irregularly bedded, is frequently interstratified with thin layers of grey, slaty, sandstone, and contains many fossil-shells and fish bones.

The constitutional peculiarities of the rock—its color, its composition and its structure—insure its ready recognition by the driller in any locality where he may find it in even an approximately normal condition. But this rock, like all others, has its geographical limits, outside of which, its geological horizon can only be traced by the exercise of the greatest of care and the best of judgment in keeping and studying the well records.

It is seldom however that good records of wells on debatable territory are kept. The well owner always starts the drill on the presumption that the oil rock will be found. He calculates in his own way its approximate depth from the surface, and makes a contract to drill so many feet.

Confident of success he urges on the drill making no particular note of the character of the upper rocks. But when the supposed horizon of the sand is reached and the evidences of its presence do not appear as anticipated, he discovers too late that he has nothing to check by, to ascertain whether the oil rock is actually wanting or only so changed in character as to be scarcely recognizable, or whether there may not have been some mistake in calculating its position in the well. Thus it often happens that wells of this class are abandoned, after drilling in doubt for a few days, without having been sunk to the proper depth; while others are carried on down many feet below the horizon of the sand they are in quest of; and much valuable information is lost which a little prudent foresight might have secured.

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

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

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

GROUP No. 12.

Interval between the Bradford "Third sand" and the Corniferous limestone, commencing in the Chemung and including the Portage and Hamilton groups of the New York geological survey. Thickness 1600′±.

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

The thickness of this interval must be left questionable for reasons previously stated. We have no means of tracing the Corniferous limestone south of Fredonia, N. Y. except approximately, by its slope. The distance from Fredonia to Bradford is about 48 miles, direction about S. 45° E. A dip of 20′ to the mile would be required to place the limestone at Bradford as shown in our section.

GROUP No. 13.

The Corniferous Limestone, probably shown in the vertical section Plate XI, in conjunction with the *Onondaga limestone.*

The composition of this group has already been referred to in the quotations given from Geology of New York.

It is the oil producing rock of the Canadian oil regions, but at Fredonia, N. Y. yields neither oil or gas. We may not presume therefore that it will ever be found to be an important oil horizon in Pennsylvania. and even if it should prove to be productive here, the great depth at which it lies beneath the surface must be a very serious obstacle in the way of its development.*

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* Beneath the Corniferous or Upper Helderberg limestone, lie, in regular order downwards:—Oriskany sandstone—Lewistown limestone and other Lower Helderberg calcareous rocks—Clinton red and other shales with fossil

CHAPTER XVIII.

Causes for withholding Well-Records from geologists.

§ 359. *Their abundance.*—It is said that about four thousand well-shafts were sunk in the oil fields of Penna. and New York during the one year of 1877.

Never before in the history of the enterprise were wells put down so rapidly. Scattered over every part of western Penna. from Smiths Ferry, near Ohio, to Olean in New York—from Lake Erie to the Allegheny mountains—they were necessarily drilled on every class of territory; on that known to be good as well as that recognized as purely experimental on account of its being outside of previously tested areas. They were drilled in districts producing oil from all the known horizons extending down from the Mahoning sandstone to the Bradford oil rock, and many of them were carried down several hundred feet below the Bradford oil horizon in quest of something new.

§ 360. *Total length of boring.*—Allowing these wells each to average 1056′ in depth (and this is undoubtedly too low an estimate) every five wells aggregated one mile of rock, making altogether 800 miles of bore hole drilled in one year!

§ 361. *Small percentage of good recording.*—What a

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ore beds and sandrocks—Medina and Oneida sandrocks, forming many of the mountains of middle Pennsylvania—Hudson river and Utica slates—Trenton, Birdseye, Chazy and Calciferous magnesian limestones, forming many of the broad valleys of middle Pennsylvania and containing great deposits of brown hematite iron ore—and Potsdam sandstone, the bottom formation of the Palæozoic system.

Under these lie vast formations of chlorite and mica slates, gneisses and primary limestones, with serpentine rocks, conglomerates, porphyries, traps, and huge beds of magnetic and specular iron ore, belonging to the Huronian and Lawrentian systems.

As the Palæozeic rocks are 20,000 feet thick in front of the Allegheny mountain, it is probable that a well in the oil region would require to be put down a good deal deeper than 10,000 feet to strike the Huronian floor.

broad field for geological study would their records have afforded if they had been properly kept and were now accessible to us. But unfortunately for the interests of the survey, the oil producer is drilling solely to benefit himself and cares very little for the advancement of science or the financial welfare of those who may drill after him. Of this large number of wells, probably there has not been preserved a special record of *one in a hundred*, and but few of those that have been preserved can be obtained in a shape to be of any use to the Survey.

To those who are unacquainted with the business of oil-producing and the methods of drilling, this may seem strange; and it will be a matter of wonder to scientific men abroad, that the survey has been able to secure so little, comparatively, to illustrate the underground structure of the oil regions, when such wide-spread developments by the drill has been constantly going on in the country.

A few words in explanation here, to set the matter right, both as it regards ourselves and the oil producer, may not be considered out of place in this report.

§ 362. *Drilling by Contract.*—Nearly all the wells at the present time are bored, not by the well owners, but by men who take the job of drilling by contract. The carpenters rig having been erected and the boiler and engine set up, the contractor agrees to furnish his own tools, cable, fuel, &c., and to drill the well a certain depth or to the oil bearing rock, for a stipulated sum, or at so much per foot; binding himself to deliver a good clear hole ready for the tubing, or no pay. Wells are drilled much more rapidly and cheaply than they were five years ago, and the compensation is such that a contractor can only make money by making fast time. The drill must be kept constantly in motion and the men employed have no time to spare for anything but the work in hand. The delay occasioned by measuring depths, preserving sand pumpings and recording facts, necessary to give a record any scientific value, would cost a contractor from fifty to one hundred dollars in loss of time on an ordinary well. We cannot therefore reasonably expect or ask him to make this sacrifice purely in the interest of science. He has no need of the minute details which it requires, and while he recognizes the different sands in a general way as the drill goes down, and mentally notes for the time being, any unusual features in their structure, his main thought is to complete the contract as soon as possible without mishap ; and when that is done, having no further interest in the matter, even these general outlines of the well's history are soon forgotten.

The well owner, manifestly can give only such a record as is returned to him by the contractor. This is usually a brief memoranda giving the depth to the oil sand, its thickness and the best point at which to explode a torpedo—facts very good as far as they go, but too meager to be of much practical use to the geologist.

§ 363. *Record circular issued by the Survey.*—At the commencement of the survey it was hoped that both well owners and contractors would see it to their interest to aid the work. Nearly every operator spoken to on the subject expressed a willingness to assist in collecting reliable well records, and some went so far as to insert a clause in their subsequent drilling-contracts requiring an accurate register of the well as a part of the work to be performed. To facilitate matters and give the contractor as little trouble as possible, blanks were furnished by the Survey, to be filled in by the driller as the work advanced ; and to make plain the method of recording the facts required, a duplicate form was struck off to serve as a guide or key. On this key a supposititious well record was printed in a different color from the body of the blank, so that any one could see at once how the blanks should be filled. A copy of the key is given on the next page, the italics representing that which was printed in color.

Record of *specimen* well, on *Smith* farm, *Donegal* township, *Butler* county, owned by *Smith & Jones*, Struck *January 7th, 1875*.

Conductor.	Shale.	Slate.	Soapstone or Mud rock.	Sandstone.	Pebble.	Red Rock.	Coal.	Fire Clay.	Iron Ore.	Limestone.	Total.	Remarks.
12											*12*	*Surface clay.*
	10										*22*	*Olive and brown.*
		7									*29*	*Coal slates (black).*
							3				*32*	
								2			*34*	
		46									*80*	*Dark.*
				50							*130*	*Grey.*
		80									*210*	
				20							*230*	*White: water vein.*
		50									*280*	*Bluish.*
										15	*295*	*"Black lime."*
							5				*300*	
		120									*420*	*Mixed with sand and shale.*
										100	*520*	*"White lime."*
	140										*660*	*Bluish, with slate.*
				160							*820*	*Mountain sand.*
		25									*845*	*Dark.*
				75							*920*	*Soft streaks in centre.*
		180									*1,100*	*Bluish.*
				15							*1,115*	*Coarse and pebbly; gas.*
						5					*1,120*	
				20							*1,140*	*Salt water and gas.*

Total depth of well, *1,140* feet. Cased at *720* feet. Best production per day, *300* bbls. Gas sufficient to run *8* well engines. Color of oil, *Green*. Gravity, *47°*.

(Name) *JOHN SMITH,*
(Address) *Petrolia.*

Date, *September 1st, 1875.*

§ 364. *Value of the circulars returned.*—The blanks and key were sent out together and it was expected that this would insure uniformity in the records and result in the acquisition of much valuable information. But these anticipations were not realized. Not one blank out of ten was returned, and many of those that did come back bore such palpable evidences of having been written up from memory after the well was completed rather than from actual measurement and annotation during the period of drilling, that their value rated very low and some of them had to be discarded altogether.

§ 365. *Utility of well records not appreciated.*—In many cases it is not alone the pecuniary consideration involved in a loss of time, that prevents a contractor from keeping a detail record, but he fails to do so because he sees no utility in it, being perfectly satisfied in his own mind that he thoroughly understands the structure where he is drilling and honestly believing that he can give a record from memory sufficient for all economical or scientific purposes.

Other obstacles are encountered in endeavoring to obtain records, which, while they are only what should naturally be expected under the circumstances might seem very singular to the uninitiated if left without explanation.

§ 366. *Secrecy observed about trial wells in new territory.*—Wells that are drilled in new and *untried territory*, and those that are sunk to exceptional depths, are of especial value to us. Their records, as a general rule are *much more accurately kept* than others, for the owners and drillers pay closer attention to the changes in stratification—as a general rule, too, no one can find out any thing reliable about them. Quite often it is so much to the interest of the driller, land owner and lessee to falsify or at least obscure the records by varying versions, that it is very unsafe to base conclusions upon them even if they can be obtained.

§ 367. *The interest of the driller in doctoring the record.*—We must not presume the average driller to be less or more scrupulously honest than other men. He is working for money and is shrewd enough to know how to take advantage of opportunities for advancing his own interests. If he is drilling for a strong company who have faith in their territory and pluck to continue to drill notwithstanding a few dry holes, he in all probability will assure them, that in the first well put down, the rocks were "regular" but the third sand was a little to fine and close in texture, showing plainly the edge of the belt. The question then arises which way to move the rig for another venture. In this discussion he is uncertain and wavering until the spot is selected by the owners. Then, although he acquiesces in their decision and readily goes to work on No. 2 he begins to express doubts as to the location of it, and feels pretty confident they ought to have moved east instead of west, or *vice versa*. No. 2 is finished. It is dry; and of course the sandrock is reported thinner and finer and not so good as in No. 1. Evidently the rock must thicken on the other side of No. 1. Result, another dry hole put down in that direction. Three wells secured to be drilled, by a little manipulation of the contractor, and the profits pocketed, when in all probability there was nothing in the first one, if the stratification had been properly watched and studied, to warrant even a second venture.

Some of the most unreliable records I have examined are those returned to extensive operators and systematically recorded in their books, by men whose interest it was to agree with the theories of their employers, and who found it more profitable to arrange the records in accordance with their ideas of structure, than to follow with fidelity the precise stratification as the drill disclosed it.

§ 368. *The interest of the land owner in doctoring the record.*—In the case of land owners and lessees very cogent reasons frequently present themselves for witholding well records from the public. Acting on some closely kept theory of his own which he has worked out from pervious successes in prolific areas; or guided by spiritual influences; or led by the divining rod or magnetic-oil-indicator of some professional well-locator; or following lines drawn from one district to another, regardless of the age or stratigraphical relationships of the rocks he is attempting to trace; or governed by the appearance of conglomerate on the surface;

or directed by whatever controlling influence it may be—the operator goes out into a new field in search of oil. He secures large bodies of land by lease or purchase investing perhaps tens of thousands of dollars. He adds to this the cost of sinking a well. Is it to be wondered at if he feels that the information he gains is his own, or that he should repel with jealous care every attempt made to pry into the history of his venture?

If the well is not a pronounced success, he may be satisfied from indications discovered in drilling, that he is near the belt and can locate his next well on the right spot. But this may necessitate the securing of more land which he can only get by concealing his record, feigning discouragement and temporarily abandoning the enterprise, until those who hold the land he wants, expecting to make him pay roundly for it in case of success, are induced to forfeit their leases or transfer them for a nominal consideration to some party secretly employed by him to secure them.

§ 369. *Traditional sentiment that wells have failed because not deep enough.*—If on the other hand the well is unquestionably a failure and he sees that he has made a mistake and located in hopelessly dry territory, it is equally to his interest to prevent the record from being made public. There is no difficulty in assigning some plausible reason for the non-productiveness of a well—bad management of the contractor; water not effectually cased-off; inadequate testing; insufficiency of depth, only discovered after abandonment, &c., &c. Rumors like these, particularly the one in relation to depth, once started, are readily taken up by the land-owners in the vicinity. They all honestly believe, as they assert, that "there is no reason why there should not be just as much oil here as on Oil creek if a well is put deep enough." The idea that a failure to find oil always proves the well not to be deep enough, seems to be universally prevalent among old settlers, and it matters not whether the location is on the Lake-slope, where the drill starts geologically 1000 feet below the Venango oil sands, or in the center of the coal fields of Westmoreland county, where it commences its work 2000 feet above them. Deeper drilling in every case is supposed to be the only thing needed to procure oil.

After a rest of a few years the oil-fever will in all probability again break out in the abandoned district. By this time the *unwritten history of the old well* has become a family legend in the neighborhood. No one knows definitely anything about the stratification, but everybody near it knows that the well was not deep enough—that the rocks were "regular" as far as drilled, the oil-show good and the prospects decidedly encouraging. A new party now comes into the field, bated by these common reports, which agree perhaps with what he conceives should be the situation according to some theory upon which he is operating, and ventures a second well. This attracts attention in that direction and creates more or less excitement which the first party probably helps to fan, and then before the second well is down, he quietly sells out to some of the sanguine new-comers, thus materially lessening the losses the enterprise would otherwise have entailed upon him, had he made the true situation known by putting on record for public use a carefully kept register of the well when drilled.

§ 370. *Publicity opposed by good business policy.*—From a business point of view and looking only to personal interest, there is no reason why any oil-producer should allow his well records to become public property. If he has made a successful venture, the prompt publication of the fact causes an eager crowd to rush in around him on all sides, and he is often obliged in consequence to drill more rapidly than he otherwise would, to protect himself, or in other words to secure his share of oil in the pool which he has discovered—for it is now well known by experience that oil cannot safely be "tanked in the rock" as formerly supposed, to be drawn forth when wanted, if in the meantime wells are drilled and pumped all around the borders of the oil-bearing "tank."

Many farms known to be good, and held in reserve for development when the price of oil should warrant, have been found when subsequently tested, to the chagrin of their owners, to be almost completely drained by the wells on adjoining lands that had been steadily at work during the intervening time in depleting the reserved pool which no farm lines could protect a thousand feet below the surface.

§ 371. *The geologist's difficulties.*—There can be no question but that these are some of the causes that have deprived the survey of much valuable information of which it otherwise might have been able to avail itself, and it is to be regretted that it is precisely that kind of material most needed in working out broadly the underground structure of the oil regions.

But who can censure the oil-producer for it. He is only doing, as he conceives, what any prudent man would do to further his own plans and facilitate the advancement of his own interests.

The verdict of "no one to blame," however, does not help the geologist in this dilemma. He is left to grope on in the dark, in relation to every new field—forced to calculate and work out deductions as best he can from data obtained at a distance, or culled from a mass of contradictory and unsatisfactory statements as liable to mislead as to instruct. At the same time he is expected to know all about it, and his views of its structure, extent and possibilities are often sought by the very men who are withholding or purposely mystifying the facts on which alone a reliable opinion could be formed.

He is thus frequently exposed to the hazard of error in judgment, sometimes by relying upon plausible representations which prove not to be well founded in fact, and sometimes by unwittingly rejecting absolute facts because they are presented to him in such shape and under such circumstances that he has no confidence in their authenticity. His task is a thankless one at best. His vocation seems to be as generally misunderstood by the well-informed oil-producer as by the most illiterate rustic. The one supposes him capable of telling from the size or shape of a pebble or from a pinch of soil just what may lie below for thousands of feet, the other is confident that a twenty-two and a half degree compass line is a safer guide for oil operations than all the geology in the world. If he attempts to trace the probable outlines of the oil-bearing rocks, he at once incurs the displeasure of all the land-owners and interested parties left out of his lines—if he makes no exhibit of the underground structure, he is set down as a failure, so that in either case his position is an unenviable one.

§ 372. *Obligations of the survey to oil-producers for good records.*—But it must not be understood that these remarks universally apply without exception. We are under obligations to many of the oil-producers of the district for special favors; for the privilege of copying their well records and maps; for specimens of sand pumpings, oil and gas from their wells; for fossils &c; and within the developed districts, free access has been had to all the facts and data preserved. The gentlemen who have thus kindly assisted us are too numerous to mention individually, and an acknowledgment of their courtesy and good will can only be made in this general manner.

As before stated, however, these data are principally such as have been furnished by the well-borer for purely practical purposes in immediate connection with the wells to which they appertain, and are frequently imperfect and omissive in those portions most essential for broad geological study.

§ 373. *Plan adopted for securing good records.*—To remedy these defects, it was found necessary to employ a special assistant for the purpose of securing a few accurately measured and detailed well sections in different localities—The results of his work will be given in the following chapters.

CHAPTER XIX.

1. Bad well records the true cause of the confusion in the popular names and positions of the Oil rocks.

(Illustrated by Plate XXXI.)

2. Method of measuring two groups of wells by the Survey.

§ 374. *How to secure well records in a complete and reliable form* has been one of the perplexing questions of the Survey. A number of plans were tried during the first two years, but with quite unsatisfactory results. The difficulties in the way are numerous and sometimes insurmountable. Some of them are stated in Chapter XVIII, and others may here be added.

§ 375. In the last chapter it has been intimated that in the ordinary course of development, proper records for geological study cannot be obtained. Every interest of the business is against it. The contractor is drilling to make the best time possible, that he may reap the largest margin of profit on his contract. The well owner cares nothing for the structure, except as it relates to the oil-producing sand, and with him too time is of great importance. The work cannot be delayed by superfluous measurements, and washing of sand-pumpings, to satisfy what they consider to be, only scientific curiosity.

In districts which are being rapidly developed and where the drill-holes are clustered closely together, a delay of a few days in the completion of a well may make a difference of thousands of dollars in the total receipts from it. There is a certain amount of oil in a pool, and those who reach it first have the advantage of a strong flow and full supply until others tap it and assist in diverting and relieving the pressure. In such situations contracts are often made giving the men employed on a well fifty cents or a dollar a day extra if they succeed in reaching the rock within a specified time. Everything is rushed with the utmost speed. There is no time for scientific inquiry with the possibilities of a hundred or perhaps a thousand barrel well in prospect. Even the most staid and methodical student of nature is apt to forget himself when he becomes a well-owner and is caught up and carried along in the whirl of excitement pervading the atmosphere of a new and prolific oil field.

§ 376. *The drillers' record is almost always defective for geological purposes*, and sometimes in very essential particulars. To him nothing in the well has any particular significance but sandrocks, and these are only deserving of careful examination when lying near the oil-producing horizon. Consequently the upper strata are carelessly noted, and the characters of shales and slates indefinitely given.

He has not yet learned the importance of a close scrutiny of *all* the measures drilled through—particularly the oil group proper—and by reason of this inattention to the character and position of the upper rocks, has been led into many errors of judgment and prevented from obtaining as comprehensive an idea of the general structure of the measures as he might otherwise have acquired.

§ 377. *The driller recognizes no geological distinction between the higher sands and the oil group*; assigns no fixed relative positions to the respective horizons of the several oil sands, in harmony with their arrangement where first found and named on Oil creek; but uses the designations 1st, 2d, stray and 3d sand indiscriminately in different districts, sometimes applying them to higher rocks in the series and sometimes to lower—thus introducing great confusion and disorder into the nomenclature of the oil measures.

§ 378. *The careless numbering of the sandrocks* gave us the 4th sand above the true 3d at Pithole and Pleasantville; carried the stray up to the lower division of the 2d at Tidioute; brought the 2d down to the stray at Church run; raised the 1st up to the Pithole girt horizon in Butler county, and introduced under it in that locality new names—the 50 foot rock, 30 foot rock, Blue Monday, Bowlder, &c.,—

making it appear as if there was no regularity in the general structure of the oil producing rocks, and so involving and obscuring the order of stratification that no one could tell positively how the sands of one district were related to those of another.

§ 379. *Sections 68 to 73.*—This *popular* Babel *of oil rock stratification* is graphically illustrated by the plate of sections on pages 178 and 179.

The same plate also shows how simple the language of nature is, after all, if we will only stop to read, and study to interpret it aright.

Six sections made from actual oil well records in different localities, and drawn to an uniform scale, are grouped upon the plate for comparison. The complete registers may be referred to as follows:

Fig. 73 Tidioute; Report II, well No. 765.
" 72 Church run; Report II, well No. 965.
" 71 Pithole and Pleasantville; Report II, Nos. 1 and 24.
" 70 Oil creek; Report II, well No. 112.
" 69 Clarion co. Chapt. XXI, this volume.
" 68 Butler co. Report II, well No. 1170.

§ 380. *Local popular arrangements of the sands.*—These records are selected because they give the order of the sands in accordance with their *numbers and relative positions as named and popularly recognized by operators and drillers in the several districts* where the wells are located. They may be viewed as typical representatives of the general structure of the areas named, although a comparison of them with other records from the same neighborhoods, but given by other drillers, will disclose almost as much *local variation and disagreement of names and horizons* in each of the respective districts themselves, as is to be seen here in these six widely separated wells.

§ 381. *True and universal arrangement of the oil sands.*—But whatever irregularity of the oil rocks may be observed in the sections given or the well records examined this one universally prevailing characteristic will be noticed in every part of the oil field—immediately above the true 1st sand lies a mass of soft rocks from 150′ to 200 feet thick—

Plate XXXI.

Fig. 68. Karns City.

Fig. 69 Edenburg.

Fig. 70. Oil Creek.

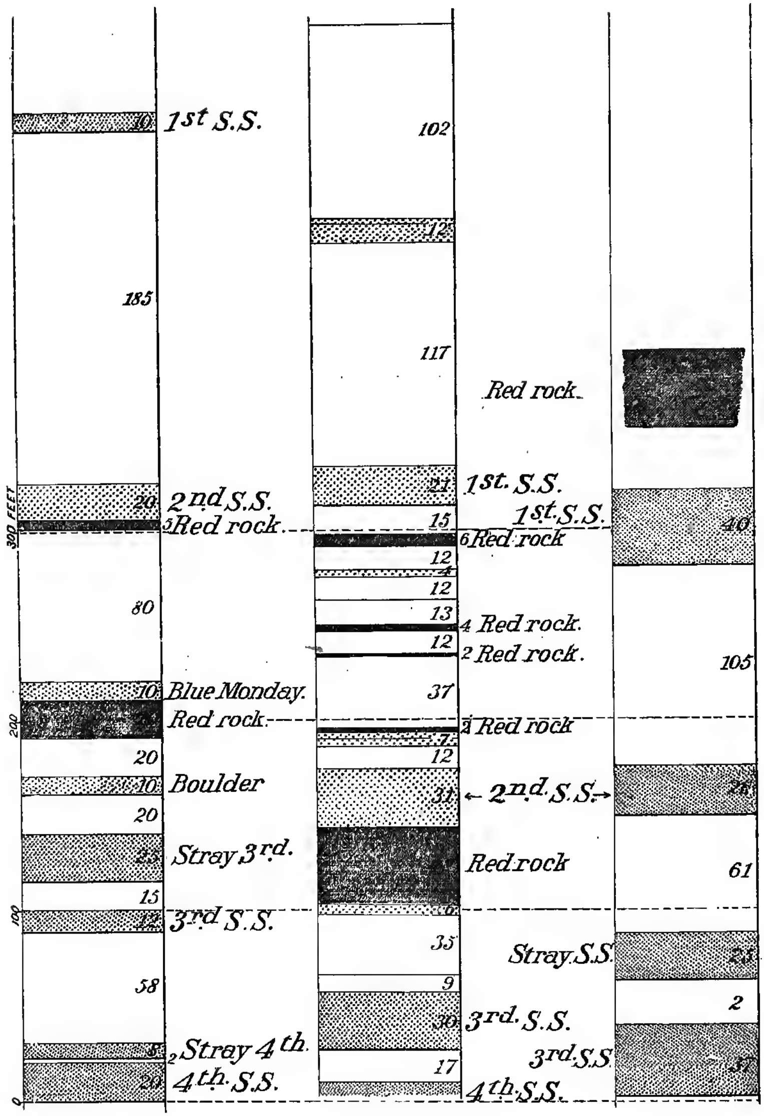
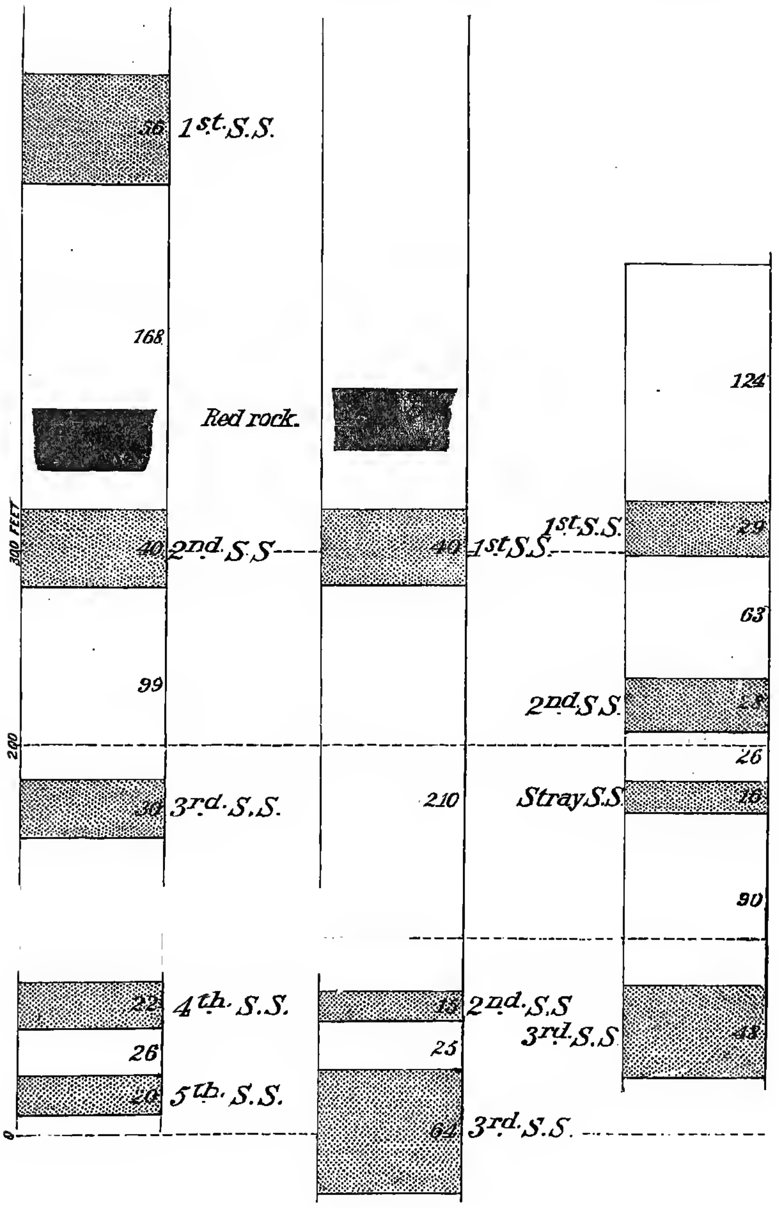


Plate XXXI.

Fig.71. Pleasantville.

Fig.72. Church Run.

Fig.73. Tidioute.



a complete and persistent division along the oil belt, between the Pithole grit and the oil group. Every driller has noticed this fact, every correct well record in the productive districts shows it; and yet no particular significance has been attached to it. It is also a fact equally as well established by deep drilling, that no sandstones like the oil sands of Venango are found for hundreds of feet below the productive oil group. We have here then, a well defined band of sandstones and shales lying between thick masses of purely argillaceous rocks, and this band, from 300 to 375 feet in thickness, includes all the oil rocks of the Venango group.

§ 382. *Variability of the oil sands taken separately.*—It may be safely said that the oil sands individually are extremely variable—thickening or thinning rapidly in this direction, splitting up into two or three members or fading into shales in that—whatever may be the persistency and uniformity in thickness of the whole series when viewed as a group;—therefore the driller discovers very marked variations in the several members—in thickness, in position, in composition—and no precise classification of them that he may make in one field will hold good in every particular in another at a distance from it. But the natural horizons of the three sands will be disclosed in every locality on a proper study of the stratification. This being the case, consistency requires that if ordinal numbers are used at all to designate these sandstones, they should only be applied at the same horizons in the group, and as near as may be to the equivalents of the same strata that they were originally intended to represent: 1st SS. to the top of the group; 2d SS. to the middle, and 3d SS. to the base—whatever other names it may be found necessary for local convenience to introduce between them.

§ 383. *First arrangement of the oil sands made on Oil creek.*—It so happened that the first wells on Oil creek were drilled in a valley which had been eroded below the Pithole grit. They consequently passed through no sandrocks but those belonging to the oil group. The whole group was there fully developed and clearly defined, and the "*Three sands*" included all there was of it. The records of tens of thousands of oil wells put down since that time, confirm, (notwithstanding their confused nomenclature) the general structure then announced and accepted; and it is folly now to think of commencing to number the oil rocks on a higher stratum, or to persist in designating the base of the group by numbers which convey the impression that new-found strata have been reached, lying below what was called the 3d sand on Oil creek.

§ 384. *No excuse for transposing the order of the oil sands.*—Referring to the plate on page 178 above, we see that there is no obscurity in the structure of the oil group when properly understood, to excuse the operator for the strange transposition of terms used in designating its several members.

The Oil creek section, Fig. 70, may be viewed as the normal type of stratification, because it represents the order and position of the sandrocks where discovered and named. Here the driller took his first lessons in oil sand structure, and if he had studied intelligently, when he afterward came to drill at Church run, the thick mass of 210 feet of soft rock below the 1st SS. would have suggested at once the absence of the 2d sand in that locality, and especially so, when he found the other two sands below corresponding so nearly in relative position and character to the Stray and 3d on Oil creek.

In the Tidioute section also, the central position of the two sands found between the 1st SS. and 3d SS. should have indicated to him that they both belonged to the horizon of the 2d sand, and not partly to the 2d and partly to the 3d, as the application of the term "Stray" to the lower member would imply.

The Pleasantville record is one selected to represent both the Pleasantville and *Pithole* districts, because it agrees with the general structure as given in the first well drilled at Pithole, in 1865, (Frazer well; II, No. 885,) and to show the manner in which the name "4th sand" originated; which name thenceforth became a common term for this stratum, (really the representative of the Oil creek stray) throughout all this region. There is no doubt, however, that a split or duplicated second sand was found in the Frazer well, but the drillers only noted one of them. The *Pithole district* and south *Pleasantville district* would, therefore, be represented more properly by a section with a second sand similar to Tidioute. This order of the rocks is given in many of the records of these localities, and then the first sand is correctly numbered, the two members of 2d SS. are called respectively 2d and 3d, and thus the stray becomes the 4th SS., as in the section shown in the plate.

It would be impossible to represent on a single plate, such as the one given on p. 178 above, all the variations in numbers and positions of sandrocks, made by the drillers, and it would only complicate matters if we attempted to do so. It is quite sufficient to show that the oil rocks can be traced as an independent group from one end of the oil belt to the other, and that if the original classification of the three sands had been adhered to as closely as possible, and confined strictly within the range of this group, operators as a class would have had much clearer views of the structure of the oil regions, and been able to work much more understandingly than they have done.

Measurements of Wells by the Survey.

§ 385. After two years of fruitless effort in attempting to convince the driller that the whole of the oil group should be carefully watched and measured as well as the oil-producing sand, and finding it impossible to secure such records from him as were needed for geological study, the employment of a special assistant was authorized, whose sole duty should be to secure some carefully-kept and complete well records for our use.

§ 386. *The wells selected for measurement.*—In the fall of 1876, my nephew, Mr. John H. Carll, commenced this work. His first charge, was six wells near Petrolia, in Butler co.; his next, three near Edenburgh, in Clarion co.; and these were supplemented in the winter of 1877–78 by one at Bradford, McKean co., taken still more in detail by Mr. Arthur Hale.

§ 387. *A full history of the drilling of these wells* will be given, in order that those unacquainted with the business may form some idea of what it is to put down an oil well; and the accompanying records, sections and illustrations, will also furnish much material of interest, we trust, to geologists.

Methods of making measurements.

§ 388. Our principal measurements in the wells were made with a *steel wire* prepared for the purpose, but as there are several methods of well measurements in vogue, it may be well to here describe them in order.

§ 389. *Rope measurement* is the most common method, or was in former years, if not at present. A stick five feet long, like a yard-stick, is made; a little strip say two inches long is then tacked transversely on one end of it and projects over on each side like a letter T. When drilling is suspended and a measurement is to be made, the rope is drawn taut by the bull-wheels until the tools are known to be just touching the bottom, and a string is tied around the cable at well-mouth level. The engine is now started slowly, and as the cable runs up, a man holding the measuring-rod in his right hand, seizes the cable with his left, and crooking his thumb at right angles to the cable, brings the end of it against the string. He then clasps the cable with his right hand, holding the measuring-stick in the palm against the rope and draws it down until the top projection rests upon his thumb, immediately removing his thumb and placing it in a similar manner on the cable under the lower end of the stick, for a repetition of the operation. Remarkably accurate measurements can be made in this way, with proper care, if the engine is run steadily and the measurer is careful to place his thumb properly and not let it slip during the changes of the rod.

§ 390. *Stick measurement.*—Another way is to take *two measuring sticks*, without the cross-top, and station two men at the well-mouth, where they alternately hold their rods firmly against the ascending cable, and abut the upper end of one stick against the lower end of the other before it is removed. This is considered a more accurate method than the first.

§ 391. *Derrick measurement.*—Still another way, ("*the derrick measurement*") is to measure accurately the distance from the well-mouth over the crown-pulley and down to the centre of the bull-wheel shaft, or some fixed point near the bull-wheels. This distance is ordinarily about 140 feet. A string is tide on the drilling cable at well-mouth as before, and when this string has gone up over the crown-pulley and come down to the point at the bull-wheels, the engine is stopped and another string is tied around the cable at well-mouth. By repeating the operation, counting the stops and measuring the last fractional part with a stick, very good and rapid measurements can be made in this way. It is more convenient, however, and economizes time, to use this method when letting the tools in the well, for the stops can be made more readily with the brake than the engine; but it is questionable whether the results are as good. In the former case the rope is firm and solid from the steady weight of the tools in drilling. In the latter it has been coiled on the bull-wheel shaft, has dried somewhat, perhaps, and is quite likely to alter more or less by stretching, as it goes into the hole with the weight constantly increasing as the tools descend, on that part of the cable where the measurement is being made.

§ 392. *The wire measurement* method is considered the most accurate, but even this may give unreliable results.

The apparatus generally used consists of a coil of No. 16 steel wire either round or flat, wound upon a hand reel which can readily be put in position at the well-mouth. The wire is marked off into 50 feet divisions which are noted by little buttons of solder brazed to it, or by fine wire or waxed silk wound firmly around it. The flat wire is sometimes marked by a short twist at each fifty feet. A light weight is attached to the end of it to carry it down. These "measuring reels" are made by different parties and the well owners buy and use them with perfect confidence in their accuracy; but no doubt many of them are far from correct. In using them one is not sure that they have been accurately marked; the wire undoubtedly stretches more or less when subjected to heavy strain in deep wells; the marking tags sometimes slip unnoticed and many other things may happen to vitiate their measurements.

The reel used for our work was prepared with a great deal of care, the tags were brazed upon the wire and plainly numbered and every part of the wire when measured was subjected to a strain beyond what it would receive in the well, in order that it might not afterward be affected by stretch. It was well taken care of and carefully used and the results ought to be perfectly reliable. Several wells were measured with this wire that had previously been measured by other wires and a disagreement was found of from 5 feet to 10 feet and in one case as much as 15 feet.

§ 393. *The wheel.*—In the fall of 1876, while preparing for our well measurements and planning how to gain our ends with the least annoyance to the driller, I suggested the construction of a wheel which could be held in the hands and pressed against the cable as it ascended, the revolutions of the wheel to be recorded by an index, on the same principal as the odometers used on the survey. The wheel was made and works nicely but was not completed in time to be of any service on these wells.

Afterward, in the spring of 1877 I saw a similar device, made by Mr. J. F. Ramsey, in use on the Economy Company's well No. 2 at Beaver Falls, and it was said to do excellent work. This was a simple grooved wooden wheel 5 feet in circumference, fixed in a frame which was shoved up to the well mouth whenever a measurement was required. A peg in the rim rang a bell at every revolution and the well was measured at any time by running up the cable and counting the bell-strokes.

Mr. Ramsey suggests that the crown-pullies for derricks be made 5 feet in circumference and then by running a wire down to a bell fixed in the derrick near the driller the depth of a well could be known every time the tools were drawn. This is a novel idea but I have no doubt the plan could be made to work well and it would suffice for all ordinary measurements.

The hand wheel measurer has recently been patented I understand by some one in the State of New York, and is now being introduced into the Bradford oil field. If it works satisfactorily, (as it must if properly constructed) it will be welcomed as a great time saver and being so easily used it will give us much fuller and more satisfactory records than we have heretofore been able to obtain.

§ 394. *Difficulties in the way of getting a good record.*—*Measuring an oil well*, *preserving sand-pumpings*, and *keeping an accurate register of the variations* of strata are not such simple matters as many suppose.

1. *In feeling bottom.*—The first few hundred feet may be managed without much difficulty, perhaps, but when *one third of a mile of measuring wire* is to be let down into a hole and reeled up again by hand it is not a speedy or an easy operation.

At great depths it requires a *sense of touch* acquired only by education and experience, to enable one to tell *when the bottom is touched* and the wire taut, particularly when the hole is partly full of oil, kept in constant ebullition by *escaping gas.* Under these circumstances it is sometimes really impossible to make a correct measurement with wire.

2. *The night drilling record.*—Another bar to absolute correctness in a record is this. Two drillers are employed on every well—one working from noon until midnight, the other from midnight until noon. An emulative feeling almost always exists between them,—occasionally one of them may from want of dilligence, or some other cause, fail to make as much headway on his "tour" as the other has done, and to excuse himself he reports hard drilling—or he may have just struck a sand before going off tour and say he has drilled in it ten feet when perhaps he has only drilled two.

Where a well is visited only once a day, and the drill is going down from 30 feet to 90 feet in 24 hours, of course *many of the changes of rock must be taken on the driller's word;* thus from the causes above stated (and others also might be mentioned,) it will be readily perceived that quite serious errors in the thickness of strata might creep into a record, in spite of the utmost care, for even if all the sandpumpings are saved it is impossible for anyone but the drillers, to say just how thick the different divisions should be.

§ 395. *Difficulties in measuring a group of wells at once.*— It soon became evident after Mr. Carll had taken charge of the *six wells at Petrolia*, that they were too many for one man to attend to properly, even with the hearty coöperation of the drillers. He could visit each but once a day; the drilling progressed rapidly at certain stages, sometimes passing through several distinct strata in 24 hours; and although a sandpumping from every change of rock was saved for him, it often happened that some points in relation to the specimens preserved by the man on the "off tour" needed explanation. This man he seldom saw, and if he did chance to meet him once or twice a week, the details wanted, which could have readily been given at the time, had then probably escaped his recollection.

§ 396. *At Edenburg*, only *three wells* were taken in hand, so that they might be visited twice a day both drillers be interviewed, and a series of specimens secured, coming in at closer intervals.

§ 397. *At Bradford* the most satisfactory plan was adopted. Here only one well was watched, and arrangements were made for saving a specimen every time the well was sand-pumped.

§ 398. *The number of specimens* secured by the several methods is as follows:

Petrolia—well No. 1,	79	specimens in	1631	feet.
" " 2,	51	" "	1436	"
" " 3,	63	" "	1616	"
" " 4,	47	" "	1512	"
" " 5,	46	" "	1549	"
" " 6,	42	" "	1610	"
Edenburg—well No. 1,	62	" "	1220	"
" " 2,	101	" "	1143	"
" " 3,	92	" "	1050	"
Bradford,	311	" "	1719	"

§ 399. *The selection of the particular wells* secured for measurement was a matter of compulsion rather than of choice.

Only those that were drilling simultaneously and likely to be completed about the same time, could be taken charge of; and these must be so situated that they could be visited in order at least once a day.

The well owners must be consulted and the contractor and drillers consent to the annoyance and interruption of frequent measurements, and the trouble and delay of emptying the sandpumpings into pails instead of the waste trough.

It was desirable also to have the wells located at equal distances apart, and on a line, as nearly as possible, transverse to the average trend of the oil belt—so that the structural differences of stratification might be clearly brought out.

§ 400. *Kindness of the drillers and owners.*—Considering all these circumstances the locations of the wells were remarkably favorable; and our acknowledgments are due to the well-owners, contractors and drillers who so courteously assisted in forwarding our designs—for without their consent and cordial coöperation nothing could have been done.

When it is remembered that from the time the tools are swung up in the derrick until the completion of a well, if no accident occurs, there is no cessation to the work of drilling, night or day—no time when the well shaft is not occupied either by the drill or the sandpump, for the moment one is withdrawn the other is inserted—the considerable inconvenience and loss of time they thus voluntarily subjected themselves to in behalf of the furtherance of scientific inquiry will be understood and appreciated. Their names will be found in connection with the records to be given further on.

CHAPTER XX.

Six wells near Petrolia, accurately measured.

(*Illustrated by plates XII and XVII.*)

§ 401. *The geographical positions* of the six wells near Petrolia, in Butler county, measured by us with particular care, in 1876, and sand-pumpings preserved for the State museum, are designated by dots in circles upon the small map on page 191.

No. 1—Represents Sutton Well, No. 4.
No. 2 " Dougherty Well, No. 2.
No. 3 " Evans Well, No. 21.
No. 4 " Hazelwood Well, No. 21.
No. 5 " Morehead & Lardin Well, No. 2.
No. 6 " Kern Well, No. 6.

The distance in a direct line from No. 1 to No. 6 is not quite three miles and a half—in a direction about N. 75° E.

§ 402. *Production.*—The area of this little sketch map covers one of the most productive portions of Butler county.

The "*Third Sand Oil belt*" passes across the map from Petrolia to Karns City; and the "*Fourth Sand Oil belt*" crosses the "Third" between the two towns, and runs in nearly an east and west course.

§ 403. *Oil bearing sands.*—Many of the wells here produced largely, both from the *Third* and *Fourth* sands; and when the Fourth sand was first tapped, 1500 to 2500 barrels per day was not regarded as an exaggerated estimate of the flow of some of the largest wells.

Such exhaustive drainage through a large number of wells could have but one result. Both sands had been greatly depleted of oil, before the six wells here referred to were drilled, and consequently none of them turned out to be large producers: as some of them undoubtedly would have been if drilled earlier. Their records, however, show the geological structure of the district just as well as if the bulk of the oil had not been previously abstracted from the sands.

As it is desirable to have all the facts in relation to these wells in the same volume with those of the three wells in Clarion county, and the one in McKean county, all four of which were watched and measured in the same manner, we here reproduce their records,* adding to them the specimen numbers; so that they may serve as catalogues, if any reader of this volume should desire to examine any of the ten suites.

§ 404. *The nomenclature of the locality.*—In the following records it will be noticed that we quote such terms as "Mountain Sand," "Second Sand," "50 foot Rock," &c. They are not our names, but those that were applied to the strata by the drillers at the several wells. As these names are so frequently heard in connection with the wells of Butler county, it may be profitable to put them on record here, to show the reader where they belong, and what they represent. I have already made it sufficiently plain in preceding chapters of this report that the Butler county "Second Sand" is really the First Sand of the oil group. This kept in mind, there need be no difficulty in comparing our records with those of wells in Clarion county, and other places, where the term First Sand is properly applied to the top member of the Venango Oil group.

§ 405. These records also furnish a description of the rocks shown in the *six geological sections on Plate XII.*†

§ 406. *The specimens.*—In examining the specimens, hereafter, in the museum, it must be remembered that while the numbers given in the following records stand for their

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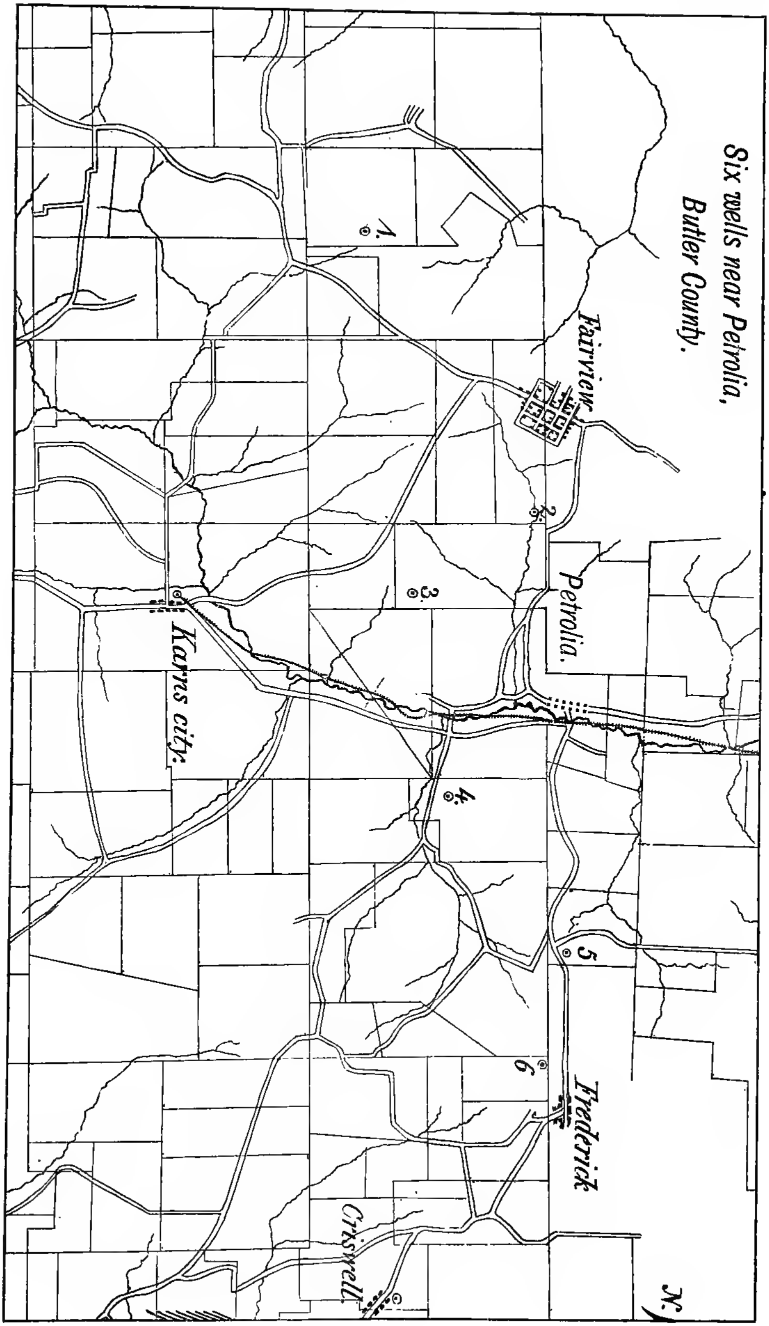
* From Report I.I.

† The sections and the records taken together, will be of interest to any one who may be inclined to study the structure of sedimentary rocks in detail. They show how variable such deposits are even within very restricted geographical limits, and suggest the necessity of exercising the greatest caution whenever we attempt to trace any particular stratum over large areas. The red rocks alone in these sections afford an instructive study. In the most westerly one *not a trace of red was found.*

Plate XXXII.



Six wells near Petrolia, Butler County.

special specimens, yet *the records are intended to indicate the quality of the strata as shown by all the facts obtained at the wells while they were being drilled*, and consequently they may not always give a *precise description* of the particular specimen referred to.

§ 407. *Records written out from an examination of specimens* have been productive of an abundance of error, when unaccompanied by explanatory notes. Specimens do not always correctly represent the character of the rocks drilled through. A great deal depends upon the manner of washing and drying them. A series of sand-shells and argillaceous shale may be so ground up together by the drill that a thorough washing will leave nothing but sand. Frequently all traces of the soft red shales are thus entirely lost.

A small percentage of pebbles in an argillaceous or slaty matrix, may be washed and manipulated so as to present a very good pebble specimen.

A muddy sand may be washed so that it can scarcely be distinguished from a pure sand.

The natural color of a specimen may be entirely changed by oxydation of the small particles of metal worn from the tools, especially if the hole contains salt water and the material is not quickly dried.

Careless sand-pumping while in a hard sand may leave the bottom of the hole full of drillings to be ground over and over, and they then come up as fine as flour, and appear more like clay than sand.

Specimens also change very perceptibly in color by age, some bleaching in the light, others growing darker.

§ 408. *A well-record should be made at the well*, and nowhere else. There a person can see the sand-pumpings as they come up; examine the tools, which show unmistakably the character of the rock they have been working upon, by being either sharp or dull, scratched or polished; and converse with the drillers, who alone can tell at what point a change of rock occurs.

A record thus made should never be altered, even if the descriptions given do not always exactly fit the specimens preserved.

§ 409. *How specimens should be collected.*—When a well cannot be visited by the person who wishes to study its record, a duplicate set of sand-pumpings should be kept by the drillers. It can easily be done in this way:

Dump the sand-pump into a pail; let the sediment settle; pour off the top; take a handful of the sediment and dry it immediately; then wash out an equal quantity and dry that. Put them in small paper bags and mark plainly the depth from which they came, and the thickness of rock they represent.

It is also a good plan to put on the date.

From specimens thus kept a very satisfactory study of the character of the measures drilled through could be made at any time.

(*I.I. 1199.*) *Sutton Well, No. 4.*

January 5, 1877.

Owned by H. L. Taylor & Co., and situated on the P. Sutton Farm, Fairview township Butler county, about 2¼ miles south 70° west of Petrolia.

Numbers of specimens preserved.						
	Well mouth above ocean in feet,					1436
	Conductor,			9 to	9 =	1427
1,2,3,	Slate,		alternating with sand shells, bluish,	133 to	142 =	1294
4,	SS.,		dark gray,	24 to	166 =	1270
	Slate and shale,			6 to	172 =	1264
5,	Coal,	**Coal**		1 to	173 =	1263
6,	Slate and shale,		dark gray,	49 to	222 =	1214
7,	Limestone,	**Limestone**		—— to	222 =	1214
8,	Slate,		dark gray,	34 to	256 =	1180
9,	SS.,		gray,	16 to	272 =	1164
10,11,12,13,	Slate, shale and sandy shells,		dark,	125 to	397 =	1039
14,	Limestone,	**Ferrif. Limestone**		20 to	417 =	1019
15,	Slate and sand shells with some iron pyrites and and trace of coal,		dark,	32 to	449 =	987
16,17,	SS.,	**"60' Rock"**	top white, bottom black,	43 to	492 =	944
18,19,20,	Slate and shale,		bluish gray, black at bottom,	45 to	537 =	899
21,	SS.,	**"20' Rock"**	grayish white,	18 to	555 =	881
22,23,	Slate and shale,		shelly, dark,	52 to	607 =	829
24,25,26,27, 28,29,	SS., ... white, 30' SS., ... grey, 20' SS., . white and soft, 50' SS., white and close, 40' SS., . white and soft, 43'	**"Mountain Sand"**		183 to	790 =	646
30,31,	Slate, shale and sand shells,		dark on top, black on bottom,	145 to	935 =	501
32,	SS.,		hard and white,	5 to	940 =	496
	Slate,		clean, bluish-gray,	30 to	970 =	466
33,	SS.,		shaly, gray,	20 to	990 =	446
34 to 39 inc.,	Shale,		slaty, bluish-gray, with a gas vein at 1,190' in a thin shell of fine bluish SS.,	260 to	1250 =	186
40,41,	Shale,		sandy with a few yellow pebbles, bluish,	52 to	1302 =	131
42,	Slate,		shaly, purplish,	34 to	1336 =	100

43,44,45,46,	SS., . . . pebbly, 3′ SS., ... gray, 9 SS.,slaty mixture, 12′ SS., gray and fine, 12′	**"Second Sand"**		36 to 1372	=	64
47,	Slate and shale,		dark,	38 to 1410	=	26
48 to 51,	SS.,	**"50′ Rock"**	uniform, hard, white,	22 to 1432	= +	4
52,	Slate,		blue,	28 to 1460	= —	24
53 to 59,	SS.,	**"30′ Rock"**	homogeneous, fine, white,	42 to 1502	= —	66
60,	Slate,		shelly, blue,	8 to 1510	= —	74
61,	SS.,	**"Bowlder"**	yellowish-gray, fine,	14 to 1524	= —	88
62,	Slate,		blue,	6 to 1530	= —	94
63,64,	SS.,	**"Stray 3d"**	gray,	16 to 1546	= —	110
65,66,67,	SS., ... pebbly, SS., ... white, SS., . gray and hard,	**"Third Sand"**		20 to 1566	= —	130
68,69,70,	Slate,		shaly, dark blue,	40 to 1606	= —	170
71 to 79,	SS.,dark "cloverseed" pebble, SS., ... fine white, SS., . . . good white pebble,	**"Fourth Sand"** (not through)		25 to 1631	= —	195

Drilled dry. Cased at 643′. A very little salt water below the casing.

Gas at 1,190′, half sufficient to fire the boiler with while drilling, but this gas was exhausted in three or four days. About the same amount of gas was found in the "2d sand."

Very little oil in the "3d sand." The hole filled up 300′ or 400′ with oil from the top of the "4th sand," and flowed when drilled a few feet deeper. No Red Rock found in drilling. Best daily production, 40 barrels.

(*I.I. 1200.*) *Dougherty Well, No. 2.*

December 7, 1876.

Owned by Dougherty and Devlin, and situated on the McCleary farm, Fairview township, Butler county, about one mile south 80° west of Petrolia, and one and a quarter miles north 60° east from Sutton Well, No. 4.

Numbers of specimens preserved.						
	Well mouth above ocean in feet,					1327
	Conductor,			10 to	10 =	1317
	SS.,		surface, yellow,	5 to	15 =	1312
	Slate,		bluish,	55 to	70 =	1257
1,	Limestone,	**Limestone,**	thickness unknown,	— to	70 =	1257
2,3,	Slate, sandy,		top blue, bottom gray and muddy,	85 to	155 =	1172
4,	SS.,		gray,	51 to	206 =	1121
5,	Coal,	**Coal,**	slaty,	3 to	209 =	1118
6,	Sand shells,		hard and blue,	10 to	219 =	1108
	Slate,		dark,	21 to	240 =	1087
7,8,9,	Limestone,	**Ferriferous Limestone,**		20 to	260 =	1067
	Slate,		soft, dark,	20 to	280 =	1047
10,11,12,	SS.,	**"60′ Rock,"**	gritty, white,	80 to	360 =	967
13,	Slate,		very dark,	30 to	390 =	937
14,	Shale,		sandy, dark gray,	50 to	440 =	887
15,16,	SS.,	**"20′ Rock,**	hard, white, with layers of black slate,	24 to	464 =	863
	Slate,		black,	8 to	472 =	855
17,18,19,	SS.,		soft and gray on top, hard and white on bottom,	83 to	555 =	772
20,	Slate,		dark, with gray sand shells,	27 to	582 =	745
21,22,	SS., { top, fine yellow, bottom, soft and gray, }	**"Mountain Sand,"**		93 to	675 =	652
23,	Slate,		shelly, bluish,	17 to	692 =	635
24,25,26,	Slate and gray sand shells,			108 to	800 =	527
27,	Slate,		bluish,	125 to	925 =	402
28,	Sand shells,		gray,	15 to	940 =	387
29,	Slate,		bluish,	100 to	1040 =	287
30,	Slate,		purplish,	80 to	1120 =	207
31,	Slate,		bluish,	58 to	1178 =	149

32,	SS.,	hard and bluish gray, 12′	**"Second Sand" and "50′ Rock,"**	87 to 1265 =	62
33,	SS.,	olive and gray, 20′			
34,	SS.,	slaty, 45			
35,	SS.,	fine gray, 10′			
	Red rock,			1 to 1266 =	61
	Sand shells and slate,		**"30′ Rock,"**	48 to 1314 = +	13
36,37,38,39,	SS.,	hard and white on top, yellowish-gray on bottom,	**"Blue Monday,"**	16 to 1330 = —	3
	Red rock,		**"Big Red Rock,"**	12 to 1342 = —	15
40,	Slate,	bluish,		21 to 1363 = —	36
41,	SS.,	very fine and light gray,	**"Bowlder,"**	10 to 1373 = —	46
	Slate,	dark,		12 to 1385 = —	58
42,43,44,45,	SS.,	fine, white,	**"Stray Third,"**	27 to 1412 = —	85
46,	Slate,	dark,		8 to 1420 = —	93
47,48,49,50,51,	SS., (about through,)	pebbly and white on top, fine and yellowish-gray at bottom,		16 to 1436 = —	109

Drilled dry. Cased the first time at 478′. Flood of salt water at 570′. Casing pulled and put in the second time to a depth of 610′, and found no water below this depth. A small amount of gas in the "2d sand." Oil in the "3d sand," at 1,423′. Average daily production, 15 barrels.

(*I.I. 1201.*) *Evans Well, No. 21.*

December 23, 1876.

Owned by Evans & Co., and situated on the Dougherty farm, Fairview township, Butler county, about four fifths of a mile south 40° west of Petrolia, and about three fourths of a mile south 40° east of the Dougherty Well, No. 2.

Numbers of specimens preserved.					
	Well mouth above ocean in feet,				1393
	Conductor,			18 to 18 =	1375
1,	Slate and shale, with bluish-gray shells,			162 to 180 =	1213
2,	Limestone,	**Limestone,**	thickness unknown,	— to 180 =	1213
3,	SS.,		very fine, dark,	45 to 225 =	1168
4,5,	Shelly shale,		gray,	64 to 289 =	1104
	Coal,	**Coal,**		1 to 290 =	1103
6,	SS.,		very muddy, fine, gray,	4 to 294 =	1099
7,	Slate and shells,		gray, muddy,	43 to 337 =	1056
8,9,	Limestone,	**Ferriferous Limestone,**		21 to 358 =	1035
10,	Slate,		very dark,	18 to 376 =	1017
	Coal,	**Coal,**		4 to 380 =	1013
	Slate,		very dark,	6 to 386 =	1007
11,12,13,14,	SS.,	**"60' Rock,"**	top gray and close, bottom fine and dark,	66 to 452 =	941
15,	Slate,		dark,	44 to 496 =	897
16,17,18,	Slate, with dark sand shells,			50 to 546 =	817
19,20,	SS.,		gray,	5 to 551 =	842
21,22,	Slate,		sandy, dark,	35 to 586 =	807
	SS.,		white, with trace of coal,	2 to 588 =	805
23,	Slate,		sandy, dark,	9 to 597 =	796
24,25,26,27,28,	SS., gray, occasional partings of dark slate,	**"Mountain Sand,"**		148 to 745 =	648
29,	Slate,		fawn-color and bluish,	20 to 765 =	628
30,	Sand shells,		gray, with partings of slate and shale,	80 to 845 =	548
31,	SS.,		flaggy, olive-gray,	50 to 895 =	493
	SS.,		white,	35 to 930 =	463
32,	Slate,		sandy, dark,	70 to 1000 =	393
33,34,	Slate,		more shelly, dark-gray,	100 to 1100 =	293
35,	Slate,		muddy, dark,	100 to 1200 =	193
36,	Slate,		sandy, dark,	74 to 1274 =	119

37,38,	SS., fine olive-gray,	**"Second Sand,"**		17 to 1291 =	102
	Slate, dark,			3 to 1294 =	99
39,	SS., fine, with slate partings,	**"50′ Rock."**	olive gray,	54 to 1348 =	45
40,	Red rock,	**"30′ Rock,"**	sandy,	13 to 1361 =+	32
41,	Slate,		dark, with gray sand shells,	36 to 1397 =—	4
42,	SS	**"Blue Monday,"**	hard, bluish-gray,	6 to 1403 =—	10
43,	Red rock,		hard slate,	27 to 1430 =—	37
44,	Slate,		dark,	29 to 1459 =—	66
45,	SS.,	**"Bowlder,"**	hard, olive-gray,	10 to 1469 =—	76
	Slate,		dark,	12 to 1481 =—	88
46,47,48,49,50,	SS., white,	**"Stray Third,"**		25 to 1506 =—	113
51,	Slate,		dark,	7 to 1513 =—	120
52,53,54,55,56,	SS., pebbly, coarse, gray,	**"Third Sand,"**		15 to 1528 =—	135
57,58,59,	Slate, shelly, purplish,		trace of red rock at 1,565′,	58 to 1586 =—	193
60,61,62,	SS., pebbly, coarse, white,	**"Fourth Sand,"**		22 to 1608 =—	215
63,	Slate,		very dark,	8 to 1616 =—	223

Drilled dry. Cased at 705′, and found no water below casing. A little gas at 1,120′. Oil at 1,519′, and no increase of oil in the "4th sand." Torpedoed, but no apparent increase of oil. Pumped about $1\frac{1}{3}$ barrels of oil per day. Torpedoed a second time, and after that said to be averaging 10 barrels per day.

(*I.I. 1202.*) *Hazelwood Well No. 21.*

December 7, 1876.

Owned by the Hazelwood Oil Company, and situated on the H. P. Shakely Farm, Fairview township, Butler county, about one half mile south 35° east of Petrolia, and four fifths of a mile north 75° east of Evans Well No. 21.

Numbers of specimens preserved.						
	Well mouth above ocean in feet,					1298
	Conductor,			16 to	16 =	1282
1,	Shells,		soft, shaly, gray, muddy,	110 to	126 =	1172
2,3,	Shells,		slaty, gray,	30 to	156 =	1142
	Slate,		hard, sandy, bluish-gray,	44 to	200 =	1098
	Coal,	**Coal**		1 to	201 =	1097
4,	Slate,		gray and muddy,	44 to	245 =	1053
5,6,	Limestone,	**Ferriferous Limestone**		20 to	265 =	1033
	Slate,		dark,	30 to	295 =	1003
	Coal,	**Coal**		2 to	297 =	1001
7,	SS.,	**"60' Rock"**	gray,	30 to	327 =	971
8,	Slate,		dark,	36 to	363 =	935
9,10,	SS.,		gray and brownish-gray,	52 to	415 =	883
11,12,13,	Slate,		with gray shells,	40 to	455 =	843
14,	Slate,		very dark,	29 to	484 =	814
15,	SS., soft bluish-gray, 70'	**"Mountain Sand"**		186 to	670 =	628
16,	SS., hard, white, 50'					
17,	SS., gritty olive gray, 30'					
18,	SS., shelly, with dark slate, 36'					
19,	Slate,		dark,	100 to	770 =	528
20,	Slate,		sandy and hard,	37 to	807 =	491
21,22,	SS., fine and hard,		top gray, bottom very dark,	28 to	835 =	463
23,	Slate,		bluish,	100 to	935 =	363
24,	Slate,		shelly,	90 to	1025 =	273
25,	SS.,		dark gray,	10 to	1035 =	263
26,	Slate,		sandy, dark,	50 to	1085 =	213
27,	Slate,		dark,	70 to	1155 =	143
28,	Slate,		purplish,	52 to	1207 =	91

29,	SS.,	**"Second Sand"**	olive gray,	6 to 1213 =	85
30,	Red rock, sandy,		chocolate color,	4 to 1217 =	81
31,	SS., olive gray, flaky,	**"50′ and 30′ Rocks"**		63 to 1280 =	+ 18
	Slate,		sandy, dark,	32 to 1312 =	— 14
32,	SS.,	**"Blue Monday"**	fine, dark gray,	6 to 1318 =	— 20
	Red rock,	**"Big Red Rock"**	soft,	18 to 1336 =	— 38
	Slate,		dark,	20 to 1356 =	— 58
	SS.,	**"Bowlder"**	gray,	3 to 1359 =	— 61
33,	Slate,		bluish,	23 to 1382 =	— 84
34,35,36,	SS., with yellow pebbles,	**"Stray Third"**		29 to 1411 =	— 113
	Slate,		dark,	1 to 1412 =	— 114
37,38,39,	SS., coarse and gray,	**"Third Sand"**		19 to 1431 =	— 133
40,	Slate,		dark,	19 to 1450 =	— 152
	Red rock,			8 to 1458 =	— 160
41,	Slate,		purplish	24 to 1482 =	— 184
42,43,44,45,46,	SS., yellowish-gray,	**"Fourth Sand"**	very fine at bottom,	27 to 1509 =	— 211
47,	Slate,		very dark,	3 to 1512 =	— 214

Drilled dry. Cased at 486′. A little salt water in the "Mountain sand," below the casing, about half enough to drill with. Very little gas in the "2d sand." Oil in the "3d sand" at 1,415′, and no increase in the "4th." Torpedoed before being tubed with no apparent increase of oil. Average daily production, 15 barrels.

(*I.I. 1203.*) *Morehead and Lardin Well, No. 2.*

January 6, 1877.

Owned by Morehead, Lardin & Co., and situated on the Mortimer farm, Fairview township, Butler county, about four fifths of a mile east of Petrolia, and three fourths of a mile north 55° east of Hazelwood Well, No. 21.

Numbers of specimens preserved.						
	Well mouth above ocean in feet,					1420
	Conductor,			5 to	6 =	1415
1,	Slate, muddy, trace of,	**Limestone and Coal**	reported at about 70′,	105 to	110 =	1310
2,3,4,5,	SS.,		gray, trace of coal at the bottom,	125 to	235 =	1185
	Slate,		black,	25 to	260 =	1160
6,	Shelly gray sand and very black slate,		interstratified,	68 to	328 =	1092
7,	Limestone,	**Ferriferous Limestone**		18 to	346 =	1074
8,	Slate,		very dark,	20 to	366 =	1054
9,	Slate,		muddy, bluish-gray,	21 to	387 =	1033
10,	SS.,	**"60′ Rock"**	gray,	48 to	435 =	985
11,	Slate, with blue sand shells,			37 to	472 =	948
12,	SS.,		white, with trace of coal,	20 to	492 =	928
13,	SS.,		gray. with slate partings,	28 to	520 =	900
14,15,16,	Slate,		black, with gray sand shells,	31 to	551 =	869
17,	SS., hard, gray, with films of coal, 20′	**"Mountain Sand"**		179 to	730 =	690
18,	SS., fine, grayish-white, 90′					
19,	SS., coarse, white, 69′					
	Slate,		common,	30 to	760 =	660
20,	SS., flaky, gray, micaceous, 30′		good drilling,	206 to	966 =	454
21,	SS., muddy, gray, 100′					
22,	SS., fine, muddy, gray, 76′					
23,	Slate,		muddy, bluish,	75 to	1041 =	379
24,	Shells,		bluish,	10 to	1051 =	369
25,	Slate,		dark,	100 to	1151 =	269
26,	Slate,		with thin sand shells,	35 to	1186 =	234
27,	Slate,		gritty, dark,	94 to	1280 =	140

28,	SS., with slate partings, muddy, olive-gray,	**"Second Sand"**		38 to 1318	=	108
	Red rock,		trace,	— to 1318	=	108
29,	Slate,		with thin sand shells, dark,	65 to 1383	=	37
30,	SS.,	**"30′ Rock"**	slaty, olive and red,	15 to 1398	= +	22
31,	Slate,		blue,	34 to 1432	= —	12
32,33,	SS.,	**"Blue Monday"**	fine, and ashy gray,	10 to 1442	= —	22
34,	Red slate,	**"Big Red"**		24 to 1466	= —	46
35,	Slate,		dark,	27 to 1493	= —	73
	SS.,	**"Bowlder"**	shelly,	4 to 1497	= —	77
	Slate,		dark,	3 to 1500	= —	80
36,37,38,	SS., top greenish, middle yellowish,	**"Stray Third"**	bottom coarse and white,	18 to 1518	= —	98
39,40,	Slate,		dark,	10 to 1528	= —	108
41,42,43,44,45,46,	SS., (1) large white pebbles, (2) very fine gray sand, (3) very fine white sand, (4) very fine gray sand, "3d sand," (not through)	**"Third Sand"**		21 to 1549	= —	129

Drilled dry. Cased at 526′ and no water found below the casing. A little gas in the "2d sand." Oil in the "3d sand" at 1,530′; flowed at 1,545′. Average daily production, 12 barrels.

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(I.I. 1204. *Kern Well, No. 6.*

November 27, 1876.

Owned by H. L. Taylor & Co., and situated on the W. Snow farm, Fairview township, Butler county, about 1½ miles south 85° east of Petrolia, and ½ mile south 80° east of the Morehead & Lardin Well, No. 2.

Numbers of specimens preserved.						
	Well mouth above ocean in feet,					1464
	Conductor,			10 to	10 =	1454
	Slate and sand, with some	**Coal,**		192 to	202 =	1262
1,	Limestone,	**Limestone,**	with a crevice sinking the water,	? to	202 =	1262
2,	Slate,		shelly, working up into "mud-balls,"	93 to	295 =	1169
3,	SS.,		fine, light-green,	50 to	345 =	1119
4,	Shale,		soft and muddy,	38 to	383 =	1081
5,	Limestone,	**Ferr. Limestone,**		21 to	404 =	1060
6,	Slate and mud,		purplish,	16 to	420 =	1044
7,8,9,	Shells and slate,		hard, black and gray, trace of coal on top,	80 to	500 =	964
10,11,12,	Slate,		shelly, very dark,	86 to	586 =	878
13,14,15,	SS., Top flaky, Bottom muddy, gray and white, 81	**"Mountain Sand,"**		223 to	809 =	655
16,	Slate, dark-gray, 30					
17,18,	SS., fine and hard, grayish-white, 112					
19,20,	Slate,		dark, bottom shelly, trace of red at 870′,	71 to	880 =	584
21,22,23,	SS.,		gray, large percentage of dark slate,	112 to	992 =	472
24,25,	Slate and shale, with thin shells,		dark-gray, muddy,	148 to	1140 =	324
26,	Shells,		hard and gray,	10 to	1150 =	314
27,28,	Slate, with shells, dark-gray,		trace of red and a few yellow pebbles at 1194′,	110 to	1260 =	204
29,	Slate,		soft and muddy, lead color,	77 to	1337 =	127

30,	SS., grayish-white,	**"Second Sand,"**		5 to 1342 =	122
	Slate,			6 to 1348 =	116
31,	Red rock,	**"Big Red Rock,"**		17 to 1365 =	99
	Slate and shale,		soft,	53 to 1418 =	46
32,	SS.,		slaty, gray,	14 to 1432 =	32
	Red rock,			8 to 1440 = +	24
33,	Slate,		dark,	40 to 1480 = —	16
34,	Sandy shale,			15 to 1495 = —	31
	Red rock,			3 to 1498 = —	34
	Sandy shale,			17 to 1515 = —	51
35,	Red rock,			2 to 1517 = —	53
36,	Shale,		dark olive-gray,	23 to 1540 = —	76
	Red rock,			5 to 1545 = —	81
37,	Shale,		dark olive-gray,	15 to 1560 = —	96
38,	SS.,	**"Bowlder,"**	pebbly, black,	5 to 1565 = —	101
	Slate,		dark-gray,	4 to 1569 = —	105
39,40,41,	SS., top pebbly, white, bottom find sand,	**"Third Sand,"**		28 to 1597 = —	133
42,	Slate,		bluish,	13 to 1610 = —	146

Drilled dry. Cased at 617′, and no water found below the casing. A little gas at 1138′, and show of oil. Oil in the "3d sand" at 1,570′. Average daily production, 12 barrels.

§ 410. *A diary of each days drilling, in a tabular form, with notes of the draw backs encountered by accidents, &c.*

(NOTE.—The number marks the well.—The column under it gives its successive daily increasing depth in feet.—The columns headed *d. a.* give the *daily advance* of each well in feet.)

1876.	No. 1.	*d. a.*	No. 2.	*d. a.*	No. 3.	*d. a.*	No. 4.	*d. a.*	No. 5.	*d. a.*	No. 6.	*d. a.*
Oct. 12,	...	...	70 ft.	...	...	...	...	...	...	...	202 ft.	...
" 13,	...	...	96	26	...	...	73	...	...	...	255	53
" 14,	...	...	144	48	...	...	128	55	...	...	335	80
Sunday, " 15,	...	...	...	...	...	...	...	...	...	...	...	...
" 16,	...	...	168	24	...	...	155	27	...	...	370	35
" 17,	...	...	210	42	...	...	210	55	...	...	410	40
" 18,	...	...	F	...	...	...	255	45	...	...	459	49
" 19,	...	...	245	35	140	...	260	5	...	...	490	31
" 20,	...	...	252	7	180	40	F	...	...	...	520	30
" 21,	...	...	260	8	215	35	325	65	...	...	540	20
Sunday, " 22,	...	...	...	...	...	...	...	...	...	...	...	...
" 23,	55	...	300	40	235	20	350	25	...	...	572	32
" 24,	100	45	320	20	B	...	395	45	...	...	598	26
" 25,	124	24	345	25	285	50	410	15	...	...	604*	6
" 26,	156	32	380	35	F	...	F	...	...	...	C	...
" 27,	172	16	426	46	300	15	F	...	...	...	642	38
" 28,	198	26	445	19	F	...	F	...	...	...	692	50
Sunday, " 29,	...	...	...	...	...	...	...	...	...	...	...	...
" 30,	222	24	455	10	342	42	F	...	...	...	735	43
" 31,	245	23	476 C	21	354	12	420	10	...	...	775	40
Nov. 1,	285	40	488	12	372	18	435	15	...	...	824	49
" 2,	303	18	B	...	390	18	455	20	...	...	870	46
" 3,	344	41	*	...	406	16	467	12	...	...	F & B	...
" 4,	381	37	*	...	418	12	486C	19	...	...	890	20
Sunday, " 5,	...	...	...	...	...	...	...	...	...	...	...	...
" 6,	409	28	538	50	F	...	536	50	...	...	957	67
" 7,	434	25	570	32	F	...	575	39	...	...	990	33

	" 8,	465	31	594	24	F		632	57			1036	46
	" 9,	485	20	†		F		660	28			1089	53
	" 10,	512	27	†		440	22	F		80		1149	60
	" 11,	532F	20	†		484	44	715	55	128	48	1194	45
Sunday,	" 12,												
	" 13,	535	3	†		500	16	796	81	F		1250	56
	" 14,	540	5	625	31	536	36	810	14	F		1310	60
	" 15,	583	43	690	65	541*	5	830	20	F		1337	27
	" 16,	617	34	715	25	553	12	903	73	F		1360	23
	" 17,	C		788	73	572	19	980	77	F		1420	60
	" 18,	643	26	865	77	588	16	1030	50	148	20	1445	25
Sunday,	" 19,												
	" 20,	663	20	935	70	594	6	1040*	10	185	37	1483	38
	" 21,	720	57	1015	80	615	21	1100	60	230	45	1520	37
	" 22,	752	32	1085	70	643	28	1160	60	275	45	1548	28
	" 23,	790	38	1175	90	F		1214	54	310	65	1570	22
	" 24,	835	45	1202	27	B		1275	61	B		1580	10
	" 25,	889	54	1250	48	685	42	1318	43	355	15	1595	15
Sunday,	" 26,												
	" 27,	935	46	1265	15	C		1370	52	385	30	1610	15
	" 28,	977	42	1315	50	705	20	1400	30	400	15		
	" 29,	1043	66	1319	4	735	30	1411	11	F			
Thanksgiving,	" 30,	1100	57	1325	6	775	40	1423	12	F			
	Dec. 1,	1155	55	1348	23	862	87	1440	17	450	50		
	" 2,	1180	25	1368	20	935	73	1474	34	486	36		
Sunday,	" 3,												
	" 4,	1224	44	1395	27	1015	80	1483	9	515	29		
	" 5,	1240	16	1416	21	1085	70	1490	7	540	25		
	" 6,	1270	30	1426	10	1160	75	1502	12	C			
	" 7,	1304	34	1430	4	1225	65	1512	10	553	13		
	" 8,	1338	34	1436	6	1290	65			*			
	" 9,	1366	28			B				562*	9		
Sunday,	" 10,												
	" 11,	1400	34			1335	45			620	58		
	" 12,	1415	15			1368	33			680	60		
	" 13,	1420	5			1404	36			770	90		
	" 14,	1425	5			1454	50			842	72		
	" 15,	1430	5			1512	58			916	74		
	" 16,	1438	8			1517†	5			972	56		

1876.	No. 1.	*d. a.*	No. 2.	*d. a.*	No. 3.	*d. a.*	No. 4.	*d. a.*	No. 5.	*d. a.*	No. 6.	*d. a.*
Sunday, Dec. 17,	1465	27	...	...	...	...	...	...	...	...	...	...
" 18,	1470	5	...	...	1519	2	...	...	1045	73	...	...
" 19,	1475	5	...	...	1530	11	...	...	110	65	...	...
" 20,	1479	4	...	...	1564	34	...	...	1176	66	...	...
" 21,	1494	15	...	...	1581	17	...	...	1245	69	...	...
" 22,	1500	6	...	...	1597	16	...	...	1300	55	...	...
" 23,	1522	22	...	...	1616	19	...	...	1355	55	...	...
Sunday, " 24,	1530	8	...	...	...	...	...	...	...	...	...	...
Christmas, " 25,	1538	8	...	...	...	...	...	...	1403	48	...	...
" 26,	1562	24	...	...	...	...	...	...	1435	32	...	...
" 27,	1586	24	...	...	...	...	...	...	1485	50	...	...
" 28,	1604	18	...	...	...	...	...	...	1530	45	...	...
" 29,	1616*	12	...	...	...	...	...	...	1539	9	...	...
" 30,	1622	6	...	...	...	...	...	...	1543	4	...	...
Sunday, " 31,	...	...	...	...	...	...	...	...	...	...	...	...
Jan. 1, 1877,	1624	2	...	...	...	...	...	...	†	...	...	...
" 2,	1627	3	...	...	...	...	...	...	†	...	...	...
" 3,	1628	1	...	...	...	...	...	...	†	...	...	...
" 4,	1631	3	...	...	...	...	...	...	1545	2	...	...
" 5,	...	...	...	...	...	...	...	...	1549	4	...	...

The letter F, shows time spent in "fishing" for tools lost or "stuck" in the well.
The letter B, shows time spent in repairing "breakdowns" in either rig or engine.
The letter C, shows time lost in putting in the casing.

*. †.—See notes on next page.

Notes to the preceding Table in § 410.

Column No. 1.

Sutton well, No. 4. Owners, H. L. Taylor & Co. Contractor, William Fee. Drillers changed several times.

Fifty-five feet deep when taken charge of, Oct. 23, 1876.

*From Dec. 29 to Jan. 4 shut down a large portion of the time on account of gas, the well flowing several times a day.

Actual drilling time about 64 days. Average 25½ ft. per day. Best 24 hours' work 72 ft.

Specimens collected from 9.00 to 11.30, A. M.

Column No. 2.

Dougherty well, No. 2, McCleary farm. Owners, Dougherty & Devlin. Contractor, Seth Andrews. Drillers, Seth Andrews and A. Wolf.

Seventy feet deep when taken charge of Oct. 12, 1876.

*Drilling water well deeper, it having been drained into the main hole.

†Pulled casing on account of salt water below. Reamed down from 476′ to 610, and re-cased Oct. 14.

Actual drilling time about 39 days. Average 36.8′ per day. Best 24 hours' work, 90′.

Specimens collected from 7.30 to 9.30, A. M.

Column No. 3.

Evans well, No. 21, Dougherty farm. Owners, Evans & Co. John Layton and Laird Maclan, drillers, and Sam Maclan, tool dresser, all owning interests in the well.

140′ deep when taken charge of Oct. 19, 1876.

*Straightening up crooked hole.

†From this point down, drilling was only done by daylight on account of danger from gas.

Actual drilling time 47 days. Average 34.4′ per day. Best 24 hours' work 80′

Specimens collected from 9.30, A. M., to 12.30, P. M.

Column No. 4.

Hazelwood well, No. 21, H. P. Shakely farm. Owners, Hazelwood Oil Co. Contractor, D. Washabaugh. Drillers changed several times.

73′ deep when taken charge of Oct, 13, 1876.

* Straightening flat hole.

Actual drilling time 42 days. Average 36′ per day. Best 24 hours' work 77′.

Specimens collected from 2.30 to 8.30, P. M.

Column No. 5.

Morehead & Lardin well, No. 2. Mortimer farm. Owners, Morehead, Lardin & Co. S. Kaufman, driller, and J. W. Kaufman and Thompson Frazier, tool dressers, all owning interests in the well.

80′ deep when taken charge of Nov. 10, 1876.

* Pulled casing, reamed down from 541′, and re-inserted casing at 562.

† Moving boiler on account of gas.

Actual drilling time about 34 days. Average 45.6′ per day. Best 24 hours' work, 90′.

Specimens collected from 2.00 to 9.00, P. M.

Column No. 6.

Kern well, No. 6. W. Snow farm. Owners, H. L. Taylor & Co. Contractors, Grace & Criswell. Drillers, John McClure and Fred Thatcher.

202′ deep when taken charge of, Oct. 12, 1876.

* Straightening flat hole

Actual drilling time 44 days. Average 36.6′ per day. Best 24 hours' work, 60′.

Specimens collected from 1.45 to 5.00, P. M.

§ 411. *Rate of drilling shown by Plate XVII.*—The variable composition of the measures through which oil wells are sunk, is graphically illustrated on Plate XVII, where may be seen sections of the six Petrolia wells drawn in *diamonds*, each diamond representing on an uniform scale the number of feet drilled in twenty-four hours.

If the quality of rock is the same in one well as that in another, we should expect to find but little difference in their *average daily rate* of drilling, where similar methods are employed and equal skill is exercised. Irregularity in the rate of drilling may therefore be presumed to indicate variability in the rocks pierced. Thus, then, by a comparison of these *time sections* with the geological sections, we may get a very good idea of where the hard and the soft rocks lie, and note how they appear to change in character in passing from one well to another.

Fig. 1 shows the time occupied in boring from the Ferriferous limestone to the First oil sand.

Fig. 2, the time spent in drilling through the oil group.

The diary and notes should be consulted to explain why some of the diamonds are so small in the oil sands and in one or two other instances.

§ 412. *Rapid drilling in soft rocks.*—The rapid advances made in drilling between the mountain sands and the oil group, confirm what has already been said about the band of soft shale universally found at this horizon along the oil belt.

§ 413. *The specimen time rack.*—These shales also give rise to a very conspicuous feature in the photograph of the rack of specimens shown in Plate XXXIII, on page 213, as will be more fully appreciated after a description of the rack has been given.

The rack is formed of six separate strips of deal three inches wide and six or seven feet long. A $\frac{1}{2}\times\frac{7}{8}$ inch cleat is tacked edgewise along the lower side to form a ledge or shelf for the specimen bottles to rest upon.

The strips are laid on sloping brackets secured to the walls—the slope being at an angle of about 45°, and having steps cut into it corresponding to the width of the strips, so that the strips keep position by their own weight, and may readily be moved, independently, either to the right or to the left, by the knobs seen near the center.

The specimens are enclosed in square bottles containing half an ounce each, and are labeled with number, depth, &c.

The bottles are put in proper position on the strips by scale, six inches on the strip representing 100 feet in the well; and they are kept in place by brads on each side.

When the specimens are mounted in this way, each bottle should represent the character of the rock up to the next one above it, and we thus have the equivalent of a glass tube filled to scale, with the advantage of being able to open a bottle at any point to examine its contents, if required.

By sliding the slips or bottle holders, comparisons can readily be made in any manner desired. As seen in the photograph they are arranged to the horizon of the Ferriferous limestone, to conform with the plan of the geological sections on plate XII.

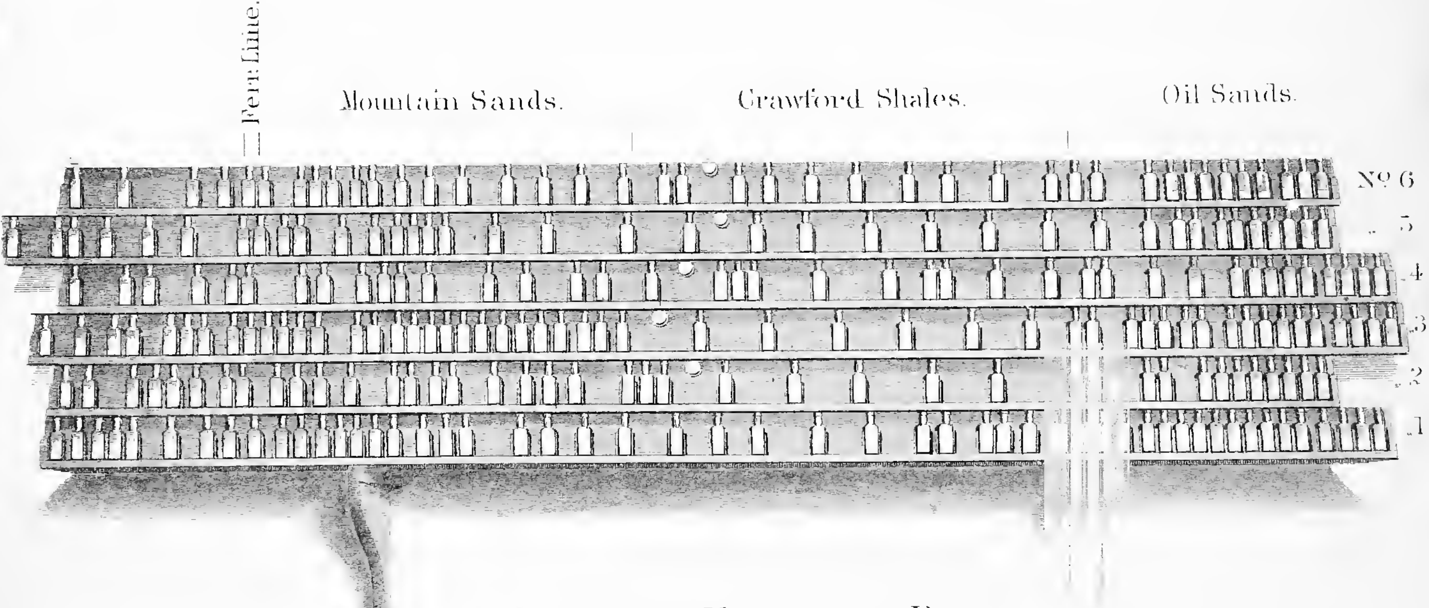
The bottom strip holds the material from well No. 1, and the numbers run consecutively upward. The drilling advanced from left to right.

The width of a bottle on this scale covers about fifteen feet and a half in the well, consequently where a number of specimens were taken close together some of them had to be left off of the rack. To obviate this objection, the Clarion county specimens are arranged on a scale of one foot on the strips to 100 feet in the wells, and the strips are mounted in two sections, one for comparing the upper part of the well, and the other the lower. A bottle, by this scale, covers 7 feet 9 inches.

The scale of the Bradford rack is one foot to fifty feet in the well. It is cut into six 300 feet sections, and contains 311 specimens, showing almost a solid row of bottles from top to bottom.

This cabinet of sand-pumpings from ten wells is, undoubtedly, the most complete of any in the State.

As the specimens from the Petrolia wells were taken every day, whether there was a change in the character of the rock or not, it follows that *where the bottles are seen close together* in the photograph on the Plate, the rocks must have been hard or changeable in character, and *where they are wide apart*, soft and homogeneous. Thus, then, the soft rocks between the Mountain sands and the Oil group are plainly indicated even in this photograph of specimens.



PHOTOGRAPHIC VIEW OF THE RACK
HOLDING THE SPECIMENS PRESERVED FROM THE SIX
near PETROLIA in BUTLER COUNTY, PA.

CHAPTER XXI.

Three wells near Edenburg, accurately measured.

(Illustrated by Plates XII and XXXIV.)

§ 414. A second group of wells, located near Edenburg, in Clarion county, was watched and measured by John H. Carll, in 1877, in the same manner as those at Petrolia had been in 1876. Thus from similarly collected data obtained at two points about 18 miles apart, we have the means of comparing the rocks of Clarion county with those of Butler. It is to be regretted that we must stop here—for had it been possible to follow up this method of investigation, by securing like groups of wells as developments advanced to the east and northeast of Edenburg, it would have aided more than all the imperfect well-records now at command, in a study of the changes in geological structure which seem to here come in and prevent any great extension of the oil producing rocks towards the northeast.

At Edenburg, three wells only were selected for measurement, so that they might be visited twice a day and undergo a closer inspection than had been possible with the six at Petrolia. Their relative geographical positions are shown on sketch map Plate XXXIV, and the records and diary following, with the three geological sections on Plate XII, will furnish all the details connected with them.

§ 415. *Brundred Well No. 4.*

June, 1877.

Owned by Benj. Brundred, and located on Capt. Kribb's farm, at Beaver City, 1 mile S. 55° W. from Edenburg, 1 mile S. 85° W. from Columbia Oil Co.'s well No. 19, and a quarter of a mile S. 20° W. from Haney well No. 4.

Numbers of Spec.				
	Well mouth above ocean in feet,			1480
	Conductor,			11 to 11 = 1469
1,	Shale, dove color, muddy,	53		79 to 90 = 1390
2,	Shale, bluish gray, sandy,	26		
3,	SS., light grey, gritty, micaceous,	40		66 to 156 = 1324
	Trace of coal,	—		
4,	SS., dark-gray, fine, muddy, micaceous,	26		
5,6,	Slate, black, lower half sandy,	43		60 to 216 = 1264
7,	Slate, with gray sand-shells,	17		
8,	SS., gray, fine, micaceous,	13		79 to 295 = 1185
	Traces of coal,	—		
9,	SS., light-gray, coarser and more gritty,	30		
10,	SS., white, fine, mixed with bituminous slate,	15		
	SS., gray, medium,	21		
	Slate, dark,			4 to 299 = 1181
11,	SS., dark-gray, fine, muddy,	5	**"Mountain Sand,"**	124 to 423 = 1057
12,	SS., dark-gray, cleaner and coarser,	15		
13,	SS., white, soft, micaceous, "buttermilk rock,"	13		
14,	SS., white, hard, fine, gritty,	13		
15,	SS., white, coarse, gritty,	48		
16,	SS., gray and dark mixed, micaceous,	5		
17,18,	SS., white, olive, and buff, fine,	2		
19,	SS., gray, fine, gritty,	23		
20,	Slate, with gray sand-shells,			17 to 440 = 1040
21,	Shells, very fine and hard, with thin layers of slate,			25 to 465 = 1015
22,	Slate, black, and somewhat sandy,			16 to 481 = 999
	Red, chocolate color slate,			4 to 485 = 995
	Slate, dark,			13 to 498 = 982

23,24,	SS., gray, fine, muddy, micaceous,	33	**"40′ or Salt Water Rock,"**	130 to 628 =	852
25,	SS., slightly mixed with slate, fossils?	59			
26,	SS., whiter and less slate,	38			
27,	Slate, with hard, dark-gray, micaceous shells,			7 to 635 =	845
28,	Shells, soft, with slate, polishing tools, good drilling,			35 to 670 =	810
29,	Slate, dark, some shells,	46		245 to 915 =	565
30,31,	Slate, dark, shells more frequent,	54			
32,	Slate, purplish, hard shell at 790′,	27			
33,	Slate, dark and sandy, with hard shells,	7			
34,	Slate, dark and sandy, shells less frequent,	46			
35,	Slate, dark, almost free from shells,	65			
36,	Shells, gray, very micaceous, with layers of slate,		**"First Sand,"**	23 to 938 =	542
37,	Slate, olive, with very fine micaceous shells,			51 to 989 =	491
38,	Shells, gray, very hard, fossils?			2 to 991 =	489
39,	Slate, dark,			25 to 1016 =	464
	Red shale,			1 to 1017 =	463
40,41,42,	Slate, with light-gray, hard shells,			74 to 1091 =	389
43,	SS., gray, hard, micaceous, a few yellow pebbles,	2	**"Second Sand,"**	16 to 1107 =	373
44,	SS., gray, very fine and hard,	14			
	Slate, dark,			2 to 1109 =	371
45,	Shell, light-gray, fine, gritty, very hard,			2 to 1111 =	369
46,	Red rock, sandy, micaceous, shelly,		**"Big Red,"**	41 to 1152 =	328
47,	Slate, dark blue,			10 to 1162 =	318
	Red shale,			6 to 1168 =	312
48,	Slate, purplish, with hard shells, nearly white,			19 to 1187 =	293
49,	Shell of sand, with white, yellow, and red pebbles,			1 to 1188 =	292
50,51,	Slate, dark, with fine, hard shells,			5 to 1193 =	287
52,	SS., dark-gray and hard,	1	**"Third Sand,"**	26 to 1219 =	261
53 to 61,	SS., cream color, small pebbles, fossils? medium grain and very uniform all through,	25			
62,	Slate, dark,			1 to 1220 =	260

Drilled dry. Cased at 427′. No salt water below casing. No gas above 3d SS., and but little in that. No solid 1st SS. found in this well—only shells where the sand should have been. Production, 35 barrels per day for some time, when it suddenly dropped to 10 barrels.

This well was 400 feet deep when taken in charge. Down to that point the record here given was obtained from Haney well No. 4. As the two wells are only 80 rods apart and nearly on the same level, the record probably does not vary materially from what it would have been if taken from this well. See note to No. 1 A, page 221.

§ 416. *Columbia Oil Company Well No. 19.*

July 7, 1877.

Owned by Columbia Oil Company and situated on their J. H. Kiser farm, $\frac{3}{5}$ of a mile S. 20° E. from Edenburg, 1 mile N. 85° E. from Brundred Well No. 4, and half a mile west from McGrew Bros. Well No. 4.

Numbers of Spec.				
	Well mouth above ocean in feet,			1443
	Conductor,			12 to 12 = 1431
1,	Slate, dove colored and very muddy,			18 to 30 = 1413
2,	Slate, dark and dove colored, very muddy,			47 to 77 = 1366
3,	Slate, black with iron pyrites,			45 to 122 = 1321
	Slate, with gray sand shells,			16 to 138 = 1305
	COAL,			1 to 139 = 1304
4,	Slate, shelly,			7 to 146 = 1297
5,6,	SS., gray, fine, gritty,			44 to 190 = 1253
7,8,	Slate, dark with an occasional thin shell,			33 to 223 = 1220
9 to 12,	SS., very dark, fine micaceous,	54	**Mountain Sand,**	146 to 369 = 1074
13,14,	SS., white, medium fine, fossils?	33		
15,	SS., white, fine,	5		
	SS., gray, fine,	20		
16,	SS., dark-gray, fine, micaceous, soft,	19		
17,	SS., dark-gray, very fine, tough, "rubber rock,"	15		
18,	Slate, with dark shells, hard drilling,			11 to 380 = 1063
19,	SS., dark gray, fine, hard, flaky, muddy,			15 to 395 = 1048
20,21,	Slate, dark blue,			31 to 426 = 1017
22,23,	SS., dark gray, very fine, tough,	30	**"40′ Rock,"**	144 to 570 = 873
24,25,26,	SS., dark gray, coarser, gritty,	29		
27,	SS., or sandy micaceous slate,	12		
28,29,	SS., like No. 1,	30		
30,31,32,	SS., gray, very fine, fossils?	21		
33 to 37,	SS., gray and white, medium, slaty, micaceous, fossils?	22		
38 to 42,	Slate, dark, tough, granulating like sand,			48 to 618 = 825
43 to 46,	Slate, with an occasional very fine sand shell,			37 to 655 = 788
47,	Slate, with frequent shells, hard, blue, micaceous,			40 to 695 = 748
48,49,	Slate, purplish,			7 to 702 = 741
50,	Slate, dark and fawn color with gray shells,			12 to 714 = 729
51,52,	SS., dark gray, fine, micaceous, soft,			7 to 721 = 722

53 to 61,	Slate, with very fine shells, green and gray,			118 to 839 =	604
62,	SS., white, with white and yellow pebbles,	2	**"First Sand,"**	16 to 855 =	588
63,	SS., pure white, medium, fossils?	4			
64,65,	SS., pure white, fine,	10			
66,	Slate, soft, "soapstone,"			24 to 879 =	564
	Sand shells, gray,			2 to 881 =	562
	Red rock,			1 to 882 =	561
67,	Slate, with gray sand shells,			5 to 887 =	556
68,	SS., white, very fine, hard,	1		21 to 908 =	535
69,	SS., white, medium, fossils?	5			
70,	SS., gray, very fine, micaceous,	15			
71,	Slate, with gray shells,	4		30 to 938 =	505
72,	Slate, with green shells,	8			
73,	Slate, with gray shells frequent,	18			
74,	Red, fine gray sand and red clay,			3 to 941 =	502
75,76,	Slate, dark, with fine hard gray shells,			40 to 981 =	462
77,78,	Sand shells, gray and olive, fossils?			4 to 985 =	458
79,80,81,	Slate, dark, with gray shells,			32 to 1017 =	426
82,83,	Red rock, red and green sandy shale,	9	**"Big Red,"**	39 to 1056 =	387
84,	Red rock, brownish red, sandy, micaceous slate,	30			
	Slate,			3 to 1059 =	384
85,	SS., gray, gritty, micaceous, flaky,			9 to 1068 =	375
86,	Slate, sandy,			13 to 1081 =	362
	Red rock,			2 to 1083 =	360
87,	Slate, purplish and green, sandy,			21 to 1104 =	339
88,	Shells, gray, hard, with yellow pebbles,			2 to 1106 =	337
89,90,	Slate, with gray, fine, hard shells,			11 to 1117 =	326
91,	SS., with white and yellow pebbles,	5	**"Third Sand,"**	26 to 1143 =	300
92,	SS., gray, very fine,	1			
93,94,95,	SS., cream color, fine,	4			
96,97,	SS., fine-pebble sand, fossils?	4			
98 to 101,	SS., cream color, fine, fossils?	12			

Not fully through the 3d sand. *Second sand* only represented by thin shells.

Drilled dry. Cased at 567′. No water found below casing. No gas above 3d SS., and but little in that. Production from 5 to 6 barrels per day.

This well was torpedoed before the tubing was inserted and made one flow over the top of the derrick.

§ 417. *McGrew Bros. Well No. 4.*

June 13, 1877.

Owned by McGrew Bros. and situated on the McIlhatten farm, 1 mile S. 50° E. from Edenburg, and half a mile east of Columbia Oil Cos. well No. 19.

Numbers of Spec.						
	Well mouth above ocean in feet,					1316
	Conductor,			8 to	8 =	1308
1,	SS., reddish, gritty, medium grain,	18		50 to	58 =	1258
2,	SS., gray, gritty, fine, with streak of coal slate,	32				
3,	SS., slate color, very fine, with slate and pyrites,	22		36 to	94 =	1222
4,	SS., slate color, very fine, hard, micaceous,	14				
5 to 9,	SS., pure white, gritty, medium, with hard streaks and somewhat gray and soft at bottom,		**"Mountain Sand,"**	98 to	192 =	1124
10,11,	Slate, fawn color and dark blue, with light gray fine hard sand shells, frequent and thick,	66		92 to	284 =	1032
12,	Slate, dark blue, with gray sand shells,	7				
13,	Slate, fawn color and blue, free from shells,	19				
14 to 17,	SS., gray, very fine, thin partings of slate, hard drilling,			61 to	345 =	971
18,19,	Slate and olive gray shells, about equal proportions,			19 to	364 =	952
20,21,22,	SS., gray, fine, gritty, micaceous,	48	**"40′ Rock,"**	64 to	428 =	888
23,24,25,	SS., dark gray, a few pebbles at top, with hard close slaty shells towards bottom,	16				
26,27,28,	Slate, blue, soft, muddy,			52 to	480 =	836
29,30,31,	Slate, blue, sandy, hard thin shells at 505′, 530′ and 565′,			102 to	582 =	734
32,	Shells, light gray, fine, hard, little gas,			2 to	584 =	732
33,	Slate, black and sandy, hard,			1 to	585 =	731
34,	Shells, hard, with blue and fawn color slate,			9 to	594 =	722
35,36,37,	Slate, dark micaceous,			117 to	711 =	605
38 to 45,	SS., white, coarse, yellow and pink pebbles on top, (7′) fine and milky white at bottom,		**"First Sand,"**	21 to	732 =	584
46,	Slate, common,			15 to	747 =	569
47,	Red, sandy, micaceous and but slightly colored,			6 to	753 =	563
48,49,	Slate, dark, with gray sand shells,			12 to	765 =	551
50,	Shells, gray, fine, micaceous,			4 to	769 =	547
	Slate, common,			12 to	781 =	535
51,52,	Shells, olive gray, fine, micaceous, with slate,			13 to	794 =	522
53,	Red, very fine, micaceous, flaky sand,			4 to	798 =	518

54,55,	Slate, dark, with fine gray sand shells,			12 to 810 =	506
	Red, olive and red sandy shales,			2 to 812 =	504
56,57,	Slate, black, with fine, gray, micaceous shells,			37 to 849 =	467
58,	Red sandy shale, hard,			2 to 851 =	465
	Slate, with hard shells,			3 to 854 =	462
59,	SS., light gray, fine, flaky, muddy, micaceous,			4 to 858 =	458
	Slate, somewhat shelly,			12 to 870 =	446
60,61,	SS., light gray, fine, flaky, muddy, micaceous,		**"Second Sand,"**	31 to 901 =	415
62,	Red sandy shale, red and green,	33	**"Big Red,"**	42 to 943 =	373
63,	Red sandy slate, very micaceous, brownish red,	9			
64,	Slate, dark, with gray, micaceous shells, some pebbles,			6 to 949 =	367
65,66,	Slate, common,			35 to 984 =	332
67,68,69,	Slate, with thin sand shells containing pebbles,			9 to 993 =	323
70,71,72,	SS., grayish white, medium,	10	**"Third Sand,"**	30 to 1023 =	293
73,74,	SS., pebbly sand, yellow and white,	4			
75 to 79,	SS., fine, dark gray, fossils?	9			
80,	SS., olive gray, with slate,	2			
81,	SS., cream color, very fine clean sand,	2			
82,83,84,	SS., orange gray, fine, flaky, fossil?	3			
85,86,87,	Slate, common, with an occasional pebble,			17 to 1040 =	276
88 to 92,	SS., gray, fine, flaky, muddy, some pebbles in top, fossils? not through,		**"Fourth Sand,"**	10 to 1050 =	266

Drilled dry, cased at 430′. A small quantity of salt water in the 1st SS. and a slight show of gas. But little gas in the 3d SS Average daily production 2 bbls. apparently from the 3d sand.

§ 418. *A diary of each day's drilling, in a tabular form, with notes of drawbacks encountered by accidents, &c. Edenburg wells.*

(NOTE.—The number marks the well. The column under it gives its successive daily increasing depth in feet. The columns headed *d. a.* give the *daily advance* of each well in feet.

1877.	No. 1.	*d.a.*	No. 2.	*d.a.*	No. 3.	*d.a.*	REMARKS.
May 8,	0	0	. . . . .	. .	0	0	
9,	46	46	. . . . .	. .	32	32	
10,	77	31	. . . . .	. .	66	34	No. 3, breakdown; 5 h. lost.
11,	130	53	0	0	85	19	No. 3, cable parted; 8 hours lost.
12,	F	.	30	30	116	31	
Sunday,	. . . .	. .	. . . .	. .	. . . . .	. .	
14,	146	16	52	22	140	24	
15,	193	47	104	52	189	49	
16,	235	42	142	38	225	36	No. 3, broke crank box.
17,	260	25	175	33	265	40	
18,	274	14	218	43	296	31	No. 1, "Rubber rock;" tough drilling.
19,	318	44	258	40	325	29	
Sunday,	. . . .	. .	. . . . .	. .	. . . .	. .	
21,	351	33	295	37	355	30	
22,	380	29	F	. .	394	39	No. 2, lost bit in the well.
23,	A 407	27	F	. .	413	19	
24,	B 410	. .	F	. .	430	17	No. 3, cased at 430.
25,	427	17	F	. .	452	22	No. 1, cased at 427.
26,	477	50	F	. .	530	78	
Sunday,	. . . .	. .	. . . . .	. .	. . . . .		
28,	531	54	F	. .	585	55	
29,	616	85	F	. .	640	55	
30,	662	46	F	. .	716	76	
31,	743	81	F	. .	756	40	
June 1,	759	16	F	. .	795	39	No. 1, repg. boiler; 18h. lost.
2,	804	45	F	. .	F	. .	No. 3, dril'gout S. pump bot.
Sunday,	. .		. . . . .	.	. . . .	. .	No. 2, bit taken out and hole prepared for drill.
4,	850	46	F	. .	850	55	
5,	895	45	340	45	890	40	No. 1, cleaning water well; 6 hours lost.
6,	967	72	372′	32	939	49	
7,	1006	39	402	30	981	42	No. 1, repairing boiler; 6 hours lost.
8,	1042	36	441	39	1003	22	
9,	1093	51	465	24	1014	11	
Sunday,	. . . .	. .	. . . . .	. .	. . .	.	
11,	1110	17	497	32	1018	4	
12,	1172	62	515	18	1026	8	No. 2, repairing rig.
13,	1197	25	533	18	1050	24	
14,	1208	11	551	18			
15,	1217	9	563	12			
16,	1220	3	567	4	. . .	.	No. 2, cased at 567.
Sunday,	. . . .	. .	. . . . .				
18,	. . . .	. .	585	18			
19,	. . . .	. .	625	40	. . . .	. .	No. 2, breakdown; 5 h. lost.
20,	. . . .	. .	655	30			
21,	. . . .	. .	713	58			
22,	. . . .	. .	731	18			
23,	. . . .	. .	768	37			
Sunday,	. . . .	. .	.				
25,	. . . .	. .	820	52			
26,	. . . .	. .	851	31			
27,	. . . .	. .	884	33			

28,	. . . . .	. .	899	15			
29,	. . . . .	. .	932	33			
30,	. . . . .	. .	972	40	. . . . .	. .	No. 2, breakdown; 4 h. lost.
Sunday,	. . . . .	. .	. .	. .			
July 2,	. . . . .	. .	1012	40			
3,	. . . . .	. .	1061	49			
4,	. . . . .	. .	1123	62			
5,	. . . .	. .	1129	6			
6,	. . . . .	. .	1136	7			
7,	. . .	.	1143	7			

Notes to the preceding Table in § 418.

Column No. 1.

A. *Upper part.* Haney & Bartlett's Well No. 4, Haney farm, four fifths of a mile S. 65° W. from Edenburg and a quarter of a mile N. 20° E. from Brundred Well No. 4.

Elevation of well mouth above ocean 1486′.

This well and McGrew Bros'. No. 4, commenced to drill on the same day, but after the former had been carried down to 407 ft. and cased, drilling was suspended on it to await a better price of oil.

No. 1, B, was then substituted for it, making a compound section—400 ft. belonging properly to Haney and Bartlett well and the remainder to Brundred well No. 4.

B. *Lower part.* Brundred Well No. 4, Capt. Kribb's farm, Beaver city; 1 mile S. 55 W. from Edenburg.

Benj. Brundred owner.

Jas. R. Adams, contractor and tool dresser.

J. A. McQuade, tool dresser.

Lee Herron, driller.

R. E. Deyoe, driller.

Actual drilling time, after the casing was put in, 15 days. Average drilling 53 ft. per day. Best 24 hours' work 85 ft.

The contractor asserts that this well was drilled with a remarkably small amount of fuel. Only 800 bushels of coal were used, while Brundred No. 3, with the same "crew," consumed 1200 bushels and Brundred No. 2, 3800 bushels. The wells were near together and did not vary much in depth.

A singular accident happened while drilling, caused by the melting of the "soft plug" in the crown sheet of the boiler, while covered by two "flush gauges" of water. This must have been owing to the formation, from the impurities in the water, of a conical incrustation over the "soft plug," thus allowing it to heat up and melt.

This well was not taken in charge until May 24, after the Haney No. 4 stopped drilling. It was then about 400 feet deep. The precise date of its commencement could not be ascertained, but it was probably about the 1st of May, as the workmen had been delayed by several fishing jobs, and encountered a vertical crevice in the mountain sand which the drill followed for 60 or 70 feet, during which time no water could be kept in the hole, and consequently the work progressed very slowly.

Column No. 2.

Columbia Oil Company's Well No. 19, J. H. Kiser farm; ⅗ of a mile S. 20° E. from Edenburg.

Columbia Oil Co., owners.

John McCool, contractor.

Mike McCool, driller.

Jas. Kearney, driller.

Barney McCool, tool dresser.

Phil. Dougherty, tool dresser.

Actual drilling time 36 days. Average drilling 31.8′ per day. Best 24 hours' work 66 feet.

Column No. 3.

McGrew Bros'. Well No. 4, McIlhatten farm; 1 mile S. 50° E. from Edenburg.

McGrew Bros., owners.

W. G. Southwick, contractor and driller.

D. R. Blair, driller.

John A Patterson, tool dresser.

A. A. Bell, tool dresser.

Actual drilling time 29¼ days. Average drilling 36 ft. per day. Best 24 hours' work 80 feet.

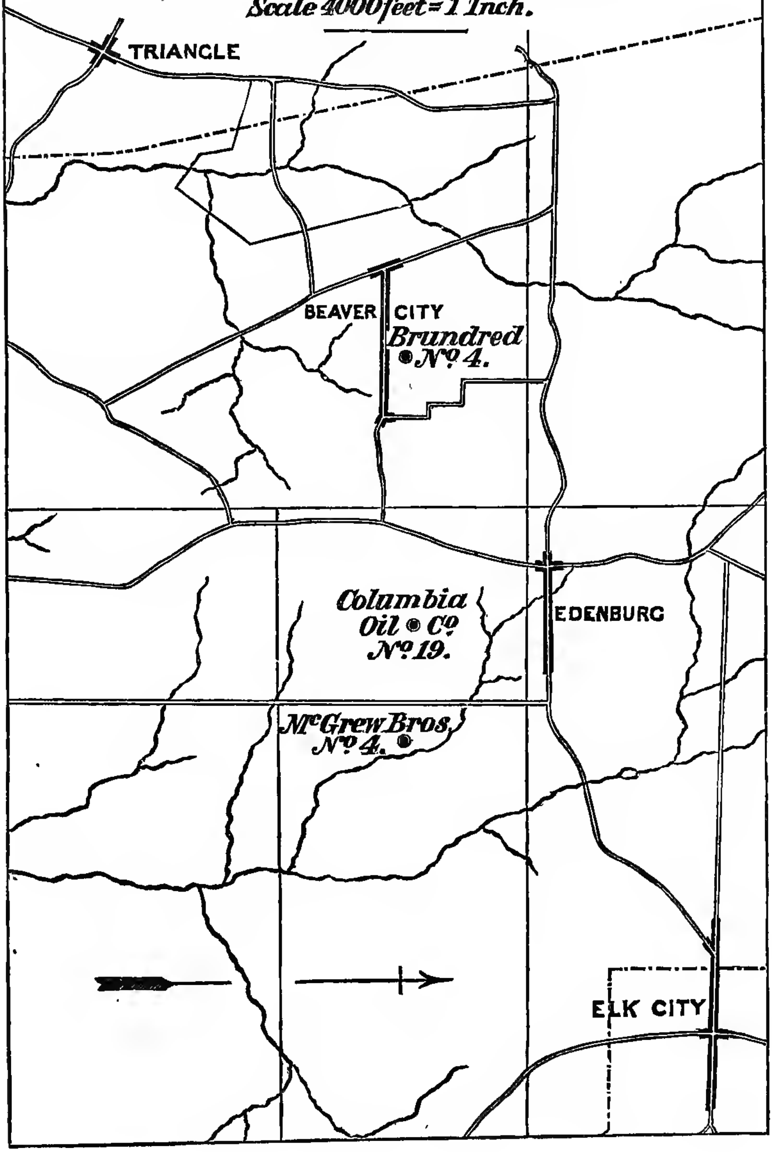
§ 419. *Elevations of a number of wells near Edenburg;* incidentally taken by J. H. Carll while running the levels for the three wells measured by him.

B. M. on maple, W. of RR., between State street and Penna. avenue, Edenburg, on authority of W. H. Smith, Chief Eng. of E. & S. RR. = 468.74′ above A. V. RR. depot at Emlenton. = above ocean,	905′ + 468.74′ = 1373.74′
Oak Shade Well No. 2,	1464
“ “ No. 5,	1341
“ “ No. 6,	1335
“ “ No. 8,	1459
“ “ No. 10,	1450
Columbia Oil Co. Well No. 7, J. H. Kiser farm,	1330
“ “ “ No. 9, “ “	1447
“ “ “ No. 10, “ “	1342
“ “ “ No. 13, “ “	1361
“ “ “ No. 14, “ “	1330
“ “ “ No. 18, “ “	1358
“ “ “ No. 19, “ “	1443
McGrew Bros. Well No. 1, McIlhatten farm,	1347
“ “ No. 2, “ “	1346
“ “ No. 3, “ “	1345
“ “ No. 4, “ “	1316
Brundred Well No. 4, Capt. Kribb's farm,	1480
Haney “ No. 4, Bower's farm,	1486
Base of Ferrif. limestone near Columbia Well No. 19,	1445
“ “ “ “ church in Edenburg,	1429

Plate XXXIV.

Sketch map showing the geographical postions of the three wells measured by John H. Carll near Edenburg in Clarion County.

Scale 4000 feet = 1 Inch.



CHAPTER XXII.

One well near Bradford, accurately measured.

(Illustrated by Plate XII.)

§ 420. *For the following record and catalogue of specimens* we are indebted to the courtesy of Messrs. C. W. Dennis & Co., and their drillers, who kindly consented to subject themselves to the annoyances attending frequent measurements and the preservation of sand pumpings, in order that the Survey might obtain a complete register of the rocks drilled through in the Bradford oil district.

Dennis well No. 1, is located on a high and narrow ridge between the east and west branches of Tunangwant creek, about three quarters of a mile in a southwesterly direction from Bradford, in McKean county.

§ 421. *The Olean conglomerate* caps the crest a short distance south of the well, its base being only 115 feet above the well mouth. This record, therefore, furnishes a section showing nearly all the strata lying between the Conglomerate series and the Bradford oil sand.

§ 422. *To insure an authentic history of the well for the Survey,* Mr. Arthur Hale was detailed to supervise it while drilling. From the time the tools were swung in the derrick until the last sand-pumping came up, he devoted his whole attention to it; and probably no well record was ever kept with greater care or more in detail than this one. A portion of nearly every sand-pumping was preserved, and the suite of specimens when bottled and arranged to a scale of $\frac{1}{50}$ as described in Chapt. XX, gives a fine exhibtion of the character of the measures drilled through.

§ 423. *The distance from Dennis Well No. 1 to the Clarion wells* described in the last chapter, is about 65 miles, in a direction south 43° west. It cannot be expected, therefore, that any very satisfactory comparison of the section of this well, as seen on Plate XII, can be made with the others there shown. A number of reliable sections are needed at intermediate points, before the horizon of the Venango oil group can be positively fixed at Bradford, or the place of the Bradford oil sand be satisfactorily determined in Clarion county. From the imperfect records of wells scattered along this interval, it is evident that important changes of structure occur, particularly in the rocks belonging to the Venango group and the mass above it, provisionally called, in this report, the Crawford shales. We are not able to recognize any one of the oil sands of Venango in the Dennis well, neither can we yet trace the red rocks seen in the section and exposed on many of the hillsides of McKean county, to a direct coalescence with the red bands in the oil wells of Warren, Venango, or Clarion.

§ 424. *As Mr. Ashburner's Reports on McKean and Forest counties* will contain all the information obtained on these subjects, no attempt is here made to identify the Bradford rocks with those of Clarion; and the Dennis well record and section are only published in this volume for the purpose of grouping together all the facts in relation to these ten measured wells, so that they may be convenient for reference hereafter.

§ 425. *Dennis Well No. 1.*

Dec., 1877 and Jan., 1878.

Owned by C. W. Dennis & Co. and located on Rodger's farm, three fourths of a mile S. 25° W. of Bradford, in Bradford township, McKean county, Pa.

Numbers of Spec.				
	Elevation of well mouth above ocean in feet, (Erie RR. depot being 1444'),			2055'
	Surface clays,	4 to	4 =	2051
1,	Sandy shale, olive gray, micaceous, muddy,	11 to	15 =	2040
2 to 5,	SS., gray, fine, micaceous, muddy,	33 to	48 =	2007
6,7,	Shale dark gray, with thin micaceous sand shells, muddy,	19 to	67 =	1988
8,	SS., gray, fine, soft, muddy,	8 to	75 =	1980
9,10,	Slaty sandstone, bluish, fine, muddy,	23 to	98 =	1957
11,12,13,	Fine gray sand shells and dark slate alternating, muddy,	18 to	116 =	1939
14,15,	SS.. ashy gray, very fine micaceous, muddy,	16 to	132 =	1923
16,	Red shale, soft,	6 to	138 =	1917
17,	SS., olive gray, fine, micaceous,	12 to	150 =	1905
18,19,20,	SS., dark olive gray, fine, micaceous,	30 to	180 =	1875
21,	SS., white, mixed with green and brown, fine,	8 to	188 =	1867
22,	SS.. bluish gray, fine, micaceous, muddy,	9 to	197 =	1858
23,24,25,	Red shale, "paint rock" top soft, bottom sandy and micaceous,	18 to	215 =	1840
26,27,	SS., gray, fine, mixed with slate, a few pebbles,	23 to	238 =	1817
28 to 31,	Slate, bluish,	22 to	260 =	1795
32,33,	Slate, bluish, with thin plates of fine sandstone,	15 to	275 =	1780
34,35,36,	Sandy slate, dark gray, fine, micaceous,	16 to	291 =	1764
37,38,39,	Slate, bluish,	24 to	315 =	1740
40,	SS., gray, fine, micaceous,	5 to	320 =	1735
41,42,	Red slate; micaceous, muddy,	8 to	328 =	1727
43,44,45,	SS., olive gray, soft, micaceous, some slate,	39 to	367 =	1688
46,47,	Red rock, mottled sandy shale, brown, green and gray,	15 to	382 =	1673
48,	Slate, sandy, gray,	8 to	390 =	1665
49,50,	SS., dark, very fine,	10 to	400 =	1655
51 to 56,	SS., gray, very fine, hard, drillings like flour; cased at 435',	35 to	435 =	1620
57 to 63,	Slate, sandy, micaceous,	38 to	473 =	1582
64,	SS., dark gray, very fine, micaceous, flaky,	6 to	479 =	1576
65,	SS., bluish gray, fine, hard, remnants of fossils,	6 to	485 =	1570
66 to 76,	Slate, sandy in streaks, micaceous, fossil bands,	95 to	580 =	1475
77 to 89,	Dark gray, thin bedded SS , fine micaceous, slate partings, fossils,	71 to	651 =	1404
90,91,92,	SS., gray, fine, flaky, micaceous, fossils,	23 to	674 =	1381
93,94,	Slate,	12 to	686 =	1369
95 to 98,	SS., dark gray, slate partings. fossils,	26 to	712 =	1343
99,100,	Red rock, purplish, sandy, very fine, micaceous, fossils,	10 to	722 =	1333

101 to 103,	Sandy slate, dark, micaceous,			20 to 742 =	1313
104 to 113,	SS , fine, micaceous, alternating with slate and "chocolate" shale, fossils,			63 to 805 =	1250
114,115,	SS., thin bedded, micaceous, slate partings, fossils,			13 to 818 =	1237
116 to 136,	Slate, an occasional sand shell with fossils,			125 to 943 =	1112
137,	SS., brown and purplish, fine, hard, fossils,			8 to 951 =	1104
138 to 146,	Slate, dark lead color,			55 to 1006 =	1049
147,148,	"Red rock," fine, purple and gray sandy slate,			14 to 1020 =	1035
149 to 153,	Gray sand shells and slate, fossils,			24 to 1044 =	1011
154,155,	Slate,			12 to 1056 =	999
156,	SS., dark, hard, fine,	3	**Bradford "First Sand,"**	16 to 1072 =	983
157 to 163,	SS., yellow-gray, drillings as fine as flour,	13			
164,165,	Slate,			5 to 1077 =	978
166,	SS., yellow-gray, fine,			4 to 1081 =	974
167 to 169,	Slate, sandy,			7 to 1088 =	967
170,171,	SS., dark-gray, fine, fossils,			6 to 1094 =	961
172 to 175,	Slate,			17 to 1111 =	944
176 to 180,	SS., brown and gray, fine, soft, with some slate, (oil show,)			14 to 1125 =	930
181 to 186,	Slate,			23 to 1148 =	907
187 to 190,	Slate, with dark sand shells,			15 to 1163 =	892
191,192,	Slate,			13 to 1176 =	879
193,194,	Slate, with gray sand shells,			5 to 1181 =	874
195 to 197,	Slate,			12 to 1193 =	862
198 to 206,	Slate, with an occasional sand shell,			44 to 1237 =	818
207 to 219,	Slate, "blue slate,"			63 to 1300 =	755
220 to 223,	SS., brown, fine, flaky, slate partings, fossils,			17 to 1317 =	738
224 to 229,	Slate,			28 to 1345 =	710
230,231,	SS., dark-gray, fine, close, hard,	6	**Bradford "Second Sand,"**	36 to 1381 =	674
232 to 237,	SS., brownish-gray, fine, slate partings,	30			
238 to 242,	Sand shells and slate,			22 to 1403 =	652
243 to 254,	Slate, sand shell at 1428′,			59 to 1462 =	593
255 to 261,	Fine sand shells and slate alternating,			25 to 1487 =	568
262 to 286,	Slate, sand shells at 1510′, 1531′, and 1573′,			118 to 1605 =	450
287 to 291,	Slate, with sand shells,			27 to 1632 =	423
292 to 295,	Slate,			32 to 1664 =	391
296 to 310,	SS., brown, fine, flaky,		**Bradford "Third Sand,"**	54 to 1718 =	337
311,	Slate and SS.,			1 to 1719 =	336

Drilled dry. Cased at 435 feet. Immediately after completion, the well was torpedoed, responding with a heavy flow of oil for a short time, and then settled down to about 35 barrels per day.

§ 426. *A diary of each day's drilling, in a tabular form, with notes of the drawbacks encountered by accident, &c. Dennis Well:*

		Daily advance.	Depth.
1877.			
Nov. 29,	Conductor, 21 ft. previously set,	12 to	33
30,	Thawing supply pipes,	—	—
Dec. 1,	Pulling tubing from water well,	—	—
Sunday,		—	—
3,		34 to	67
4,		48 to	115
5,		60 to	175
6,		35 to	210
7,		50 to	260
8,	Engine gives out,	31 to	291
Sunday,		50 to	341
10,		49 to	390
11,		45 to	435
12,	Putting in casing,	10 to	445
13,		101 to	546
14,		86 to	632
15,		66 to	698
Sunday,		—	—
17,		72 to	770
18,		68 to	838
19,		81 to	919
20,		34 to	953
21,		34 to	987
22,		34 to	1021
Sunday,		—	—
24,	Broke jars and lost tools at 1056′,	35 to	1056
Christmas,		—	—
26,	Fishing,	—	—
27,	Fishing,	—	—
28,	Fishing, got tools out, minus bit,	—	—
29,	Fishing,	—	—
Sunday,		—	—
31,	Fishing,	—	—
1878.			
Jan. 1,	Fishing, pin broke above jars,	—	—
2,	Fishing,	—	—
3,	Cleared the hole,	7 to	1063
4,		7 to	1070
5,		15 to	1085
Sunday,		—	—
7,		15 to	1100
8,		16 to	1116
9,		9 to	1125
10,		19 to	1144
11,		31 to	1175
12,		39 to	1214

Sunday,		— —
14,		40 to 1254
15,		33 to 1287
16,		30 to 1317
17,		29 to 1346
18,		55 to 1401
19,		49 to 1450
Sunday,		— —
21,		27 to 1477
22,		38 to 1515
23,		35 to 1550
24,	Bull wheel broke down,	12 to 1562
25,		21 to 1583
26,	Cable parted, 9.30, P. M., tools and 1400′ rope in hole,	62 to 1645
Sunday,		— —
28,	Fishing,	— —
29,		17 to 1662
30,	Struck the oil sand at 1664′,	9 to 1671
31,		14 to 1685
Feb. 1,		14 to 1699
2,		20 to 1719

Total time of drilling about 47 days. Average progress, about 36½ ft. per day. Sixty-six days from time drilling began to completion of well. Best 24 hours' work, 101 feet.

Contractors, O. P. Boggs and L. B. Andrews. Drillers, Lester B. Andrews and J. W. Boggs. Tool dressers, H. W. Thomas and C. M. Andrews.

CHAPTER XXIII.

Structure of the Venango Oil Sands.

§ 427. In investigating any branch of physical science, as in all other logical processes of the human mind, true deductions depend upon and can only be drawn from correct premises. The operations of many natural laws are so patent, and the results produced so plain, that there is no difficulty in following the chain of events up from cause to effect, or down from effect to cause. But there are other more mysterious and occult agencies, which have been and still are at work, and the effects of which we see, that are not so readily understood or explained. The mountains rise above us, but who can write an indisputable history of the precise manner of their construction? the oil sands spread out beneath our feet, who can go down into the dark places of the deep, or back into the unknown ages of the abysmal past, and gather the facts for a special and detailed account of their deposition which shall carry the conviction of truthfulness to all who may read it?

In all subjects of this kind, where positive proofs cannot be readily adduced to sustain every position assumed, there is always room for great diversity of opinion—for vague theories, bold hypotheses, bald assertions and all kinds of crude speculations. Still, there may usually be found a common sense way of arriving at a reasonable solution of these mathematically undemonstrable problems, by appealing to analogies in nature, where cause and effect are open to investigation and the conclusions reached by a study of them cannot be gainsayed.

The manner in which the oil sands were deposited is one of these measurably uncertain problems, and one to which may be obtained a very erroneous solution, unless the premises upon which the deductions are based be previously well established.

§ 428. *Many strange and fanciful theories* have been advanced to account for the presence of the oil sands in the positions where they are found. They have been supposed by some to have been ejected through a portion of the superstrata by subterranean forces operating beneath them. They have been described—and by reputable geologists, too—on the one hand as fractured anticlinal arches, on the other as synclinal troughs, traversed by fissures and crevices containing salt water, oil and gas. They have been pictured as long sand-cores cast in grooves a few yards wide and running as straight as an arrow for miles—as if some huge grooving-machine had passed over the bed rocks of shale in a northeast southwest direction, making an uniform furrow a few rods wide and 30 feet or more in depth in the center, which was in some unaccountable manner filled in at a latter day with coarse sand and gravel.

We shall not stop to attempt to refute these baseless theories and speculations, for they are shown to be untenable by the many facts given in other parts of this report, but proceed at once to a consideration of the question involved in a study of the physical structure of the oil sands.

§ 429. *These questions are*, (1) what dynamical agents were employed in the construction or building up of these rocks? (2) what was the character of the materials used in the formative processes? and (3), with such forces and such materials, what would be the probable structure of the rocks, judging from what we see under analogous circumstances at the present time?

Fortunately we are not driven into a discussion at the outset, to prove in which grand division of the consecutive series of formations composing the earth crust the oil rocks are found. Lying as they do at the top of the Devonian system, or, perhaps, more properly speaking, in the transition measures deposited while the Devonian was merging into the Carboniferous, their *sedimentary* origin cannot be disputed. The question thus narrows down at once to a consideration of those forces alone which have been energetically engaged in the past, and are still employed in the deposition and building up of this class of rocks.

§ 430. *Sedimentary rocks* are defined by Lyell, as those which "are formed from materials thrown down from a state of suspension or solution in water."

This definition, at first sight, seems hardly broad enough to cover the ponderous mechanical sediments of conglomerate and sandstone composing the oil sands. But a second thought will vindicate its correctness, for even the largest pebble of the conglomerate must have been, temporarily at least, held in suspension by the energy of the transporting current as it was swept along rolling or ricochetting near the bottom.

Sea-beaches of sand and gravel which were thrown up along shore by waves and winds, high above ordinary tide level, belong also as truly to the sedimentary series when sunken and covered with other stratified deposits as do the accumulations of finer materials at a distance from the shore—which have been in a more literal sense, "held in a state of suspension in water."

§ 431. *If then the oil sands are of sedimentary origin*, it therefore follows that they could only have been laid down in oceans, lakes, or rivers, beneath the water level, or at or near its surface.

The forces employed in their construction could only have been those prevailing through aqueous conditions, and they are the same, and no others, that are possessed by water to-day, to wit: The buoyancy of the fluid, the transporting capacity of swift currents and the tremendous energy of rolling waves and dashing breakers. These forces, in connection with probable terrene oscillations causing alterations in relative levels of land and water, are sufficient to account for all the phenomena discovered in studying the structure of the sedimentary strata.

§ 432. *What the component materials of the oil group are*, may readily be ascertained by an inspection of the contents of sand-pumps, coming up from thousands of drill-holes, scattered throughout the oil district, and by an examination of the exposed portion of the out cropping oil measures and the coal rocks above them, as seen in northwestern Pennsylvania—for both masses appear to be generically the same, and have evidently been deposited under similar conditions.

The materials vary from coarse conglomerates containing quartz pebbles occasionally two inches in diameter, through all grades of conglomerates, down to pebble-sand, sandstone, sandy-shale, slate, and the most finally levigated mud-rock or "soapstone" of the driller.

§ 433. *With such forces in action* as are enumerated above, varying in energy abnormally, with winds, and tides, and storms; affected by changes of levels, intensifying their powers at one time in this place, at another time in that, and with such heterogeneous materials to work upon, as the resultant strata indicate, we could only expect to find our oil-sands and their associates, (as indeed we do find them,) a variable mass of pebble, sand and shale beds, laid down locally with great irregularity and disorder, within the areas most sensibly affected by these changing conditions.

§ 434. *Water as a vehicle of transportation* for substances of greater gravity than itself, is strong or weak in proportion to the velocity with which it moves. It follows, then, that *the character of the sediment laid down is an index of the strength of the current depositing it.*

The oil-sands are frequently massive conglomerates, made up of the coarsest materials to be found in the formation to which they belong; the influence is unavoidable, therefore, that they owe their origin to the action of the strongest depositing currents prevailing at the period of their deposition. There are but three classes of currents that may be presumed to possess the adequate requisites for the performance of this kind of work, *river currents, deep-sea currents and shore currents.* Let us see which one of these has left the recognizable marks of its paternity upon the rocks in question.

Fluviatile Currents.

§ 435. In attempting to refer these sandy deposits to fluviatile currents, many objections present themselves, although this view of the origin of their sedimentation is stoutly maintained by some experienced and well informed oil miners who claim to have closely watched the structure of the rock as interpreted by the drill and sand-pump.

Allowing that a river current was competent to bring down sandy material, and deposit it in islands, sandbars and marginal banks along its borders at any given period of its history, how are the intermittent intervals to be accounted for, when fine materials, only, were deposited above the sand-beds? How are we to explain the strewing again and again of alternating sand and mud over the same areas, when the river beds meantime had filled up hundreds of feet and ample opportunity was afforded for the channel to mark out a new bed at each successive period? Or for the wide diffusion of similarly arranged sediments over the whole of the Appalachian basin, for we cannot ignore the fact before stated, that the impress of the same mechanical agencies which fashioned the structure of the oil-strata, is stamped upon all the measures deposited above them.

Those who advocate this view, looking only at the arrangement of the pebbly, or oil-producing portions of the sand rock, seem to lose sight of the fact that the synchronal equivalents of these pebble-pockets can be unmistakably traced in almost continuous, although variable, sheets of sandstone and sandy-shale, for miles in either direction transversely to the axes of their assumed river currents.

Another argument against the river current theory, is found in the even assortment and systematic arrangement of the sands and pebbles composing the strata. *There is no confusion in the strewing of the materials, no intermixture of angular, partly worn fragments of local rocks*, as would necessarily be the case in sediments piled up by fluviatile forces—but everything betokens that the material has been subjected to the sifting, assorting, triturating processes, which are known to belong only to the action of sea waves.

Deep Sea Currents.

§ 436. The comportment of deep sea or off shore currents and the results of their actions, are not so open to observation as are the like characteristics of fluviatile and littoral currents. We cannot therefore judge so confidently by analogy concerning them. It appears quite probable, however, from what is known of ocean currents of the present day, that one having sufficient velocity to transport for long distances, such coarse materials as the oil sands in many cases are composed of, would keep its own channel clear, if indeed, it did not also wear away the floor upon which it moved; and that the pebbles and sand carried along by the flow would only be thrown off along the margins of the submerged stream;—in which case, so long as the transporting forces occupied a fixed channel, geographically, two sand-bars would be formed, separated by a distance corresponding to the width of the central, rapid current, without any direct communication of sandy deposits between them.

But if the position of the ocean stream was not constant—if liable at one time to swing to the right, at another to the left—this lateral movement might cause a partial re-arrangement of the sand-bars and a silting up of the old channels as the deposits accumulated.

The hypothesis that the position of the current was dependent upon the geographical outlines of the sea basin through which it flowed; that these outlines were subject to great variation by reason of changes in relative levels of land and water; and that thus the current was made to swing at one time east, at another west; strewing the materials over a broad area transverse to its axis—sometimes going so far to the one side or the other, as to leave its previous sandy deposits on the side of its recession in comparatively quiet water during a period of time adequate for the accumulation of those finer sediments which are found interstratified between the sand beds—might plausibly account for many of the phenomena discovered in the drilling of oil wells. But, if as before claimed in discussing the possible effects of fluviatile currents, there are good reasons for inferring that the oil rocks were deposited in a similar manner to the coal rocks—that the laws of mechanical deposition which in after ages controlled the stratification of the latter, were then in force, and in like manner governed the sedimentation of the former—then it can hardly be admitted that they were deposited by deep sea currents; for we have indisputable evidence that the coal rocks could not have been deposited under these conditions, but must have been laid down at or near water level.

Other objections to this hypothesis are found in the discontinuity of the sandy deposits along what would appear to be the margins of the ocean stream; the intermingling of red shale with the oil sands at different horizons in different localities, the splitting of the sands into two or more members going in a southeasterly direction from the main deposit, all seeming to indicate the effects of disturbing causes, due apparently to shore influences which could hardly be expected to affect a grand ocean-current capable of transporting and strewing such a ponderous deposit of pebbles and sand along its course, as is here found for a distance of seventy-five miles at least.

The methods of deposition still in doubt.

§ 437. After a patient study of the geological structure of the oil region for years, before, as well as since the organization of the present survey, with all the data collected by the survey at command and all the assistance that the researches of geologists and the practical operations of oil developments can give, I cannot but acknowledge that I am still unable to offer any well digested theory of the precise methods by which the oil sands were deposited. To my mind there are many facts in connection with their stratigraphy, structure and geographical position, pointing strongly toward the probability of their being shore-line or sea-coast accumulations, and it will be noticed that this report is written throughout on the assumption that they were so formed. But the task of *proving* this is by no means an easy one. I shall not attempt it. The problems involved are so complex, the operations of nature so erratic, (paradoxically speaking,) because controlled by fixed laws which must produce, under certain circumstances, one class of results, and under other combinations, another; and the physical forces and mechanical sediments we have to deal with in our investigations—waves and currents, winds and tides, sand and mud—are so variable in their actions and so mutable and prolific in specific results, that they all must be subjected to a closer and more comprehensive study than they have yet received, before the varying results of their combined action can be fully understood or satisfactorily explained.

The aim in these pages is to put on record the facts as we find them, and when conclusions are drawn, as they sometimes necessarily must be, for the purpose of argument, or as a base to work out from, they must be considered as tentative only, and held subject to such modifications as future developments and discoveries may demand.

With this acknowledgement of an inclination to view the oil group as virtually a shore deposit we will now review this method of deposition and see if it does not give results more in consonance with the observed phenomena exhibited in the structure of the oil-sands than either of those previously considered.

A new epoch commencing with the Venango group.

§ 438. The lowest member of the Venango oil group—whether it be called third sand, or fourth, or fifth—appears to mark the commencement of a new era in the history of that part of the Appalachian basin where it is found. Anterior to its formation, the conditions of the ocean bed geographically coincident with the trend of the group, seems to have remained comparatively constant and uniform for ages. Drillings from rocks lying from one to two thousand feet below it, disclose only such finely levigated sediments as would naturally be deposited in comparatively still, deep water, beyond the perturbing influences of surface or shore.

There are abundant evidences in other parts of the country to prove that during the time this immense deposit of underlying soft rocks was being formed here, several important and widely-felt oscillations of the earth-crust occurred, resulting, in other localities, in alternations of sediments at this horizon, which exhibit, lithologically, marked constitutional differences, and are readily distinguishable one from the other by the genera and species of fossils found entombed in them. That these changes were not more definitely recorded in like lithological variations of the cotemporaneous strata beneath the oil rocks, (of the palæontological variations, of course we cannot speak, as fossils are seldom brought up in the sand-pump,) can only be accounted for on the presumption that the area over which the latter were afterwards superimposed, was at that time so far seaward and so deep below the water surface, as not to be sensibly affected by these great physical movements, which must have been broad and almost continental in their scope.

So long as these broad oceanic conditions which had obtained for ages in this latitude, continued, so long the same kind of sediments resulted. But at this point of time (the commencement of the oil group) a new class of sediments come in; coarse sand and gravel are now laid down over large areas, where previously only mud and occasionally arenaceous shales and slates had been deposited. A radical change evidently must here have taken place both in the physical conditions and geographical outlines of the great basin receiving the sediments, and the adjacent lands supplying the materials; and it is to be remarked, too, that the new order of stratification here introduced—sands and shales alternating—continued ever afterward during the deposition of all the oil and coal rocks, and until the final post carboniferous uplift.

The base of the oil group appears to furnish a well defined plane of demarkation between the mud-rocks of an age of uniform conditions and the sandstones and shales of a period of mutability and unrest. Below this horizon everything appears to be of a deep-sea, still-water type; above it, strong transporting currents, shifting in position and level, and locally intermittent or variable in action, have inscribed the evidences of their presence, and left us the witnesses of their achievements, in irregularly alternating strata of conglomerate, sandstone, and shale, all the way up to and through the coal measures.

Possible elevation of sea-bottom above water level.

§ 439. We may reasonably infer that the crust of the earth has always been rugose; that inequalities both of sea-bottom and dry land have existed ever since the Azoic rocks first raised their crests above the universal "waters of the great deep." If, then, in after times, a broad and gradual uplift of the bed of the old Devonian ocean should have occurred, say at or near the close of the Chemung period, it would in all probability have brought up to daylight large tracts of the uneven sea-bottom, particularly those portions of it adjacent to the shoaling shores; and who knows but that some islands might have appeared also, while the ancient sub-marine valleys remained submerged?

New shore lines would thus be formed, new currents established, new sources of sedimentary supplies become available. The emerging land would be simply a broad stretch of sea-bottom, composed of mud and fine sand, which for hundreds of feet in depth had not yet been subjected to the proper conditions of pressure, heat and desiccation to become concreted into rock.

Under these circumstances we may suppose that a system of drainage would soon inscribe its outlines upon the newly formed land, bringing down to the sea immense volumes of mud from the flats and sand from the old beaches, to be transported, assorted, and deposited in the basin, according to the direction of the currents and quality of materials.

The new shore-lines, composed of soft and easily abraded mud banks not yet adjusted to the sweep of ocean currents or accustomed to the lash of waves, were subjected, no doubt, to numerous transformations, while the relations of land and water were being established on a natural basis; and these transformations were multiplied and complicated by the varying contour of the upland and by the unequal shrinkage, vertically, of the newly raised measures, as they began to feel the physical effects of their altered position—the amount of shrinkage depending in a great measure on the position of the beds affected by it, and the quality of the materials locally composing them.

Thus, for instance, if one part of a coast line, backed by a stable and rather abrupt mainland, so situated in relation to the currents as to receive and retain the sandy accumulations swept along in front of it, should meantime slowly and steadily sink, might not a deposit of sand pile up in an unbroken mass over a restricted area, forming, as at Triumph, in Warren county, 120 feet of Third sand, while at another point, say in Butler county, an unequal and irregular rate of shrinkage and subsidence, along a coast line not yet established in harmony with the currents, (but to which they were obliged, temporarily, to conform until they could work out their own natural boundaries,) assisted by a low sloping shore which the waves were incessantly impinging upon and cutting away, and where a few feet of subsidence might let the waters sweep inland for miles, cause a similar volume of wave-washed sand to be laid down in several beds and spread it out transversely for miles over the sinking and corroding shore, thus forming successively the Fourth and Third and Stray sands of that district, which altogether occupy only about the same vertical space that the solid Third sand does at Triumph.

Alternating changes in relative levels of land and water.

§ 440. There seems to be no plausible way of accounting for the alternations of sandstones and shales piled up one over the other all through the oil and coal measures, except on the hypothesis that many changes in the relative levels of land and water occurred during the periods in which these rocks were being deposited. Whether these changes were caused solely by the rising or sinking of the land while the ocean level remained constant, or whether the ocean level has been periodically affected by cosmic causes as some astronomers and geologists have claimed, or has fluctuated at different times by reason of sub-marine elevations or depressions of large tracts of its deep water bed in distant parts of the globe, is immaterial to our discussion. The effect, if the oscillations were uniform throughout the oil district would be the same in either case; we may, therefore, speak as if it were only the land levels that changed.

The evidences of these elevations and depressions as recorded in the rocks, indicate that they were quite irregular both as to the periods of their occurrence and the methods of their accomplishment. Sometimes they appear to have been slow, uniform and inconsiderable in vertical range, making but slight alterations in relative positions of sea and land; at others quick and grand rising or falling hundreds of feet at a throe, and completely obliterating or confusedly obscuring all traces of their previously existing geographical relations. In the former case they seem to have occurred consecutively in regularly alternating sequence, in the latter they were intermittent being interrupted by long periods of comparative repose.

By this oscillating method of deposition it is clearly to be seen that we should have two lines of shore deposits; one made when the land was at its highest elevation, the *lower* shore-line along the base of the recently uplifted mainland; the other made when the land was at its lowest level, the *upper* shore-line, laid down along the face of the sunken mainland hills 100′, 500′ or 1000′ as the case might be, above the former beach—according to the amount of depression suffered by the land. It is also evident that so long as these oscillations continued, no deposits could be *permanently* laid down, except those that remained below the water at its *lowest* stages, for all the upper, inland deposits would be exposed to sub-aerial erosion whenever a recession of the waters occurred. In this way an unlimited supply of loose materials derived from these unconsolidated upland deposits was always at command though the constant action of inflowing streams, for the rapid building up of the permanent formations at low water levels.

There can be little doubt that our oil sands are simply the *re-arranged materials of other ancient shore deposits*, which have been wrought over many times in this manner, without having been previously consolidated into rock. The pebbles and sand have not been brought down *direct* from their place of origin, broken up, triturated, assorted and deposited where we now find them, by the currents of a single period; but they have *traveled by stages*, as it were, and made many a *halt along the sandy beaches of previously existing seas.*

We said above that no *permanent* deposit could be laid down except at low water level, but it may have happened that some portions of the mountain or high water beaches were so situated in relation to the agencies of sub-aerial erosion as to escape destruction; in which case patches of them might remain almost intact during the interval required for filling up the basin below, and when by subsidence they were brought down to the horizon of low water or permanent deposits they might be incorporated with very little alteration into the then forming strata. Where such an occurrence happened, there would be an apparent exception to the well established geological rule that the sequence of sedimentation is always upward, from the older to the newer; and if the rocks chanced to carry fossils purely distinctive of their age some confusion, palæontologically might arise, for here would be an older rock, lying in the horizon of the new and apparently stratigraphically the same as those of the horizon in which it was found.

It seems quite probable that a composite stratification of this kind has occurred in several places in northwestern Pennsylvania, where occasional beds of massive sandstone and conglomerate are found, which cannot be correlated with any of the continuous sand-belts of the country. They have every appearance of being nothing more than fragmentary patches—the isolated remnants of some old mountain beach.

Structural variations in sandrock due to varying physical agencies of deposition.

§ 441. The structure of a sandrock formed under the conditions above alluded to, would depend very much upon the details of the movements accompanying the changing levels of land and sea—whether the oscillations were regular or intermittent as to time, quick or slow as to motion, great or small as to vertical range. Let us see what some possible combinations of these several circumstances would result in.

First, suppose the levels to have remained constant, or to have varied only a few feet for a long period. Where the conditions were favorable, long stretches of sandy beaches have accumulated, with bays in many places between them and the main land, as seen at the present day all along our ocean coasts. Deltas have formed at the confluence of rivers with ocean. The mechanical sediments have been sifted and assorted, arranged and re-arranged by tides and currents, by winds and storms, and perhaps they have been further wrought upon, also, by tidal waves, occasioned by earthquakes at a distance; but the materials are all arranged in lines, rudely parallel with the average trend of the shore or of the currents depositing them. If now a rapid and considerable subsidence of the land occurs allowing the ocean to flow far inland, and this be followed by another period of comparative rest, the old sea-beaches will be deeply covered with water, and receive above them the off-shore muddy deposits brought into the newly outlined basin, without involving any material change in their position or structure, except, perhaps, a leveling off of some of the uneven surfaces as the rising waters sweep over them.

The buried deposit might be described as consisting of (1) a rather narrow and somewhat continuous main-belt of sand, containing lenticular patches of coarse gravel, flanked seaward by finer and more uniform sand, gradually becoming argillaceous and finally merging into shale; (2) sand-bars at the river mouths containing more or less coarse material laid down in lines corresponding to the direction of the currents; (3) occasional coarse sandy deposits of the same character as the main belt, formed along the currents of the inlets, outlets, and channel-ways of the shallow land-locked bays and estuaries, and perhaps, also, in some places adjacent to the upland shores.

This structure seems to correspond with what the drill has developed in connection with the lowest or green oil member of the Venango group.

For another example, suppose the land to be slowly rising. The sandy beaches are drawn out and widened along the gently sloping shore, as the waters recede, leaving long parallel lines of hills and ridges exposed to the action of atmospheric agencies, ponds with connecting drains are formed among them; these depressions are occasionally overflowed by unusually high tides, and become the receptacles for seaweed, mud and the wind-driven sand and dust of the beach which eventually accumulate to a considerable thickness; a rise of say thirty feet along a shore of this character, sloping seaward at the rate of eight or ten feet per mile, might thus widen out one of these beaches three or four miles. Now let the motion be reversed and the waters again slowly encroach upon the land. The last made sand ridge is driven back land-ward, filling up all the inequalities of the beach, covering the mud deposits in pond and creek with sand, and the water line sweeping onward leaves behind it a perfectly even floor to receive the muddy deep-water deposits, when it has sunken to a sufficient depth to retain them.

The structure of this rock would be similar to that of the chief oil producing rock of Clarion county, the third sand belt of Butler, and the stray sand of the old Venango district. The sand or pebble drifts lie in approximately parallel belts in some places over wide areas, they are irregular in thickness, sometimes in one member and sometimes in two or more, the splitting being occasioned, we may suppose, by the mud deposits in pond and creek which were subsequently covered with sand. A well drilled through one of the original sand hills finds a continuous sandrock, while one driven down through an old pond site encounters a variable sand with "mud veins" and interstratified shales.

Many other possible and very probable combinations of the varying agencies of sedimentary deposition might be imagined, but combine them as we may and study their effects under every possible combination as best we can, and still we shall find many extraordinary features in the structure of the oil sands which might be as plausibly accounted for under the deep sea-current hypothesis as by the shore-line theory.

CHAPTER XXIV.

Crevices in the Sandrock. Are they essential to a paying oil well?

§ 442. During the early years of petroleum development, the theory of oil rock crevices obtained great currency, not only among well-drillers and well-owners, but also among geologists, who examined and reported upon the the underground structure of the oil country. It was the popular belief that a fissure must be struck in the oil sand or a well would be a failure. Entertaining this idea, the driller, upon reaching the sand, was constantly on the alert to find a crevice; and if he happened to get a good well, he always remembered that at a certain spot the drill dropped, and his judgment of the distance it fell would now, of course, be influenced somewhat by the production of the well. As a consequence, we have had crevices reported all the way from one inch to three feet in depth. It was not to be wondered at, perhaps, if the driller did find crevices, when the geologist told him they ought to be there and his employer considered them essential to a paying well. Neither was it surprising that those who had never seen an oil well should freely accept the opinions of those who were supposed to understand the subject thoroughly.

§ 443. *Crevice searcher.*—The crevice furor finally became so prevalent that an instrument was devised and patented, called a "crevice searcher." It was lowered into a well by means of poles like sucker-rods, and designed to indicate how many, where located, and how deep were the crevices in the oil sands. The cylindrical body of the "searcher," which was about two feet long, nearly filled the bore-hole. In lowering it, whenever a crevice was reached a little finger about an inch long, (which was kept pressed out against the wall of the well by a spring) snapped out into the opening and checked the downward movement. Then by raising the rods until the finger struck the top of the crevice, its exact measurement could be obtained. When this was done and the depth recorded, the finger was drawn back by a cord running up along the rods to the well mouth, thus unlocking the instrument from the crevice and allowing it to be lowered until another one was found.

This was an excellent device for measuring the depth of a well, for the rods were accurately marked in feet and inches, and there could be no stretch or slack to mislead, as in the case of measurements made by rope or wire. For several years it must have been the source of considerable revenue to its owners, as it was largely employed at a charge of thirty dollars for an insertion, to ascertain the most favorable point at which to explode a torpedo, when the original driller's record had been lost or could not be relied upon. The operators of the machine became so proficient in its use that they claimed to be able to tell the difference between shale, slate and sandstone, by the sound and jar communicated through the rods at the well mouth, as the finger scratched against the changing strata in descending. But however this may have been, it is plainly seen that the snapping out of a catch or finger into a recess in the well-wall was no proof of a *crevice.* A rough spot occasioned by a spalling of the rock while drilling, would allow the catch to comport itself precisely as it would in a crevice. There was nothing to show whether the stoppage was occasioned by a crevice or a rough spot; whether the cavity extended half an inch back from the wall, or half a mile.

Since the introduction of the plan of drilling wells dry, that is through large casing which prevents the surface waters from entering the hole, this device has gone into disuse. Since that time too, crevices are not so much talked about. This method of drilling enables the well-borer to tell just how his work advances, for there is no water in the hole to buoy up and obscure the action of the tools, or to hold back the gas and oil when their reservoirs are penetrated. And now, the driller, having discovered that large wells can be obtained in porous sandstone without any discoverable fissures, will tell you that crevices in the oil rocks, especially where they lie deep below the surface, are of rare occurrence, and may be considered as exceptions to the general rule.

Crevices in the Upper Sands.

§ 444. But this subject of fissures and crevices should not be treated flippantly or dismissed summarily, whatever may have been the extreme notions of fifteen years ago. It demands a careful consideration. That crevices or vertical fissures do ramify through all our *surface sandstones*, is plainly manifest. We see them in every quarry that is opened, in nearly every water-well that is blasted into sandrock.

They are encountered in many oil wells where a sandrock lies near the surface, particularly where shafts are located on the top of an escarpment along a stream, or on a hog-back between two ravines, and are often the fruitful source of a great deal of annoyance and expense to the well sinker. They are seldom found to be absolutely vertical; their walls may stand apart a few inches or a foot or more; their faces are often oxydized and hardened almost like iron;—where the auger strikes into one, it will glance and follow the lead in spite of the most judicious management of the workmen, and result in a "crooked hole." Sometimes torpedoes are exploded in the crevice in hopes of fracturing the face of the rock, so that the hole may be straightened. Large quantities of broken stone are then thrown in and rammed down to fill the hole and crevice to the top of the rock where the trouble occurs; wings or guides are put on the tools to keep them plumb and steady in the perfect hole above; but all to no purpose—the drill still glances and follows the inclined face of the rock. The only remedy now is to abandon the shaft, move the rig a few feet, and commence anew. In all probability no difficulty whatever will be experienced in sinking the second well through the creviced rock.

§ 445. *Smaller crevices containing fresh water* are frequently found below the surface or bluff sand. As the *Mountain sand group* is generally composed of several arenaceous and sometimes pebbly bands, interstratified with slates and shales, the drill may penetrate a water-crevice in an upper stratum, and afterwards another in a lower. If the lower one be connected with a free outlet, the water from the upper one falls down and is carried off by it, thus draining the upper rock and creating a waterfall in the well which can be plainly heard in the derrick and clearly seen by lowering a candle in the hole. Many instances have occurred where valuable never failing springs and wells fed from an upper stratum, have been almost instantly dried up and ruined by the striking of a lower crevice of this kind in an oil well in the neighborhood. It is not always, however, the *nearest* boring that taps a spring or well, but the one that happens to strike the same water lead in the rock. The points of interference are sometimes one hundred rods apart.

§ 446. *In every new oil development on high ground*, one of the first effects noticed is a diminution in quantity or a total failure of the normal water supply in springs and wells. The shallow wells of the country, dug only to the first sand beneath the surface, soon fail, and a permanent supply of water can now be obtained only from sandrocks lying at a lower horizon. It then becomes necessary also to drill wells to furnish the water required for the purposes of steam. These holes are drilled in the derrick, about three feet from the oil well and are usually from 200 to 300 feet deep, (see Plate XIV.) They sometimes go dry, however, for when the deep oil hole is opened below the level of the sandrock supplying them with water, the fluid may flow into it, follow on down and pass out through a lower rock as mentioned above. The remedy in such cases is to drill the water well deep into the slates or shales below the sandrock so that it may have a pocket to collect and hold the water coming into it. There are seldom any fissures or water courses in these compact shales to furnish a communication from one well to the other, although they are generally only about three feet apart.

§ 447. *Below the fresh water-bearing rocks* the crevices are quite infrequent and smaller, as a general rule. Still there appear to be localities, where, judging from the heavy flows of salt water, quite extensive fissures exist in some of the lower sandstones, as at Pittsburgh, Sharpsburg and other places which might be mentioned. When the flow of salt water is not so copious and is accompanied by a large amount of gas, it may be inferred that there are sufficient avenues for its inflow through the porous sandstone without requiring the aid of crevices.

Occasional fissures in the oil sands, but no communication between the different members of the group.

§ 448. *In the oil rocks* it seems quite probable that in some localities and under certain conditions, *fissures do exist.* Several instances have been known where one oil well interfered with another in such a way that the accompanying phenomena could not be satisfactorily explained on any other hypothesis. But these occurrences are comparatively rare, and may be said to be confined to isolated areas of the rocks. The principal points where these crevices are reported, are in the Venango district, where the drilling is the shallowest;—at Tidioute, in Warren county, the rock lying about 100 feet below the river; on Oil creek, depth about 450 feet; near Franklin (in First sand), from 200 feet to 300 feet. In the hill wells of Venango district, which are from 800′ to 900′ deep, and in the 1500′ wells of Butler county, crevices in the oil rocks are very seldom reported, and when they are there is always a shadow of doubt resting upon the authenticity of the record.

§ 449. It is also quite apparent that the fissures belonging to one stratum or member of a sandstone group are not connected with those of another stratum above or below it. For instance, in the vicinity of the Noble well, on Oil creek, where these connecting crevices seem undoubtedly to exist, as shown by the action of the wells, confirmed also by the drillers' report of crevices struck while drilling, the stray *Third sand* and regular *Third sand* are separated by only about twenty feet of shaly slates; still the *Third sand* produces the typical *green* oil, and the *Stray*, (when productive), the typical *black* oil, showing quite conclusively that there can be no direct crevice connection between the two strata.

Crevices more numerous in the upper sands than in the lower.

§ 450 Reviewing the subject, then, we find the upper sandstones much more frequently and extensively fissured than the lower ones, and containing fresh water; the middle series occasionally fractured and producing salt water; the lower series seldom fractured, and containing salt water and oil.

But the terms upper, middle, and lower, are not fixed terms, as here applied. The upper sandstones of Butler county have no existence in the high Pleasantville district of Venango county; the upper sandstones of Pleasantville are wanting in the valley wells at Tidioute, in Warren county. This is due to the gradual rise of the whole mass of rocks going northeast from Butler, by which the higher strata crop out successively and terminate, one after the other, on the hilltops in that direction.

As a result of this, the upper or fresh water rocks at Tidioute embrace all the measures from the *Second Mountain sand*, capping the hilltops, down to and including the *First oil sand*, while in Butler county these strata bear only salt water, and in intermediate places the bottom of the fresh water series is in some cases the *Second Mountain sand*, and in others the *Pithole grit*. The lower fresh water sands of Tidioute yield salt water at Pleasantville, and going higher up in the series the Pleasantville fresh water sands are in turn found to be charged with salt water in Butler and Clarion. Thus we see that these sandstones, which all, no doubt, at some time contained salt water, have experienced radical changes in their water-bearing attributes, according to the several conditions in which they have been placed since their uplift from the ocean bed.

The facts recited above point plainly to the conclusion that the surface sandstones have been more fractured and disturbed than those lying at a greater depth; and that wherever the position of a bed offers an opportunity for it to be affected by atmospheric agencies, or traversed by water from the surface, it has been so thoroughly washed by the percolation of rain-water that no trace remains of the saline materials it formerly contained.

Porous Sandstone as a reservoir and channel for large flows of oil.

§ 451. *Some oil producers stoutly maintain* that a flowing well of one, two, or three thousand barrels per day cannot be obtained unless a crevice is struck; that a sandrock, however porous it may be, cannot afford a sufficient channel for so large a quantity of fluid to come into a well.

If we examine a piece of oil rock brought up after a torpedo has been exploded, or some of the Third sandstone taken by hand from the stratum in place and laid open to view at the bottom of the large oil-shaft sunk by blasting, at Tidioute, we shall find it simply a conglomerate of pebbles seldom larger than grains of wheat, loosely held together in a sandy matrix. At first sight it hardly seems possible for any large quantity of oil to pass into a well through the interstices between the pebbles, but experiments made in a crude way on a number of pieces of this oil rock, prove quite conclusively that it is capable of absorbing and holding from *one-fifteenth to one-tenth of its own bulk of water or oil;* this, too, when the pores of the rock are more or less clogged with residuum from the oil previously held by it, and without its being charged under pressure.

§ 452. *The diameter of an ordinary oil well being* $5\frac{1}{2}''$ the circumference of the circle is therefore $17\frac{28}{100}$ inches and the area of its cross section $23\frac{76}{100}$ square inches. Suppose the interspaces of the oil rock to amount in proportion to its whole bulk, to only one-seventeenth, instead of one-fifteenth, or one-tenth, as we have ascertained it to be in some cases; then for every inch of depth drilled in an oil sand, by which $17\frac{28}{100}$ square inches of its surface is laid bare, (saying nothing about the bottom area of the hole,) we shall have at least one square inch of oil ducts, venting into the well. A depth then of $23\frac{76}{100}$ inches would give $23\frac{76}{100}$ square inches as the combined area of the inflowing oil leads, and this equals the full capacity of the 5½ inch hole. In other words the aggregate sum of the pores or interspaces of a sandrock of this kind, as exposed in the walls of a well of 5½ inches diameter, is equivalent to the area of an open *crevice one inch wide, extending from top to bottom of the gravel bed*, whatever its thickness may be.

No account is here made of the friction encountered by the oil in passing through the thousands of pores in the sandstone, nor of the compensating force of gas impelling the oil under a tremendous pressure through them.

This imperfect calculation is not intended to show *just how much* oil a porous rock could deliver, but simply to exhibit the *possibilities* of a flow through and from it, equal even to the full capacity of the well-bore. When there is from five to ten feet of this kind of rock to drill through, it can readily be seen that a flow of three or four thousand barrels per day might easily be maintained through the operation of these numerous oil leads, making ample allowance for friction and all other contingencies, without requiring the aid of crevices to convey the oil into the well.

§ 453. *There are others who imagine that the oil lies in a series of lakes or caverns* connected together by underground streams and sometimes receiving supplies from long distances. Otherwise, they affirm, individual wells could not produce so largely as some have done, nor could farms and districts have such an immense amount of oil stored beneath them as has been extracted from some localities, particularly along Oil creek.

In answer to this idea we append a few figures below, which will afford the means of readily calculating the possible capacity of a porous sandstone, and any one who will take the trouble to study and apply them will perceive that "*lakes of oil*" may be stored in a sandstone 30′, 50′ or 100′ in thickness without the intervention of extensive caverns or fissures.

Superficial quantities.

43.560 square feet in an acre.
27.878.400 square feet in a square mile.
6.272.640 square inches in an acre.
4.014.489.600 square inches in a square mile.

Cubical quantities.

9.702 cubic inches in a barrel of 42 gallons.
$5.\frac{6146}{10000}$ “ feet “ “ “

Production of oil per acre.

$646\frac{53}{100}$ barrels if the sheet of oil be 1 inch deep.
$1293\frac{06}{100}$ “ “ “ 2 “
$1939\frac{59}{100}$ “ “ “ 3 “
$4.997\frac{68}{100}$ “ “ “ $7\frac{73}{100}$ “

Production of oil per square mile.

$414.779\frac{65}{100}$ barrels if the sheet of oil be 1 inch deep.
$827.559\frac{30}{100}$ “ “ “ 2 “
$1.241.338\frac{95}{100}$ “ “ “ 3 “
$3.198.515\frac{20}{100}$ “ “ “ $7\frac{73}{100}$ “

§ 454. We have said above that experiments made in a crude way indicate that an oil sand may contain as much as *one tenth of its bulk in oil.* There can be little doubt, however, that a good rock in its normal condition and under pressure might hold an equivalent of *one-eighth.* This would be equal to a solid sheet of oil one and a half inches in thickness in every vertical foot of good oil sand, or nearly 1000 barrels per acre. On Oil creek there is generally from 30′ to 50′ of *Third sand*, and also from 15′ to 30′ of *Stray sand*, both locally producing oil. Of this total, suppose only 15′ is good oil-bearing pebble; we shall then have a producing capacity of 15,000 barrels per acre, or 9,600,000 barrels per square mile, which is adequate to the requirements of the most exceptional cases known.

Nothing need be said of small wells and moderately productive districts, for there is no difficulty whatever in discovering ample storage-room in porous sandstones of very inferior quality for all the oil that may be obtained from them.

§ 455. The above remarks having been confined exclusively to the *Venango Oil Group* and strata above it, the question may be asked, do the same conditions exist in the Warren and Bradford oil-fields? To a certain extent they undoubtedly do. But nearly all the valleys of the last named sections are cut down into the Chemung formation; consequently the sandstones of the *Lower District* only appear in the high land and ridges of the *Upper District*, and those which are the most prominent belong principally to the Mountain sand series. These form "rock cities" on the hilltops, are creviced and broken in a manner similar to those of Venango and Butler, and frequently perplex the driller with similar difficulties. So far, there is no point of difference to be noted. But the characteristics of the principal oil-producing sands of the three districts are entirely dissimilar. The Venango *Third sand* is a coarse pebble-rock associated with a clean white sand; the "*Warren Third sand*" is fine-grained, bluish-grey, and somewhat muddy; the "*Bradford Third sand*" is of medium grain, friable, but sometimes almost floury and of a decided brown or snuff color.

Still, while these sands differ so notably in composition, texture and color, and while they differ also in the character and color of the oils produced, there is nothing in the action of the wells, as far as I can discover, to warrant the inference that crevices are more frequent in one stratum than another.

§ 456. *But the measures above the Warren and Bradford "Third sands"* have produced considerable "shale or slush oil," which may perhaps be attributed to a fissured condition of these rocks.

At North Warren oil is obtained irregularly in shale or sandstone, and at very variable depths; one well may find it in shale at 300 feet, the next one in sandstone at 600 feet, and others in the immediate vicinity at almost any intermediate point. The character of the shales, the variability of the points of inflow, and the action of the wells, which start off at the rate of two or three hundred barrels per day and soon dwindle down to ten barrels, lead to the inference that the oil lies in crevices. As far as known, however, these conditions exist over but a limited area, and are undoubtedly due to comparatively local causes, not at present sufficiently understood to be satisfactorily explained.

§ 457. *In the Bradford* district "slush oil" is also obtained in some localities under conditions very similar to those above described, and it is furthermore claimed that on the "Tuna flats," in the neighborhood of State line, wells but a few rods apart strike oil in rocks below the "*Third sand*" at unequal distances, and in such an unusual manner that the occurrence can only be accounted for on the supposition that the rocks at that horizon and in that locality are fissured in an exceptionable manner.

CHAPTER XXV.

(Illustrated by Plate XXXV.)

"Flooded territory." How water invades the sandrock to the exclusion of oil and gas. A review of some of the circumstances attending its occurrence.

§ 458. As a general rule, the first oil wells in a prolific district produce but little salt water with the oil, unless they are located in shallow territory where the oil rock lies in such a position as to be somewhat affected by communication with the surface. The movement of water through the oil sands, called "*flooding*," is an abnormal condition following development, and occurs only after the oil has been partially exhausted from the rock. It may always be attributed to the letting down of surface water through abandoned well-shafts—no precautions having been taken when wells were dismantled, to effectually shut off all communication between the upper, or water bearing rocks, and the oil sands; either by filling up the lower part of deserted wells with sand and sediment; or by inserting wooden plugs in the borings, below the horizon of fresh water veins.

Now as the partial drainage of a district must first be accomplished before it can suffer from the effects of flooding, and as a structure of sandrock which facilitates a rapid delivery of oil affords a correspondingly free medium for the reception and onward movement of water, we may very properly in a consideration of the subject of flooding, commence with a "*pool*" of oil in its normal state and follow it through all of its changes until finally invaded and destroyed by water.

§ 459. *The word "pool"* has been rather arbitrarily pressed into service in this connection. It is an oil miner's term intended to convey the idea of a body of oil stored in the porous portions of a sandrock and practically independent of other pools or deposits of the same character:—thus he speaks of the Pithole pool, the Cashup pool, the Church run pool, &c. It is also used in a more restricted sense to designate rich spots in the same district which may have some slight connection with each other—as the United States well pool; the Homestead well pool; the Burtis well pool—all near together and within the great Pithole pool, but having small wells or dry holes between them.

§ 460. It is a fact well established by experience, that the pioneer wells of any district, if drilled within the possible limits of a productive pool, are more certain to prove remunerative than those put down at a later date after the field has been fairly developed—although the latter may be sunken through a sandstone of better quality than the former; and the reason of this is obvious if our theory of the physical structure of the oil sand be correct.

Suppose a lenticular deposit of pebble rock stored with oil, to lie embeded in fine argillaceous and almost impervious sandstone which completely isolates it from other deposits of similar character lying perhaps but a short distance from it. In this shape it is practically an hermetically sealed oil tank full of oil and gas, under a tension not susceptible of precise calculation, but which, judging from the effects observed when the pool is tapped, may be 300 pounds or more to the square inch. The first well piercing this deposit, although it may only touch the extreme thin edge of it, will have a large reservoir to draw from, and a tremendous pressure of gas to assist and augment its delivery; whereas one put down after the bulk of oil has been extracted and the pressure reduced to two or three atmospheres, receives but sluggish streams of oil and feeble gas aid, even if it passes through a much greater thickness of oil bearing rock, and cannot therefore yield so largely.

Those who still adhere to the old notions of crevices and fissures ramifying through all the measures, with free circulation of fluids through them, will object to this hypothesis of sealed reservoirs. But we submit that in view of the many facts cited in these pages, which harmonize with such a conclusion, the inference that they do exist, practically, is not an unreasonable one, even if the proofs of it do not amount to actual demonstration.

§ 461. *Geologically speaking as to time*, there is no doubt a slow process of circulation through all the measures; for nature is ever active and on the alert to restore any disturbance of an equilibrium. But practically, during the short time they are being drained, the oil pools are sealed reservoirs.

A thoroughly drilled district partially deprived of its oil and relieved from excessive gas pressure, will undoubtedly be again supplied and filled with water, oil, or gas from the contiguous rocks, until the equilibrium is restored—for "nature abhors a vacuum"—but this re-filling would be a slow process, were it not for numerous free passages opened by the drill, through which surface water may find access into the oil rock. The manner in which the intruding currents deport themselves, will be seen to be, as we proceed, a strong argument in favor of the inferred discontinuity and isolation of the pebble deposits of different districts.

§ 462. *The first wells to tap a new pool of oil have more vitality than those which follow*, but these wells do not always happen to be on the best part of the rock. For instance, *National well No. 1*, situated within a few rods of No. 2, (II, No. 57.) was struck in February, 1866. It was very near the northwesterly edge of a large and well stored pool, and passed through rather an inferior oil rock, as compared with that afterwards found on the axis of the belt. Still it had a sufficiently free connection with the supplying reservoir to furnish a delivery of about 85 barrels per day, and it maintained its production with wonderful constancy for two years, having only declined to about 60 barrels in that time. In the summer of 1868 wells were drilled on the center of the deposit from which it had been deriving its supply. Some of these wells produced as much as 150 barrels per day. The effect on the *National* was immediately apparent. Its production dropped off rapidly and dwindled down to 10 barrels or less per day.

§ 463. *Rock well No. 1*, (II, No. 359,) in the same neighborhood, but on the opposite (south) side of the pool, had a similar history although it never was so large a producer as the *National*.

A few rods north of *National No. 1*, a fine, close rock with very little oil was obtained in drilling other wells. In wells a few rods south of Rock well similar features prevailed, but a number of other pools, not directly connected with this one came in at intervals to the southeast between it and Pithole city.

§ 464. *Harmonial well No. 1*, (II, No. 24,) was on the thinning northerly edge of the Pleasantville belt. The main body of oil and the best sandrock as afterwards demonstrated, lay to the south. It started with a small yield and at the end of a fortnight was pumping about 30 barrels per day. Gradually increasing its production, as if enlarging and cleaning out the passages leading into the supplying reservoir, it finally commenced to flow and ran up to 125 barrels, where it remained until wells of larger flow were drilled on the center of the belt and relieved the gas pressure, when pumping had to be resumed. After this it soon fell down to an unremunerative production and was abandoned.

§ 465. *Nettleton well No. 1*, (II, No. 8,) another edge well furnishes a similar history. It maintained a comparatively steady production for two years, but quickly succumbed when the center of the pool was attacked.

§ 466. *Holmes and Brown well No. 1, Cashup*, (II, No. 981,) may be referred to as another example of the comportment of these edge wells.

§ 467. *Scores of similar references could be given*, but these are ample to show that where direct communication does exist through the porous sand rock or through crevices it is soon made manifest in the action of the wells. Therefore the inference is, that if the oil deposits do not lie in practically disconnected pools as above suggested, we should not from year to year find new oil fields within short distances of exhausted areas, lying under a normal pressure of gas and not having been sensibly affected in any manner by the depletion of contiguous territory.

If but a small communication exist between two reservoirs each filled with oil and gas under a pressure of from 100 to 300 lbs. to the square inch, and the pressure in one of them be reduced to a point within three pounds of an absolute vacuum, (as has been done by the agency of gas pumps at Triumph in Warren county and elsewhere,) it would seem that at least a partial restoration of an equilibrium ought to be effected within two or three years' time, even if a considerable distance intervened between them.

§ 468. *Pithole was practically exhausted in 1867.* Yet Cashup, only two miles to the northeast, lay undiscovered until 1871. When the latter district was tapped it exhibited all the normal conditions of new territory, a tremendous pressure of gas and an abundance of lively oil which attested their energy and force by a well flowing over 1000 barrels per day.

§ 469. *Shamburg was discovered* several years after the Oil creek rock had been practically drained and although not more than three miles from the world renowned *Noble well district*, no direct communication has ever been traced between the two oil fields.

§ 470. *Bullion the champion district of 1877*, lay with its wonderful store of oil and gas within a mile and a half of *Scrubgrass*, unaffected by the drainage and almost complete exhauston of the latter six or seven years before.

§ 471. *Butler and Clarion* are now constantly furnishing new pools outside of previously developed areas, which show no symptoms of having been interfered with or weakened by any of the previous operations.

Facts like these, (and many more might be given in detail were it necessary,) point strongly to the correctness of the inference that the oil producing pebble sands lie in pockets or patches so completely surrounded by an almost impervious rock, that practically they may be considered as independent masses and treated accordingly.

In conformity then with this view of the subject let us trace the history of one of these oil pools from its *first tapping by the drill to its final abandonment on account of becoming flooded with water.*

§ 472. *With the present method of drilling* through casing and thus preventing the surface water from following down to the lower rocks, the effect upon tapping the oil sand is quite different from what it was under the old process when the drill hole was full of water. In the latter case the column of water in a deep well held the gas and oil in check and but slight indications of oil would be seen until the well was tubed and a portion at least of the water pumped out. But now the hole having only a few feet of fluid in it when the sand rock is pierced, the effect is similar to the sudden liberation of the safety valve to a steam boiler under a full pressure of steam. The tremendously compressed gas and oil rush at once into the opening—the drill hole is soon filled—and when the depth of well is not too great in proportion to the force of gas, the boiling, foaming mass is driven upwards against the forces of gravity, against the resistance of the atmosphere, and vents at the well mouth or shoots high above the top of the derrick.

§ 473. *The date of the first flow from one of these pools* marks the commencement of a new era in its history. For ages the oil has been locked up in the pores of the rock, and there can be little doubt but that an equitable pressure has been established throughout every freely communicating portion of it. The equilibirum is now suddenly destroyed in the immediate vicinity of the well by the liberation of compressed gas and oil seeking a rapid exit through the drill hole, because the pressure in the rock is greater than the forces to be overcome by the oil in its ascent. The result is the rarification of the elastic and expansile materials filling the pores of the sand rock immediately surrounding the perforation made by the drill. Suppose the pressure in a radius of ten feet to be thus quickly reduced from 300 ℔s to the square inch to 150 ℔s, this allows the next concentric area proportionately to expand and reduce in like manner, and that the next and so on, the movement gradually widening, the pressure gradually reducing until all the freely communicating portions of the rock are relieved, when the oil for lack of propelling force ceases to flow. An equilibirum has been restored. The rock is still full of oil and gas under pressure, but it is counterbalanced by the weight of the column of fluid in the hole and the atmosphere above it.

§ 474. *The pump is now introduced,* and lifting the fluid from the level of the sand rock relieves it of a pressure equivalent to the weight of the oil in the hole and leaves the gas free to again go through with the expanding and rarefying processes as before, it having now to overcome only the weight of its own column of gas ascending between the tubing and well walls against atmospheric pressure.

After the introduction of the pump a generous flow centres toward the well, and this continues for a longer or shorter period, dependent in a great measure upon the number of wells at work in the immediate vicinity; but gradually in any case the pressure in the rock is relieved, it falls to 50 ℔s.—40 ℔s.—30 ℔s.—20 ℔s.; both oil and gas decreasing as the pressure decreases. When it lowers to 16 or 18 ℔s. very little gas can make its way to the surface; but still the rock contains an abundance of oil, for when a gas-pump is now attached to the casing-head to further relieve it of atmospheric pressure, the effect is quickly apparent, in an increase of both gas and oil. If the gas-pump be a good one we have by this means, in effect, added from 10 to 12 ℔s. pressure to the oil in the rock by relieving the gas from that amount of atmospheric opposition which it previously had to overcome. Still, after all this is done and the well chamber is so thoroughly exhausted by the gas pump that a vacuum gauge may show a downward pressure of 13 ℔s. to the square inch, the rock contains oil, as is proven by the manner in which it is further acted upon by the introduction of water into it.

§ 475. *Oil and gas in their normal conditions,* appear to lie in the sandrock not as distinct bodies occupying separate portions of the rock, but as one substance, the gas being as thoroughly incorporated with the oil, as gas is with water in a bottle of soda-water. Drawing oil from the rock may be compared to drawing beer from the barrel. The barrel is placed in the cellar and a bar pump inserted—at first the liquor flows freely through the tube without using the pump, but presently the gas weakens and the pump is called into requisition; and finally the gas pressure in the barrel becomes so weak that a vent hole must be made to admit atmospheric pressure before the barrel can be completely emptied even by the pump.

§ 476. *The flooding of an oil district is generally viewed as a great calamity*, yet it may be questioned whether a larger amount of oil can not be drawn from the rocks in that way than by any other, for it is certain that *all* the oil cannot be drawn from the reservoir without the admission of something to take its place.

If one company owned all the wells drawing upon a pool, and had accurate records of the depths and characteristics of the oil producing stratum in each well, it is quite possible that some system might be devised by which water could be let down through certain shafts, and the oil forced towards certain other shafts where the pumps were kept in motion, and thus the rocks be completely voided of oil and left full of water. As it is however, no systematized plan of action can be adopted. The careless handling of one well, by which water is let down to the oil rock, may spoil several others belonging to different parties. A clashing of interests at once arises and is likely to result in disaster to the whole district.

§ 477. *The early operators on Oil creek* knew nothing about "*casing*." Wells were drilled "*wet*" no effort being made to shut out the surface water; consequently when oil was struck, it met a static pressure of water corresponding to the depth of the well. In new and shallow territory the pressure in the rock was sufficient to hold the water in check and prevent it from entering the oil sand and sometimes it had force enough to eject a column of water from the hole and flow on steadily for some time in defiance of it. But as developments progressed and oil currents began to be diverted towards numerous outlets through pumping and flowing wells, it often very naturally occurred where the circumstances favored it, that this column of water in a well just completed would force itself into the oil sand, driving the oil before it, and quickly flood a neighboring well. When the new well was tubed and seed-bagged it frequently took several days pumping to relieve the sandrock of the water thus forced into it, and regain the oil. These troubles increased more and more as territory became older and the pressure of gas in the rock decreased through the removal of large bodies of oil. At that time the seed-bag which prevented the surface water from passing down, was affixed to the tubing, and any difficulty in the working chamber or valves which necessitated the withdrawal of the tubing, (and these contingencies occurred frequently,) involved the letting in again of the surface waters upon the oil rock. Frequent repetitions of this operation finally brought ruin not only on the well itself but on others in the vicinity. In the abandonment of a well thus spoilt, or of one which had been drilled and proved unproductive, no care was taken to prevent the water from entering the oil rock. Indeed it seemed to be a satisfaction to those who had been unsuccessful in their ventures, to spoil if possible the good wells of the more fortunate. From these causes it happened that nearly all the farms along oil creek were very much injured by water before the true situation of affairs was rightly understood.

§ 478. *Small casing ($3\frac{1}{4}''$) was first introduced in 1865.* This held the seed bag on its lower end and extended down below the fresh water veins, so that the tubing could be inserted inside of it and withdrawn at pleasure without letting in the water (see Plate XIV). Many of the old wells were then cased—the abandoned holes were filled up or stopped with a wooden plug above the oil sand to prevent the further admission of water—large pumps were set in motion to exhaust the water and after great expenditures and persistent effort some tracts were partially reclaimed and certain wells yielded oil freely, for a time. But conflicting interests and a want of coöperation among the many well owners prevented systematic work, the flood consequently again became unmanageable, and large areas of old oil territory were finally abandoned.

§ 479. *The manner in which water invades and takes possession of the oil sands*, has created a great deal of discussion among well owners and others. Some producers have imagined they so thoroughly understood the subject that they could go ahead and put down new wells or operate old ones in flooded territory, in such a way as to catch the oil driven before the water-wave and make a profitable business of it; but they have generally been convinced by experience if they persisted in their operations long enough, that success in this kind of oil producing might be attributed to chance quite as reasonably as to good judgment.

It is an easy thing to *theorize* as to how the water currents *might* conduct themselves, but quite another to show precisely how they *do* act, for we can only have, at best, a very imperfect knowledge of the constitution of the sand-rock, and therefore cannot foresee all the contingencies dependent upon details of structure, which may arise to thwart the most shrewd and judicious calculations.

§ 480. *In judging of the probable effects of the introduction of water* into any particular oil district several things are to be considered.

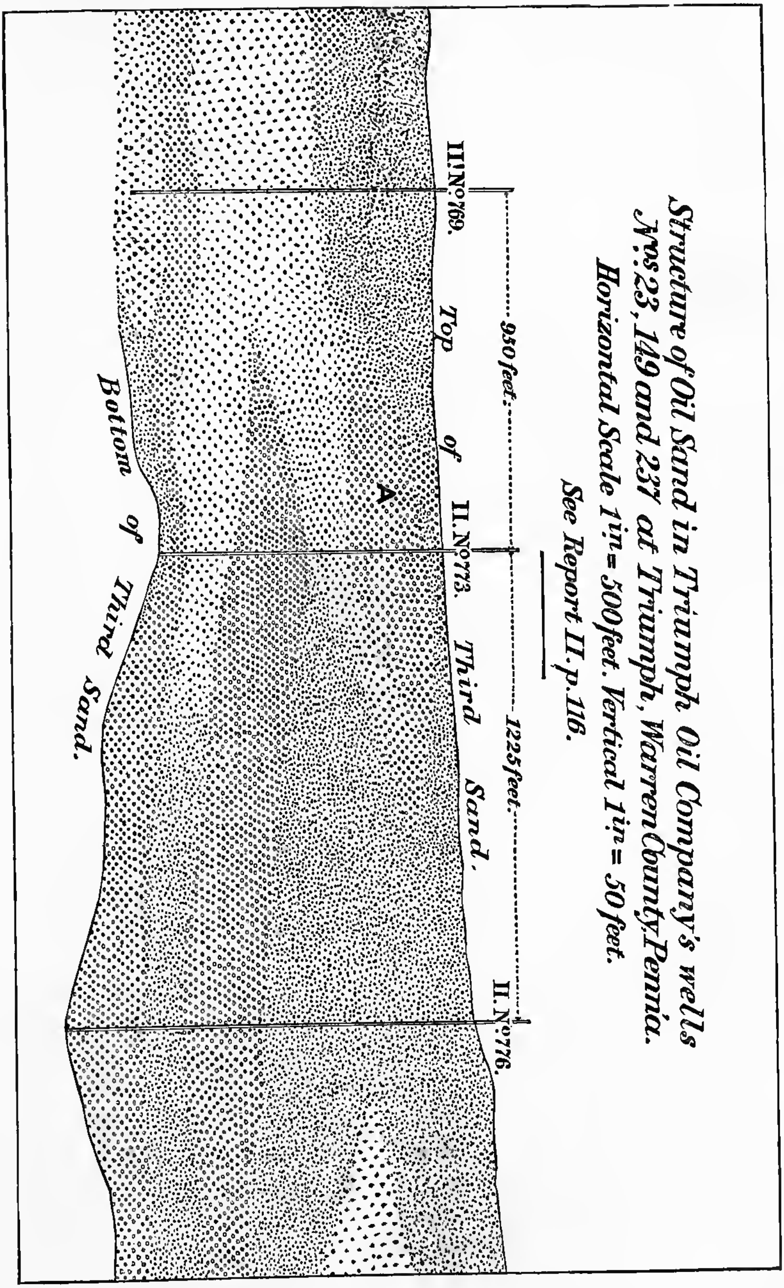
(1) *The time of flooding*—whether early in the progress of development, while yet a large percentage of oil remains unexhausted, or at a later period after the supply has suffered from long continued depletion. (2) *The structure of the rock*—whether regular and homogeneous throughout, or composed of fine sand interbedding connected and irregular layers of gravel, sometimes lying near the top and at others near the bottom. (3) *The shape of the area being flooded.* (4) The position of *the point at which water is admitted*, in relation to the location of the surrounding wells still pumping oil (5) *The height* (which governs the pressure) *of the column of water* obtaining admittance. (6) *The duration of the water supply.*

It will readily be seen that a *temporary flooding* in comparatively *fresh territory*, such as frequently occurred in early days along Oil creek from the drilling of new wells without casing or the overhauling of old ones where the seed bag was attached to the tubing in the primitive way, must necessarily be quite a different affair from one caused by a *permanent deluge* through unplugged and abandoned wells in *nearly exhausted territory.*

In the former case the flood may be checked before much water has accumulated in the rock, and then the oil flow can be reclaimed after a few days of persistent pumping; in the latter the recovery of oil is very uncertain, because from its long continued extraction a greater capacity has been given to the rocks for storing water, and this being supplied from scattered and obscure sources, there is little probability that it can be shut off, although the most thorough and systematic attempts may be made to check it.

§ 481. *A good illustration of the action of a temporary flood* in comparatively new territory was furnished years ago by a well on Oil creek. It was drilled in close proximity to large producing wells, and seems to have pierced the oil rock at a point where the water let in by drilling and overhauling surrounding wells had accumulated to the exclusion of the oil originally stored there as well as in other portions of the rock. On starting the pump nothing but water was obtained. Day after day the machinery was kept in motion, but no improvement appeared. All but the owner rated the well as a total failure and he came to be looked upon as a man with a great deal of faith but very little judgment. The pumpers at adjoining wells delighted to annoy him and thought it a good joke to send every traveler who inquired for a drink of water, to the "water well" as they had named it. Still the owner kept pumping night and day, and at the end of six weeks the water exhausted, oil immediately appeared in large quantities and the well proved to be an exceptionally remunerative one. After flowing and pumping for a long time, however, I believe it again became flooded, when the surrounding territory had been nearly drained of oil, and much uncontrollable water had found access to the rock, and then a large amount of time and money were fruitlessly expended in trying to regain the oil.

§ 482. The following sketch (Plate XXXV) was made from the records of three oil wells at Triumph, Warren county: It probably exhibits the general structure of the oil sands not only at that point but in many other parts of the oil district, and it will serve to show on a small scale how the



Structure of Oil Sand in Triumph Oil Company's wells
Nos 23, 149 and 237 at Triumph, Warren County, Penna.
Horizontal Scale 1 in. = 500 feet. Vertical 1 in. = 50 feet.
See Report II. p. 116.

introduction of water at various points might affect the flow of oil in the several wells drawing from a deposit. In No. 773 a pocket of pebbles lies near the top of the rock, where only fine grained sand was found in Nos. 769 and 776. Suppose No. 773 had not been drilled until Nos. 769 and 776 had partially exhausted the oil and been abandoned, letting the water down into the oil sand. The heavy gravity of water would cause it to seek the lower portion of the pebble rock, thus lifting the oil and gas remaining in the rock and compressing them in the upper parts. Thus the pebble pocket A would be filled with oil and gas, for by reason of its high position and impervious surroundings it had no lateral escapes for its contents when the water line rose above a certain point. If the body of oil contained in A, when thus cut off from escape, had already been compressed to a sufficient degree to withstand the static pressure of the column of water operating upon it, the water could have no further effect, but must pass on to points of less resistance, but if they had not yet been sufficiently compressed, the water line would rise in the arched basin until the proper compression had been accomplished. If now, after the lower part of the rock has been flooded, well No. 773 be drilled, the pool of oil stored in pocket A will yield freely until it is exhausted and the water fills the rock, when it will be useless to expect a further supply.

§ 483. *When water is let down into the center of a district* which has been rapidly drilled and partially exhausted, at it was, for instance, at Pithole City in 1865, the effect must be to drive the oil remaining in the rock in all directions. Not only will it force *down the dip of the strata* (the direction which some assert it must always take), but up the dip also; for being supplied from sources several hundred feet above the oil-sand, a slight dip in it of 15 or 20 feet to the mile practically amounts to nothing. It must naturally travel the fastest *towards the points of least resistance.* If the district be an elongated one, with the pebble deposits lying in beds, as is usually the case, and a line of wells be pumping, up the dip, or above the point at which water is admitted, and none below, thus creating a draft in the up-dip direction, these higher wells will be attacked one after the other as the water wave advances, just as surely as if the conditions in relation to slope were reversed. But as the flood advances, and well after well is reached in succession and flooded, it must naturally sometimes happen that in consequence of the irregular structure and geographical outlines of the rock and the accidental locations of the wells drawing from the deposit, that stray marginal pools of oil will be forced out into the pebble pockets not yet drilled upon, and from which it can find no outlet, as illustrated in the preceding sketch.

§ 484. *Two or three such pools* containing a large amount of oil have been discovered on the outskirts of Pithole since the central district was flooded, and several others also bordering on Oil creek. That they were pools stored and held in place by the flooding of the central district, was shown by the fact that when oil failed in the first well, water immediately came in, and the wave followed on from well to well in regular succession, as if radiating from a central source.

§ 485. *The first intimation of the flooding of a district* is given by an increased production from the wells affected by it. Old wells, without any observable cause, improve gradually, running up from five barrels per day to ten or twenty, or even fifty. After pumping in this way for some time the oil quickly fails and they yield only a few barrels of salt or brackish water. As the wave moves on, the wells in advance, one after another, are affected in the same way. In some districts the movement is quite rapid, and wells are invaded and "watered out" in quick succession; in others it is so slow that large quantities of oil are obtained from those which are favorably located to receive a "benefit." Flooding a well is sometimes a very profitable way of closing up its career, inasmuch as it thus yields more in a few months than it otherwise would in years, and when the water reaches it the owner knows at once what it betokens and stops work, thus saving the time and money usually expended in fruitless efforts to reclaim a well failing through natural decline.

CHAPTER XXVI.

Origin of petroleum.—A chapter of queries.

§ 486. "*What is your theory concerning the formation of petroleum?*" is one of the first questions asked of the geologist when matters connected with the oil regions are mentioned, and the question is put as if it were one on a simple subject, surrounded by no obscure and perplexing conditions and therefore easily answered by any person who might be conversant with the general structure and characteristics of the rocks containing oil and the methods of its procurement.

A superficial or partial examination of the facts connected with its origin has led to the publication of various and conflicting theories regarding it. Many of these are evidently based upon insufficient hypothetical premises, and we apprehend that even the most plausible one of them now in vogue will need much modification as our knowledge on the subject becomes more comprehensive.

When we have discovered the place of its nativity, ascertained the horizon and conditions of its birth, obtained an approximate idea of its age, studied its constitution and habits, so to speak, and become in like manner familiar with its cognate associate gas, then we may possibly be able to propose a tenable theory to explain the genesis of petroleum. But at present, with all these points in dispute or ill understood, we must treat the question above propounded as one which may be discussed but cannot be satisfactorily answered.

§ 487. *There are many grades of petroleum* even in the comparatively thin band of Pennsylvania oil rocks. They may be readily distinguished one from the other by marked variations in gravity, color, smell, and the manner in which they are affected by heat and cold. Have they all one common origin or are they the products of different ages? Do they vary in composition and character because of the stratigraphical position and chemical constituents of the several rocks in which they are stored, or do they vary on account of local peculiarities obtaining in successive ages, in the growth of the assemblages of marine flora and fauna from which they are supposed by some to have been derived?

§ 488. *If the originating organic matter* has been converted into oil at different periods during the earth's history, corresponding chronologically with the deposition of the sands in which the oils are found, what effect has this difference in time of birth had upon the character of the several oils since their generation?

In view of the universal law of mutability, to which both organic and inorganic matter is subject, the law of growth, or progressive development from generation to maturity, of decay, or gradual decomposition from maturity to dissolution, should we not expect to find certain distinguishing characteristics in the several oils, (if they were formed at widely separated periods of time,) from which some idea of their relative ages might be obtained?

But there are so many unknown factors involved in a solution of these problems that we must be content to work slowly and—wait.

§ 489. *The fundamental questions to be answered seem to be these:* From what *source* does petroleum originate and *when* was it formed? and a consideration of them involves a review of two of the most popular theories of the day, the one claiming that it has been elaborated by nature from materials contained *in the rock where it is now found*, that the oil producing rock is the parent rock; the other, that it is *the product of gas* originating in much deeper strata, the sandstones being merely condensing reservoirs for its storage.

There are strong arguments in support of both theories and they each have their earnest and distinguished advocates, but it is not an easy matter to prove either the one of them or the other to be universally applicable to facts as we find them. The probabilities are that we shall discover, when the subject is more thoroughly understood, that there is what might be called an indigenous oil in conformity to the one theory and an exotic oil in agreement with the other.

Genesis of petroleum in the sandrocks.

§ 490. Reviewing the facts connected with the production of oil from the Venango group, we find that the largest wells are those which are sunk through the coarsest part of the oil bearing sandrock. The drillings show nothing but coarse sand and pebbles. Pieces of the unpulverized rock one or two cubic inches in bulk are often brought up after torpedoing, but nothing can be detected in them that could possibly originate petroleum. Could a rock of this character have originally contained a quantity of organic matter sufficient to yield a cubic foot of oil to every ten or twelve cubic feet of rock, and these organic remains be so completely converted into oil as to leave no residual trace of their existence? Could so large a quantity of organic matter be held by such loose sands during the slow processes of their deposition, without decomposition and waste? and if so held, *when* was the organic tissue thus preserved converted into oil? It could not have been while the sands were lying at sea level as sand beaches exposed to atmospheric influences, for then the oil would have been volatilized and dissipated in air. Neither could it have been while the sands were in contact with the water, (if they were formed beneath water level,) for then the oil would have risen to the surface and floated away as fast as generated. It must have been then at a period subsequent to this.

But if no oil was stored in the sand beds as they slowly sank to receive the succeeding deposits upon their backs, the interspaces between the grains of sand and pebbles which now contain oil, must have been filled with salt water, for they could not go down unoccupied, and the sand-beds must also have contained within themselves large quantities of organic matter, which sooner or later, when the conditions became favorable, was to be converted into oil.

§ 491. What are the requisite conditions to convert this organic matter into oil? Presumably a certain degree of heat and pressure to be attained only when the strata have reached a proper depth below the surface or ocean level. At what depth this horizon which may be termed the plane of spontaneous distillation may lie, we do not know, and it is immaterial to our present purpose that it should be definitely fixed. Wherever it may be, however, it must be reached and occupied successively by each one of the oil producing sands in order that the organic matter from which the oil is to be evolved, may be subjected to the proper conditions and the transformation effected.

We will suppose that the *Venango Third oil sand* has gradually sunk as the sediments accumulated above it, until it has arrived at this oil making horizon. Spontaneous distillation now ensues. The salt water contained in the sand is partially absorbed or displaced in the process, and the stratum is charged with oil. But the measures still continue to sink and other rocks are deposited above; the *Second oil sand*, *First oil sand*, *Pithole grit*, *Seral Conglomerate* and *Mahoning sandstone*, must all, one after the other, have been brought down to the oil making horizon, according to this hypothesis—for they all now contain oil in one place or another.

The vertical distance between the *Third oil sand* and *Mahoning sandstone* as shown on generalized section Plate XI, is about 1550 ft. Therefore, when the *Mahoning sandstone* occupied the plane of spontaneous distillation, the *Third oil sand* must have been 1550 ft. below it, and subject, by reason of this additional depth, to a degree of heat much greater than that of the horizon in which the oil contained in it was formed.

§ 492. Supposing all the oils in the several sands to have been identical in character when first formed as they passed through the oil making horizon; must not that in the *Third sand* at least, have undergone a great change during the immense period occupied in slowly sinking 1550 ft. while the sand beds above it were being successively stored with oil—and especially so, when to the changes incident to age must also be added the changes wrought by chemical action under such altered conditions and so considerable an increase of temperature. Would not the increase of heat in deeper horizons have had a tendency to reduce the gravity of the oil, so that we should now find the *Third sand oil* heavier than that of the *Second*, and the *Second* heavier than the *First*, whereas we now find it in exactly the reverse order?

§ 493. The depth of sedimentary strata known to have been deposited above it, shows that the *Third oil sand* must have been at some time at least 3000 ft. below ocean level. It now lies at Tidioute 1000 ft. above this datum plane. How much deeper it may have sunk, or how much higher it may have been elevated, we do not know. If now the oil was formed during its descent while passing through the oil making horizon (and we can imagine no other point or time at which it could have been formed, according to the hypothesis under consideration) and the stratum after being charged with oil slowly sank 1550′ as argued above; then came up again, it may be slowly or it may be quickly, several thousand feet, who can imagine the changes the oil would be likely to undergo during all these varying circumstances of depression, elevation, temperature and time.

§ 494. And then what further mutations may be supposed to have taken place in such variable and volatile hydrocarbons as these during the long periods intervening between the post carboniferous uplift and the present time, while the sands containing them have been lying in various positions in relation to surface erosion, some of them being far above sea level and some below; having lost their original horizontality, and being in consequence, more or less affected in some localities, by underground drainage, local escapes of gas and oil at the surface and accessions of surface water.

We are hardly prepared to assign so great an age to petroleum as the above view of its formation would require; and yet, if it is generated in the sandrock, from organic matter intermixed and buried with the sand, we can imagine no more probable sequence of events than those outlined above, by which to arrive at some idea of its age and the possible horizon of its birth.

§ 495. So far we have spoken only of the *Venango oil sands and those above them;* and if we are already amazed at the immense age of their respective oil deposits, as measured by the theory under review—and are inclined to doubt whether oil could be preserved unchanged for such incalculable ages in rocks exposed to such vicissitudes as these have experienced, our amazement will only increase if we go on and apply the same line of argument to the *Oil measures of Warren and Bradford* which extend down more than 1000 ft. below them, and whose oils must therefore be *much older.*

§ 496. *Further;*—It is evident that an oil producing rock of the character we are speaking of, could only be formed by the conjoint action of two classes of widely differing physical agencies—one to furnish the organic matter, the other the inorganic. If only sand and pebbles were deposited in any place, they could make no oil. Sea weeds and mollusks must live and flourish in great abundance on the forming sand beds, or be within reach of the waves and currents to be brought in and deposited with them—otherwise the materials for generating oil would be wanting. It is reasonable to infer that these two necessary conditions did not everywhere conjointly prevail; that in some localities sand was deposited without organic matter and in others organic matter without sand; and that consequently we should now find considerable areas of sandrock barren of oil. In that case, no doubt, great irregularity would be noticed in the distribution of these barren spots throughout the oil producing sand sheets. Each stratum would have a structure in that respect peculiarily its own, regardless of the local variations of the one below it or the one above; but the same *general features* observed in the distribution of the productive and non-productive spots in one stratum, ought to obtain in the others also.

Thus if the *Third sand* produces oil almost universally wherever its characteristic oil bearing rock is found; then the *Second sand* should in like manner produce oil wherever *its* characteristic oil bearing rock is found; and so on with all the other oil sands above. Or, in other words, if oil is generated solely from materials deposited cotemporaneously with and contained in the rock where it is now found, there can be no reason assigned why there should not be good oil deposits, scattered over the whole area of one sand as well as of another, wherever the typical oil bearing rock is well developed, regardless of the measures above or below it; no reason why, all other things being equal, the *Conglomerate* and *Mountain sands* should not produce oil as freely where the *Venango group* lies below them as where it does not; no reason why the *First and Second oil sands* should not produce their normal quantities as well where underlaid by the *Third sand* as where the latter is wanting, or imperfect.

§ 497. Now what do we find the facts to be. Where the *Third sand* of the Venango group is well developed it almost universally contains oil in one or the other of its three or four divisions, and where these productive members spread over a wide area as they do in parts of Venango, Clarion and Butler counties, the sands above them, although they are frequently of excellent quality and exhibit every characteristic of the oil producing portions as found elsewhere, yield scarcely a show of oil. Yet the *Second sand* produces oil in large quantities in many places skirting the edges of the *Third sand*, where the latter is of inferior quality or wanting—the *First sand* produces oil in similar situations over an inferior *Second* and *Third sand*, or where one or both of them are wanting—the *Mountain sands* produce oil in some localities, but only where the Venango group in its integrity is wanting—all of which circumstances lead to the inference, that somehow, the absence or presence of the lower sands exercise a controlling influence upon the productiveness of those above them, which should not be the case if the oil in each rock was generated in the rock where found from organic matter interbedded in the stratum itself.

Genesis of petroleum from condensed gas.

§ 498. The hypothesis, that petroleum is the product of condensed gas evolved from carbonaceous shale lying at a greater or less depth below the oil sands, while, as before intimated, not yet sufficiently understood to claim the place of a demonstrable theory, seems nevertheless not to be open to so many cogent objections as the one just considered.

As generally understood at present, this hypothesis also requires organic growth to furnish materials for generating the hydro-carbons, and mechanical agents to prepare the sand-bed reservoirs to collect and retain them; but the operations of the two classes of agencies need not necessarily have been synchronous, nor is it requisite that the areas primarily occupied by them should have been geographically co-extensive. The carbonaceous gas-producing materials may have been brought into the Appalachian basin from various sources, at different times, and by many channels, long anterior to the deposition of the sand-beds. But they only become *oil producing* through the supervention of the sandstones; therefore, to secure this end, both carbonaceous shale and sandstone must underlie a productive oil field, for if the shale be wanting, no gas can come up for condensation in the sandrocks, if the sandrocks are wanting, there being no reservoirs to receive and condense the gas, it continues on upward and escapes imperceptibly as gas at the surface.

§ 499. When we reflect that large quantities of organic matter were stored in the limestones and shales of the immensely thick beds of the Silurian formation, that they were augmented in a later period by the contents of other rich carbonaceous deposits of Lower Devonian age, that these all now lie far below the Oil sands, and that we may reasonably suppose many of them are now or have been, buried at a depth which would subject them to a degree of heat competent to all the requirements of spontaneous distilliation of gas, we cannot but admit, in view of the known intimate relationship and association of gas and oil, that the hypothesis of the formation of petroleum from this source is worthy at least of a candid consideration.

The great bituminous coal basin of western Pennsylvania and Ohio, under which the Silurian rocks plunge from the east and northeast to appear again as they come up and fold over the Cincinnati anticlinal on the west, seems to be, so to speak, one vast cauldron filled with deeply buried carbonaceous matter subjected to great heat, and therefore constantly generating gas.

It may be doubted whether a well was ever drilled in all this area, where gas was not obtained, or at least where it might not have been found if drilling had been continued to a proper depth.

§ 500. It is true that in many wells the volume of gas is small and sometimes almost imperceptible, and this fact has been brought forward as an argument against the theory of a general diffusion of gas throughout the lower measures, traveling from its assumed source in deeper rocks through every available avenue to find an exit at the surface.

But let us examine this point—and to illustrate, suppose a gas holder with an unlimited supply of gas under a constant pressure of three or four hundred pounds to the square inch, to be buried thousands of feet beneath the surface. From this reservoir let numerous pipes varying in size from one sixteenth of an inch to three inches in diameter, run up in branching and tortuous lines toward the surface. If now, in drilling an oil well one of the smaller pipes should be tapped at a depth of five hundred or a thousand feet, the small volume of gas emitted, mixing with the air in an ordinary well shaft, would make but little show at the surface—we should have a well with "no gas." But if one of the larger leads were tapped a lively gas-flow would at once ensue. Yet, here both leads come from the same source and vent under the same normal pressure; and although the different measures of friction belonging to pipes of large ~~are~~ or small diameters would exercise some influence, still for all practical purposes we may consider cause and effect as operating the same in one pipe as the other, the only marked difference being in the amount of product; and even this difference, in so far as it relates to their capacity for filling limited reservoirs, is equalized by time, for a gasometer which would be filled by the larger pipe in a day, would as surely be filled by the smaller one, eventually, if a sufficient period of time were allowed for the work.

Let the buried gas holder and ascending pipes, represent the gas generating measures of the lower rocks and the innumerable natural leads and fissures through which the gas is constantly rising to the surface. The supplying reservoir is never reached by our drill holes; the escape pipes may be tapped or may not as the accidental circumstances of location of well and structure of rock may determine—we see then that a varying volume of gas-flow in a well, or even an almost entire absence of it cannot be considered as a good argument against the theory in review.

§ 501. Wherever the drill descends below the horizon of the Venango group, a large proportion of mud rock (the drillers "soapstone") is found, interstratified with slate and occasional "shells," or thin bands of hard, flaggy, fine grained sandstone. These mud-rocks are compact and impervious and must necessarily interpose an almost impassable barrier to the upward flow of gas. Probably all the measures have been fractured more or less by oscillations, shrinkage and warpings of the earth crust, and the main avenues for the passage of gas through them follow principally these lines of fracture.

It may be inferred then that a porous sandstone which chanced to overlie one of these *crazed* lines, would be much sooner filled and stored with gas than another of the same quality not so favorably situated. But this does not imply that the latter would *never* be filled, for we must not lose sight of the fact that nature works slowly and that there has been no lack of time for the accomplishment of all her undertakings. Forgetting this we frequently misinterpret her operations and overlook the achievements of some of her slow but most effective agents. The smallest jets of gas, scarcely noticeable in an oil well, insignificant as they apparently are, have no doubt had ample time during the geologic ages, through their agencies alone, to deposit in the retaining sandrocks the immense volumes of gas which now so astonish the world in flowing gas and oil wells.

Water drops falling one every hour will fill a barrel in time, when full, an inch opening empties it in a few minutes. So with our underground gas and oil reservoirs we draw out through drill holes in a few months, what nature has been ages in accumulating.

§ 502. The question previously asked: "What are the necessary conditions for converting organic matter into oil?" repeats itself here in a slightly varied form; what are the requisite conditions fo converting organic matter into *gas* and gas into *oil?* and must receive again only an hypothetical answer.

If in the one case an horizon of distillation be required, in the other horizons of distillation and condensation seem to be demanded, but it is as impossible to precisely locate or define the latter as the former.

The disquisition which might very naturally here intrude, as to whether it is *possible* or not for gas to be converted into oil, must be left for those who have made a special study of such matters. On the presumption that nature has some way of accomplishing the fact, although her processes are not at present understood by us, we may provisionally admit the possibility and pass on to notice some of the physical conditions which would seem to be required to bring about such results, and then see if the significant phenomena exhibited by the oil development are in harmony with these requirements.

§ 503. According to this hypothesis there must have been two distinct stages in the genesis of oil, a gas-making stage and an oil-making stage, two distinct and dissimilarly conditioned natural laboratories where the work was performed, one possessing all the requirements for generating gas from the carbonaceous shales brought within its limits, the other containing all the essential qualifications necessary for reducing the gas entering within the sphere of its influence into oil. A study of the latter, which, for convenience, may be called the horizon of condensation, concerns us most at present, as that is the one where oil is found and below it (if this hypothesis be correct) it will be useless to sink the drill, whatever the character of the strata may be, except in expectation of finding gas.

Whether this hypothetical horizon of condensation should be expected to embrace a uniform thickness of measures lying in a horizontal band having a fixed relation to ocean level throughout the several oil fields, or may be supposed to vary from horizontality in consequence of the gradual uplift of the rocks toward the northeast, its position being dependent more upon surface influences than sea level, we do not know.

The facts as developed by the drill are these, and they seem to suggest that both of the above propositions should be kept in view while attempting to ascertain the limits of this horizon.

§ 504. *At Tidioute, Warren county, the oil producing sand lies about 1,000 feet above ocean level*, the highest altitude, I believe, at which oil has been obtained in the State. At Parkers, Armstong county, the rock has sunk to *very near tide level*, and at Herman station, or Great Belt city, Butler county, to *500 feet below tide.* Thus the Venango *Third sand* in its range from Tidioute to Herman station, a distance of about sixty-five miles, runs diagonally through a horizontal section of the earth crust 1500 feet in thickness.

§ 505. It will be seen by reference to the generalized profile section from Black Rock, N. Y., to Dunkard Creek, Pa., (Plates X and XI,) that the Warren and McKean oil horizons as well as those of Slippery Rock, Smith's Ferry and Dunkard Creek all lie within the same vertical range of 1500′, covered by the Venango group. Therefore all the oil thus far produced in Pennsylvania has come from strata lying between a point 500 feet below ocean level, and one 1000′ above ocean level; and, as far as I am informed, no oil has yet been produced here from rocks *below* ocean level, except from those wells located in Armstrong and Butler counties south of a latitudinal line crossing the Allegheny river a short distance south of Parker city, as shown on dip diagram, Plate VIII, (see also Plate IX,) and perhaps from one or two small wells near the south line of McKean county, where the "Bradford Third Sand" which lies at Bradford 400′ above ocean level just begins to dip below that datum plane.

§ 506. Another suggestive fact may be mentioned. Notwithstanding the large number of deep holes put down in the country I have never heard of a well producing oil from a depth of 2000 ft. below the surface. Some of the McKean co. wells may closely approximate to that depth, but if they do they are located on high ground, more than 2000 ft. above ocean and the oil rock still lies above tide level.*

A list of some of these dry holes which have been put down more than 500 ft. below ocean level, may be given to show that the absence of oil below the point named is not an inference based upon negative evidence alone.

	Depth of Well.	*Bottom of Well below ocean level.*
Well at Sharon, Mercer co., Pa.,	1600′	700′
" New Castle, Lawrence co.,	2700′	1890′
" Beaver Falls, Beaver co.,	2330′	1600′
" Pittsburgh, Allegheny co.,	2360′	1508′
" Tarentum, Allegheny co.,	2284′	1416′
" Pine creek, Armstrong co.,	1693′	893′
" Titusville, Crawford co.,	3553′	2263′
" Jackson station, Warren co.,	2041′	855′
" Fentonville, Warren co.,	1830′	590′

§ 507. I do not mention these circumstances to *prove* that there is no oil below a plane 500 ft. below ocean level, or that it is useless to look for it in a well over 2000′ deep; but simply to place the facts on record and to call attention to them, let their significance be what it may, so that if hereafter, deeper productive wells and deeper oil horizons are found, (as it is quite possible they may be) their import as new features in a study of the oil rocks may be properly understood and appreciated.

§ 508. Geologists as well as oil producers have been inclined to look upon the question of the origin of oil as one of secondary importance, and have apparently acted upon the presumption that the oil bearing strata were to be studied

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* Since this was written productive oil wells about 2100 feet deep have been obtained on some of the high hills in McKean county; but still the oil rock lies above tide level.

and traced just the same whether petroleum was indigenous to the rocks where found or a foreign deposit accumulating there from other sources. But we see even from the above very imperfect review of some of the conditions which appear necessarily to belong to the two methods of generating oil that this is a great mistake.

If oil originates in the rock where found, our business is simply to trace that rock; for it may reasonably be supposed in that case, that the oil was formed and stored there before the uplifting of the strata, and similar conditions prevailing at that time (as far as we can perceive) throughout the whole range of rock, similar oil deposits ought to be expected over all parts of it, regardless of the subsequent elevation which destroyed its horizontality. But if it is formed from gas, it has probably been collected and stored since the uplift and we can only expect to find it in certain kinds of rocks lying within a definite horizon. Where those rocks by reason of their dip rise too near the surface or plunge too deep below it, no oil has been elaborated and stored in them.

How important then to decide which is the correct theory, so that we may study the subject aright and obtain an approximate idea of the maximum depth to which it is judicious to bore for oil.

§ 509. Why have all the deep wells proved failures? Is it because no proper oil bearing rocks were perforated, or because they were encountered at too great depth to be embraced within the oil making horizon? Why have these wells found only gas and salt water where oil was expected? Why does the Venango group—so abundantly productive above ocean level, and so freely yielding oil in Butler co. down to about 400 feet below the ocean—become an uncertain oil horizon at 500 feet below ocean, and after that furnish only salt water and gas, in all the wells further down the slope toward the south; as at Beaver Falls, Pittsburgh, Sharpesburg, Tarentum, Leechburg, &c.? Why does the McKean oil rock, so completely stored with oil at Bradford, 400 feet above tide, become the depository of immense supplies of salt water and gas with but little oil, near the south line of the county, as the oil horizon sinks beneath ocean level?

Why do all of our oil producing rocks (with the exceptions above mentioned) lie above ocean? The equivalents of the Venango, Warren and McKean groups plunge to the south and southwest far below that level, and if the home of oil is in the rock where it is found why should there not be oil in these deeper rocks? Is it not a singular coincidence that the deposit was only made in such portions of each several stratum as chanced subsequently to be elevated in a slightly inclined position above the surface level of the ocean, while the balance of the rock remained barren?

These and many other curious and pertinent questions may be asked—not merely to arouse idle curiosity in the matter but to incite to judicious inquiry. If there be a point in depth below which it is useless to look for oil, (and all our practical experience thus far warrants the entertainment of the supposition that there is) then the sooner the probability is admitted the sooner will investigations be made to establish the fact, and when the point of maximum depth is ascertained it may be the means of saving large expenditures of money which would otherwise be lost in blindly sinking wells to unreasonable depths in search of oil.

CHAPTER XXVII.

Description of the above ground machinery employed at an oil well; derrick, running-gear, rig-irons, boiler, engine, &c.

(Illustrated by Plates XIII, XXXVI, XXXVII, and XXXVIII.)

§ 510. "*Carpenters' rig.*"—Having secured his land and selected a location for his well, the first step of the oil-producer is to contract for the erection of a complete "carpenters' rig" over the spot where the bore hole is to be sunk.

This "carpenters' rig" consists of (1) a derrick, with bull-wheels and crown pulley, for raising and lowering the drilling tools while drilling, and for handling the tubing, sucker-rods, &c., after the well is completed; (2) heavy mud-sills, main-sill, and sub-sills carrying above them the samson-post and jack-posts; (3) walking-beam, band-wheel and sand-pump reel; (4) mud-sills and block for the engine to rest upon; (5) an engine-house and all the necessary wood work required about a well, so that drilling may commence as soon as the boiler and engine are put in position and the belt is attached to the band-wheel.

§ 511. *Cost of rig.*—This part of the work costs from $400 to $700, varying according to location, price of lumber and season of the year when erected. A "winter rig," or one put up for winter use costing somewhat more than a "summer rig" on account of extra lumber required in temporarily housing in the lower part of the derrick to protect the workmen from the inclemency of the weather.

§ 512. *Wooden conductors.*—The next step is to sink a "conductor" through the loose surface accumulations of gravel and clay, to the "bed-rock."

If the location be on a hillside, where the superficial clays and gravels are seldom more than ten or fifteen feet thick, a common well shaft six or eight feet square, is dug with pick and shovel until the solid rock is reached. A wooden conductor eight inches square in the clear, made by spiking together two 2″×10″ plank of the proper length, is then set up perpendicularly between the "bed-rock" and the derrick floor, the lower end being carefully adjusted in the rock in such a manner that no gravel or mud from the washings of the surrounding surface can enter the well at this point.

Meantime, the boiler and engine having been "set up" all things are now ready for the driller to commence his work.

Quite frequently all of this work—building the "rig," "setting up" the boiler and engine, and adjusting the conductor, is included in the contract for the carpenters' rig.

§ 513. *On Plate XIII* will be found complete *mechanical drawings* of every part of the carpenters' rig; prepared in minute detail by Mr. H. Martyn Chance, from working plans furnished by Mr. J. H. Carll, while engaged in securing the Butler county well records given in another place.

These drawings should enable a mechanic in any part of the world, to construct a first class "rig" adapted to the sinking of a bore hole 2500 or 3000 feet deep, although he may never have seen an oil well. It may assist him however if we briefly refer to some important points in construction, and then show how connections are made between the several parts so that the machinery may be directed to do the work required of it.

§ 514. *Foundation timbers.*—Practically, the quality and dimensions of the foundation timbers are governed by no arbitrary laws, but depend very much upon the circumstances surrounding the well. In some places, sawed timber like that shown in the drawing, can be obtained; but generally, it is cheaper to fell trees as near the well as possible and flatten them on two sides only, in which case the hewed sticks will necessarily vary somewhat in size. We have given the dimensions for a good, solid foundation, and any competent mechanic can judge how far he may safely alter the details.

The mud-sills, *a*, (Plate XIII,) are generally sunk in trenches, where the nature of the ground admits of its being done. They have gains cut into them to receive the main-sill, *d*, and sub-sills, *e* and *e′*. After all have been put in place and leveled up, the keys or wedges, *h*, are driven, and the whole foundation is thus firmly locked together.

§ 515. *The Samson-post*, *k*, *and Jack-posts*, *l*, *s*, *& r*, are dovetailed into the sills and held by properly fitted keys, *h*, as seen in the *side elevation.* The braces are all set in gains, and keyed up, *no mortises and tenons being used* in the structure. The advantages of this method of construction are:—(1) greater strength; (2) the keys can be driven from time to time to compensate shrinkage; (3) the posts and braces being adjustable, the different parts are easily put into line and kept there; (4) the whole is quickly taken apart in a convenient shape for removal, when the well is abandoned.

§ 516. *Center line of main-sill not always parallel with center line of walking-beam.*—Referring to the horizontal projection on Plate XIII, it will be observed that the samson-post is placed flush with one side of the main-sill, and the band-wheel jack-post is put flush with the other side. In this way the walking-beam is made to run parallel with the main-sill. But if the main-sill be less than 24 inches wide—say 20 inches, for instance—the samson-post must necessarily be moved two inches in one direction to get a full bearing upon it, and the jack-post two inches in the other direction. The effect of this will be to swing the derrick end of the walking-beam six inches away from the well-hole as here located, and to throw the engine foundation and all the running-gear out of line.

If, then, a smaller main-sill is to be used, the work may be laid out as follows:

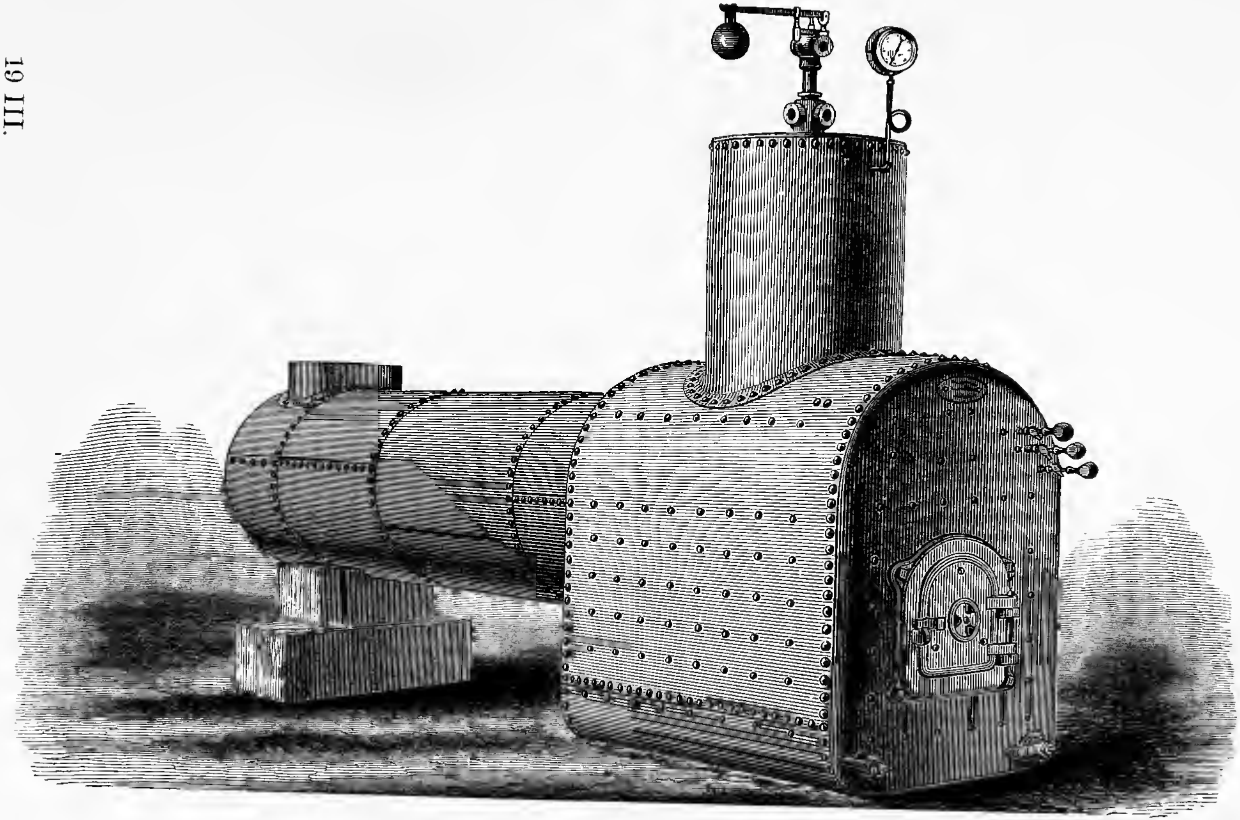
After placing the main-sill in the position desired, mark the point on it where the center of the samson-post is to come; then mark also the point on which a perpendicular will fall from the center of the wrist-pin. Knowing the size of samson-post, length of walking-beam and dimensions of band-wheel irons (that is, the length of box, thickness of arm and length of wrist-pin to the center of pitman), these points are easily fixed. Now snap a chalk line passing through these two points and take that to work from, *squaring everything to this line*, the same as if it ran parallel to the main-sill, as seen in the drawing. It virtually alters nothing except the main-sill which is thus thrown a little out of square with the other work.

A crooked stick is sometimes used to very good advantage for a main-sill, for a slight bend in the right direction gives both posts a more central bearing upon it than if it were straight.

These points are mentioned to put the inexperienced on their guard, should they attempt to build on the *general plan* here given, without properly considering the trouble an alteration of a few inches might make, especially if it affected the center line. Any intelligent mechanic, however, when he understands the plan, will readily see how he can vary the details to meet the requirements of his case and still secure the results desired.

§ 517. *The boiler* supplying steam for the engine is not shown on Plate XIII, but a cut of one now in popular favor is given on Plate XXXVI, opposite. It was formerly set up in the engine-house—in fact, portable boilers and engines were generally used, the engine being bolted on the top or side of the boiler, and the boiler sometimes mounted on wheels. But deep wells and heavy drilling tools now make it necessary to have a stationary engine; and since the plan of drilling through dry casing has been universally adopted, so many explosions and fires have occurred from the ignition of gas at the furnace fire that it is found more prudent to place the boiler at some convenient spot outside of the engine-house, and then when the oil rock is approached by the drill and danger from a sudden out-

Plate XXXVIII.



burst of gas and oil is apprehended, drilling is suspended and the boiler (together with the tool-dressing forge which up to this time has occupied one side of the derrick) is removed to a safe distance—perhaps 20 or 30 rods—from the well.

After the well is completed and the gas and oil are under control, the boiler will again be moved and permanently set up in the engine-house, if the well is an isolated one, and is to be pumped independently of others.

But if, as is frequently the case, the owners have already drilled or intend to drill five or six wells in the vicinity, it is more economical to centrally locate a 30 or 40 horse-power boiler, and from it convey steam to the engines at the several wells, through pipes wrapped with felt or encased in boxing ten inches square and filled with saw-dust, tan-bark, or some other partial non-conductor of heat..

Thus the small boilers become available for drilling in other places, and two engineers or pumpers, working alternately twelve hours each, can look after all of the wells in the cluster.*

§ 518. *The engine*, *b′*,—a twelve or fifteen horse-power,

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* A still more economical method for pumping groups of wells has come into very general use in some localities, within the last five years. It is called the Sucker Rod connection, and by it as many as a dozen wells may be pumped by one boiler and engine, but slightly increasing the usual cost of pumping a single well.

From the central well strings of sucker rods branch out in all directions and form direct connections with the other wells, so that when the central one is put in motion all the others must move also. To avoid friction, the rods are held suspended a few feet above the surface of the ground and swing on cords depending from the tops of posts set at proper intervals along the line; or they are supported by placing triangular horses under them, which rock backward and forward with the alternating movement of the rods. Wells 1500 feet apart are thus connected and successfully pumped, and by ingenious applications of rocking-levers, elbows, knuckle-joints, and tees, the lines are made to run up hill or down, straight from one well to another, or to turn at any angle desired. The wells are balanced in pairs and so connected that when the pump-rods in one come up those in the other go down; therefore but little increase of power is needed to pump additional wells.

Sucker rods were first used for these connections, because they were convenient, and old rods were plenty and cheap; but as they became scarcer, other things were substituted—scantlings nailed together in continuous strings—hoop-iron and wire—all of which are successfully used.

reversible movement, is bolted to the engine block, *b*, and by means of its driving pulley, carrying belt, *o o*, (which is made of four-ply rubber, eight inches wide,) communicates motion to the band-wheel, *m*, and through it to all other parts of the machinery.

To make the above descriptions more plain, we give two full page cuts of a popular style of boiler and engine, on Plates XXXVI and XXXVII; the electrotypes for which were kindly loaned by the Gibbs & Sterrett Manufacturing Company of Titusville. Probably over 10,000 boilers and engines are constantly at work in the oil region, and of course there are many manufacturers of them and a variety of patterns. The well-sinker may have a preference for this machine or that, according to his own ideas of excellence; but for the purposes of illustration there need be no choice between them, for they are all constructed essentially after one model and vary only in details which can not here be referred to.

§ 519. *The throttle-valve, l l*, is operated by a grooved vertical pulley. From this pulley an endless cord or wire (technically called "the telegraph") extends to the derrick and passes around a similar pulley, *n n*, fixed upon the headache post, *z*, within easy reach of the driller. With the two pulleys thus connected, the movement of one communicates a like motion to the other; consequently the driller has only to place his hand upon the derrick pulley to operate the throttle-valve, and thus he starts or stops the engine and increases or decreases its speed, without leaving his position at the well mouth.

§ 520. *The reverse link, p p*, is also operated from the derrick by the cord, *q q*, which passes over two pulleys, one fixed in the engine-house, and the other in the derrick. A slight pull upon the cord raises the link and reverses the movement of the driving-wheel of the engine. When the cord is released the link drops back and restores the regular motion.

In deep wells and with such heavy tools as are now employed, it is laborious work for non-reversing engines to make the first two or three revolutions upon starting to drill, and they frequently "stall" or come to a stop on the "dead center;" but with the devices here shown, the driller commands the throttle with one hand and the reverse with the other, and by adroitly manipulating them both together, he is enabled to start without difficulty.

§ 521. *The band-wheel, m,* receives its motion direct from the driving-pully of the engine, to which it is connected by the belt, *oo*. On or near the end of its shaft, *o*, is the bull-rope pulley,* *n*; and to its other end is attached the arm or crank, *o′*. In this arm a number of holes are drilled to receive an adjustable wrist-pin, *p*, which may easily be moved from one hole to another, to regulate the length of stroke required in drilling or pumping.

As the band-wheel communicates motion through the pitman, *q*, to the walking-beam, while drilling; to the bull-wheels, by the bull-rope, *r r*, while running up the tools; and to the sand-pump reel, by the friction-pulley, *w*, while sand-pumping; and as these movements are all used separately and at different times, it is necessary that the machinery be so constructed in its different parts that connections may be quickly made or broken, and one kind of motion substituted for another at pleasure.

§ 522. *The sand-pump reel, w,* is put in motion by pressing on the lever *v*, which is joined by the connecting bar, *u*, to upright lever,† *t*. This brings the face of the beveled pulley, *w*, into contact with the face of the band-wheel. It is simply a friction pulley and can be thrown in and out of gear at will, no matter at what speed the band-wheel may be revolving.

The sand-pump descends into the well by its own gravity,

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* Some prefer to set the jack-post close to the band-wheel, so that the bull-rope pulley may be put outside of it on the end of the shaft. In this way the bull-rope is more accessible, and the bull-wheel shaft in the derrick can be made a little longer, but the band-wheel bearings are thus shortened up and cannot be said to be improved by it.

† This lever should be made of some tough and elastic wood, cut thin near the upper end, as shown in the drawing, so that it may act as a spring and relieve the man at hand lever *v* from the disagreeable "jerky" motion which otherwise results from the slight irregularities of the two friction surfaces, when everything is rigid.

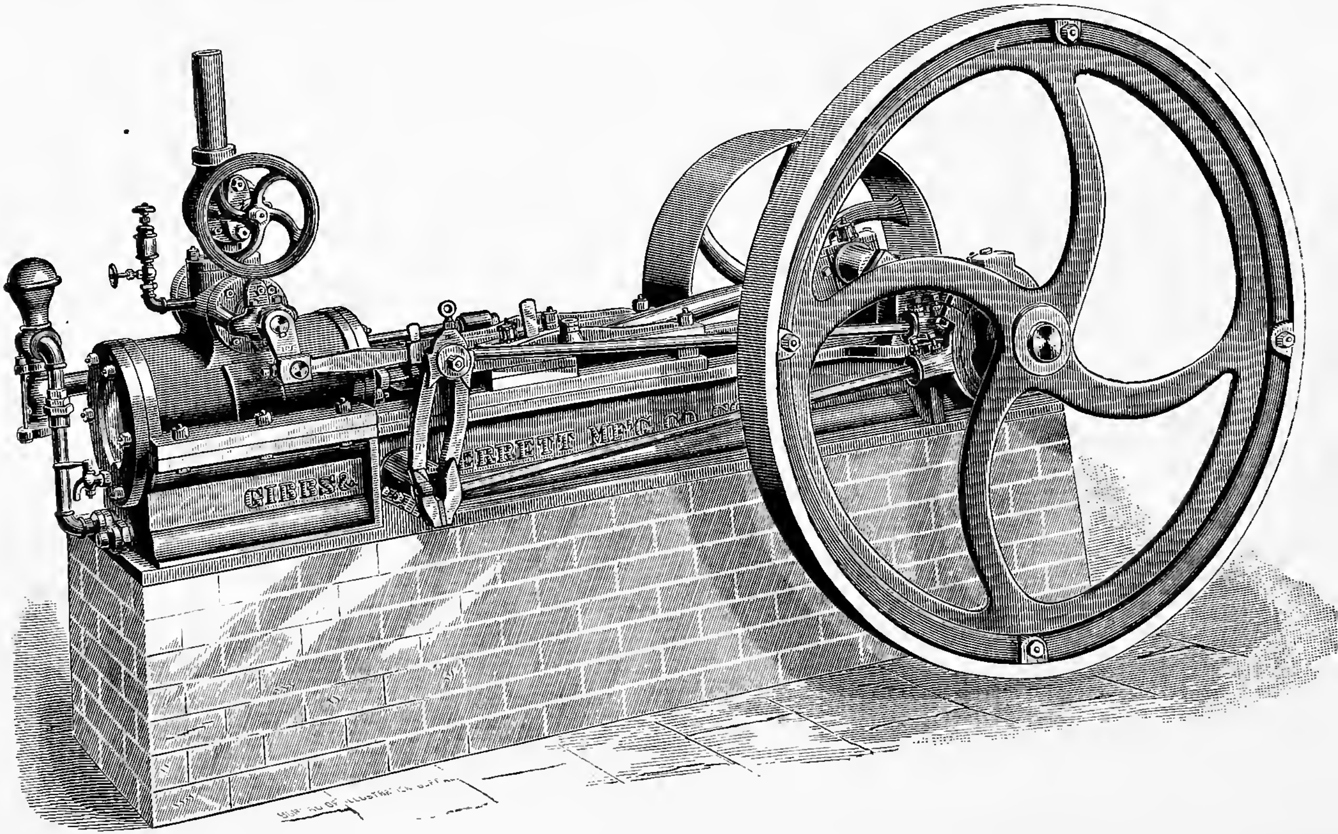

Plate XXXVII.

and to prevent it from attaining too great speed, it is checked by pressing the lever, *v*, backward so as to throw the friction pulley *w*, against a post, or a curved piece of sheet iron set behind it in proper position to act as a brake when the wheel is pressed against it.

The sand-pump line is coiled upon the shaft, *x*. It is a cable laid rope ⅝ of an inch in diameter, and passes direct from the shaft over the pulley, *ii*, and thence down inside of the derrick to the well mouth, where it is secured to the bail of the sand-pump.

Sand-pumps and bailers of several kinds are in use. The most common one is a plain cylinder of thin galvanized iron with a bail on top, and either a leather flap-valve or a metal stem-valve in the bottom. It is usually about 6′ long, but when large quantities of water or oil are to be dipped from the well, it may be lengthened to 15 or 20 feet. Stem-valve bailers are much esteemed on account of their convenience in discharging contents. The valve stem projects downward a few inches beyond the bottom of the cylinder. To empty the pump it is only necessary to let it rest on the bottom of the waste-trough, when the stem opens the valve and the sediment escapes. The flap-valve pumps are emptied through the top, by inverting them.

Other sand-pumps are made of wrought iron casing and in addition to the bottom valve they have a plunger attached to an iron rod which passes through a hole in a stirrup spanning the top of the case. The sand-pump line is secured to an eye in the top of this rod and the pump chamber hangs suspended from the bottom of it—held by the plunger, which cannot pass through the hole in the stirrup. When the pump stops at the bottom of the well, the slack of the rope allows the plunger and rod to settle down into the pump chamber; consequently on an upward movement the plunger and rod start first and travel the length of the cylinder drawing in the sediment from the bottom; but when the plunger reaches the stirrup the cylinder starts upward also, closing the lower valve and retaining the sediment thus drawn into it to be delivered at the well mouth.

§ 523. *The bull-wheels, b b*, are driven by the "bull-rope," *rr*, which is made of two inch plain-laid cable, joined together by iron couplings.* When not in use the rope or belt is thrown out of its grooved pulley on the bull-wheel and thus remains lying so loosely in the grooved pulley, *n*, on the band-wheel shaft, that there is no friction upon it, and the pulley revolves so smoothly that the rope is seldom displaced from the groove. When the rope is raised to its place on the bull-wheel pulley and drawn taut, motion is communicated from the band-wheel, it slips into its groove and the bull-wheels revolve. It can be thrown on and off at pleasure when the engine is not running too rapidly.

§ 524. *The walking-beam connections* cannot be made or broken while the band-wheel is in motion. To disconnect at the pitman, *q*, the engine must be stopped. The wedge seen above the wrist-pin, *p*, is driven back to loosen the follower,† and then the pitman is pulled forward off of the wrist-pin, carried back toward the samson-post, *k*, and lowered to the main-sill out of the reach of arm, *o′*, when again revolving. This tips the walking-beam to an angle of about 25° to the horizon, in which position the derrick end of it is thrown back a foot or more from its former perpendicular over the hole, and there is thus no danger of

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*As the band-wheel and bull-wheels revolve in opposite directions this rope must be crossed, and it is advantageous to have it so, for it thus gets more bearing surface upon the pulleys, by which its tractive power is materially augmented.

†The dimensions of the lower part of the pitman are 4″ × 6″. After inserting a stout bolt near the end to prevent its splitting, a hole is bored for the wrist-pin and a slot about six inches long cut upward from it to receive *the follower* which is made of some hard durable wood and forms an adjustable box for the wrist-pin to work in. Another mortise, say 1½″ wide and 4″ long is then cut for *the wedge* at right angles to the other, the bottom of it being an inch and a half below the top of the follower slot. But the corresponding cut in the top of the follower should only be one inch deep, so that when the wedge is driven it bears upon the follower alone and holds it tightly against the wrist-pin, preventing the "chuck" which would otherwise occur if no means were provided for keeping this important joint in proper adjustment.

The wrist-pin has a hole drilled in it and is furnished with a washer and pin to prevent the pitman from working off in front. The driller seldom takes the trouble to use them, however, for the pitman never flies off if the machinery is kept in proper running order.

its interference with the cable, tools, or sand-pump as they are run up and down in the derrick.

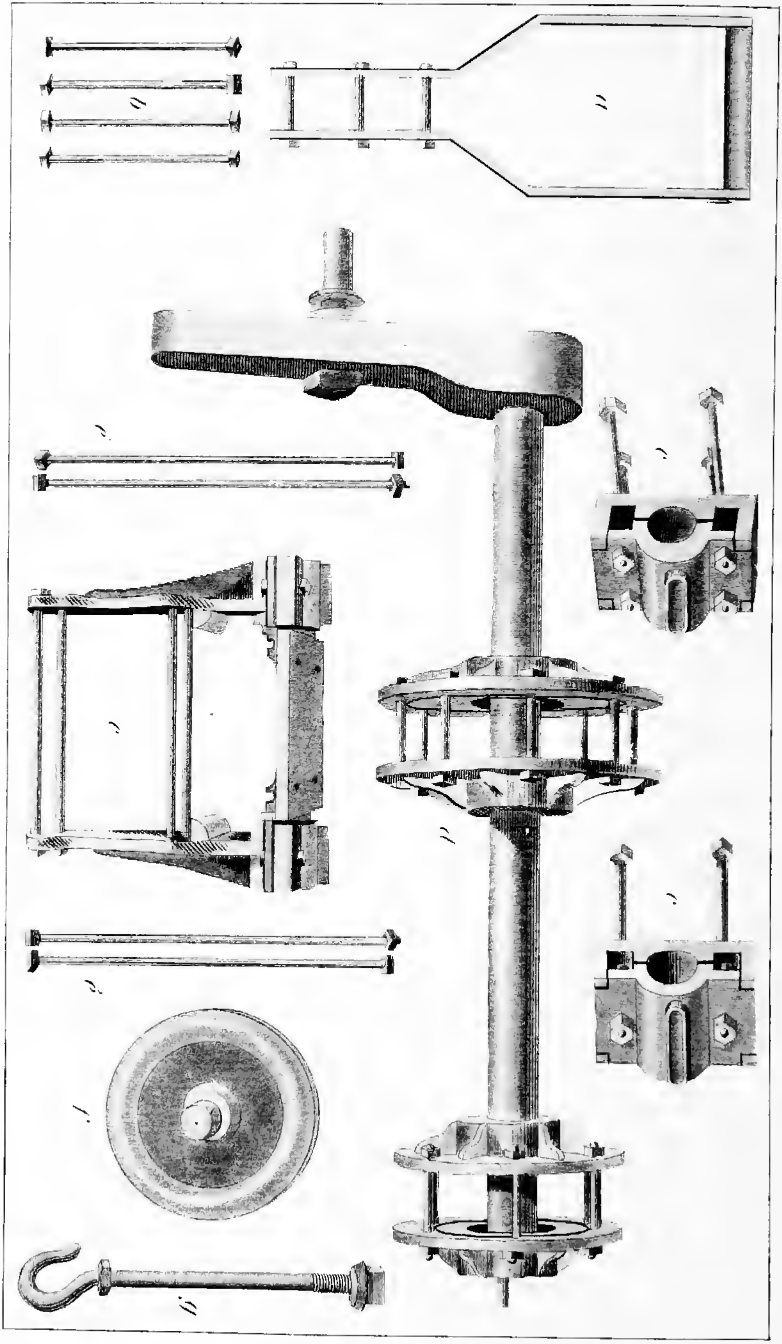
§ 525. *The "headache-post, z,* also called a "life-preserver," is comparatively a recent improvement, designed, as its name implies, to save the driller a headache or perhaps his life, in case the wrist-pin should break or the pitman fly off of it while drilling, thus suddenly causing the derrick end of the walking-beam to drop under the great weight of the suspended drilling tools and endangering the safety of all who might be within reach of it. This post, which may be made from any sapling six or eight inches in diameter cut to the proper length, is set upon the main-sill immediately under the walking-beam, so that if such an accident occur the walking-beam can fall but a few inches and do no harm. It is also useful when some slight repairs to the pitman or band-wheel crank are needed while the tools are suspended in the well. By placing a block between it and the walking-beam, the pitman is relieved of weight and can be unshipped without disconnecting the tools from the temper screw.

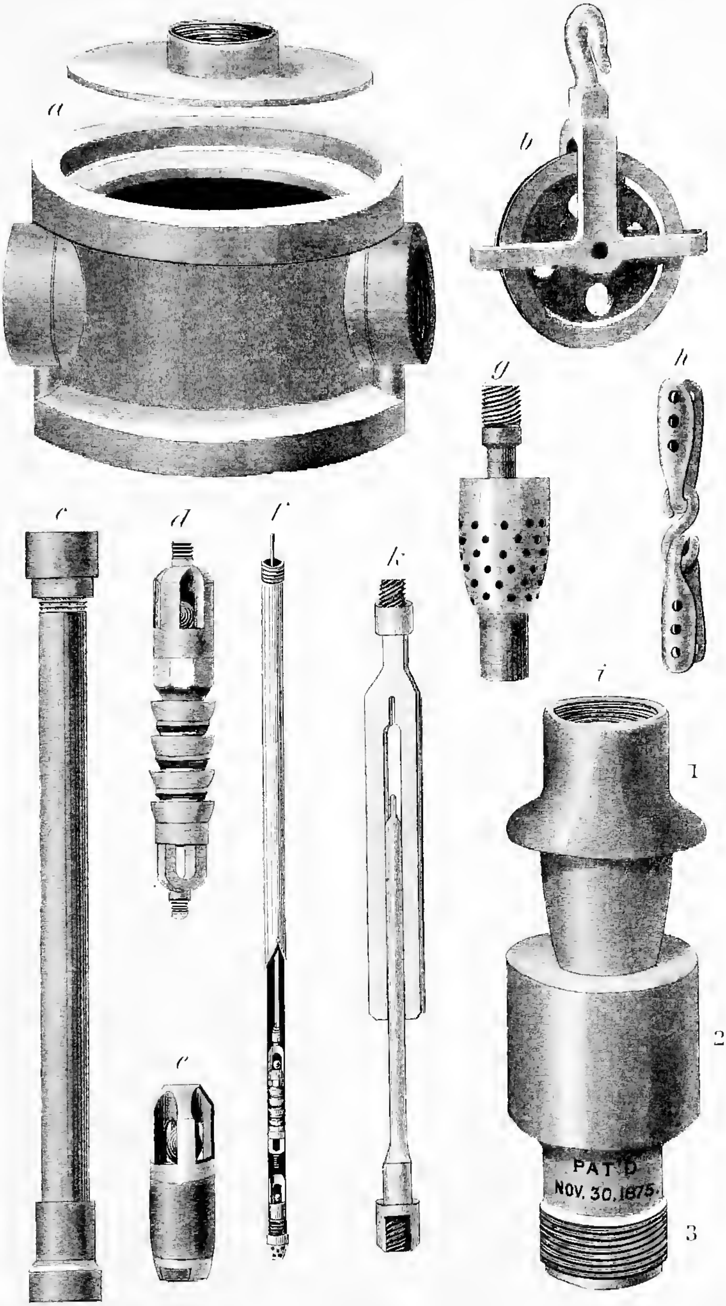
Oil Well Rig Irons.

§ 526. The details of Plate XIII may be further illustrated and explained by the figures on page Plate XXXVIII, which represent the complete set of irons belonging to a carpenter's rig. They are as follows:

a, Walking-beam stirrup.
b, Bolts for securing it by a wooden cap to walking-beam.
c, Boxes for band-wheel shaft.
d, Band-wheel shaft, arm, and flanges.
e, Center irons for walking-beam and samson-post.
e′, Bolts for securing the saddle to walking-beam.
f, Derrick or crown pulley.
g, Walking-beam hook, to hold temper-screw.

§ 527. *Cost of Rig-irons.*—In 1879, when low prices were ruling, these irons complete, (shaft 3½″ in diameter and 4′ 6″ long, flanges 20″ in diameter,) together with a sand-pump pulley and two gudgeons and two bands for the ends of the bull-wheel shaft, cost $75 00.




a
b
g
h
c
d
f
k
i
1
2
3
e
PAT'D
NOV. 30, 1875.

For parts of sets the following prices are given in the price list of Jarecki Manufacturing Company of Erie, date 1876:

d,	Shaft, 4′ 6″ long, 3½″ diameter,	$9 50
	Crank, 14″ to 46″ stroke, 6 holes,	7 00
	Wrist-pin, 2⅜″ diameter,	3 50
	Pair of flanges, 24″ diameter,	8 25
	Pair of flanges, 20″ diameter,	5 60
	Flange-bolts, 7″ long, ¾″ diameter, each	12½
	Steel keys for flanges and crank, each	50
	Collar, with steel set-screw,*	1 20
c,	Two boxes, babbitted and with bolts,	8 50
a,	Walking-beam stirrup, 2¾″ × ¾″,	5 00
b,	Four bolts for securing the cap,	1 00
e,	Saddle for walking-beam,	4 50
e,	Side-irons, boxes, and bolts for samson-post,	7 00
e′,	Four bolts for saddle,	1 20
f,	Derrick-pulley, 20″ diameter,	5 00
g,	Walking-beam hook, heavy,	3 35
	Sand-pump pulley,	3 25
	Two gudgeons with bands, for bull-wheel,	5 00

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* This collar belongs on the shaft, and is clamped to it by a set-screw, close to one of the boxes, to prevent the shaft from moving endways. It is not shown in *d*, because the flanges of the bull-rope pulley are outside of the box, and may be keyed close against it, so as to answer the same purpose as the collar.

CHAPTER XXVIII.

(Illustrated by Plate XVI.)

Description of drilling tools. "Stringing" them in the derrick. "Spudding" and drilling.

§ 528. But little need be said in explanation of plate XVI. The tools are drawn to scale so accurately and their dimensions given so fully that each figure speaks for itself.

Only the plain drilling tools are shown, for it would require a large volume and be almost an endless task to describe and illustrate the *thousands of fishing tools* that have been invented and used by the driller and well manager to meet the varied accidental emergencies daily occurring in well boring and well pumping. These tools are of all kinds, from the delicate grab designed to pick up a small piece of valve leather or a broken sucker-rod rivet from the pump chamber to the ponderous string of "pole tools" containing tons of iron, which, at a depth of 1500 feet or more, can unscrew a set of "stuck tools" and bring them up piece by piece, or cut a thread upon the broken end of a sinker-bar or an auger-stem, so that it can be screwed fast to and loosened by the use of "whiskey jacks" at the surface.

§ 529. *"A string of drilling tools"* consists of rope-socket, sinker-bar, jars, auger-stem and bit, weighing altogether about 2100 pounds as will presently be shown in detail. It is divided by the jars into two members, one delivering its blow downward, the other upward.

§ 530. *The auger or drill* which cuts and pulverizes the rock by its impact, weighs about 1320 pounds, and consists of the bit, the auger-stem and the lower wing of the jars.

§ 531. *The sinker-bar* with the upper wing of the jars and the rope-socket attached, and weighing about 780 pounds, adds no force to the blow of the auger-stem, for it hangs at all times suspended on the cable. Its function is to deliver a blow to the auger-stem on the *upward stroke* so that the *jar* may loosen the drill in case it should wedge or stick in the rock it is cutting.

If an auger-stem be attached directly to the cable it will be found impossible to drop and raise it with a regular motion, for the bit will frequently stick, when the cable alternately stretching and contracting allows the walking-beam to make its accustomed sweep while the drill remains stationary at the bottom. A slight jar on the upward stroke prevents this sticking.

§ 532. *The jars, therefore, form a very important member of the drilling tools*, being the connecting link between the drill and the means of operating it. Fig. C, on Plate XVI, is a very good representation of them,* but as they are there shown closed, or with the upper wing resting upon the lower one, (instead of the lower *suspended from* the upper, as they would appear when in use,) and as the *improved rounded wing* in front entirely conceals the central slot from view, we give a sketch of another pair, where both wings are made alike and the links are *open.* (See Fig. K, page Plate XXXIX.) The two sets are precisely alike in principle, and vary only in details of construction. If the upper wing in Fig. C be drawn up, it will move 13 inches before the cross-heads, (that is the solid part playing in the slot,) seen in section C′, strikes the cross-head seen in C″, and we shall then have the upper part of the slot in the upper wing in view, as in Fig. K, Plate XXXIX. This slot is 1¾ inches wide and 21 inches long, exclusive of the 5-inch narrow crotch-slot, already in sight in Fig. C. Both wings are slotted in the same manner, and when put together, the cross-head of the upper one passes through the slot of the lower; and the cross-head of the lower one through the slot of the upper—like two flat links in a chain. As the cross-heads are each 8 inches long, and the slots 21 inches, there remains 13 inches of the slots unoccupied, which represents the "play" of the jars.

§ 533. *The manner in which the jars perform their work* may be best explained, perhaps, in this way. Sup-

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* The jars are sometimes *welded* to the auger-stem instead of being connected by a box and pin, as here shown.

pose the tools to have been just run to the bottom of the well—the jars are closed, as in Fig. C—the cable is slack. The men now take hold of the bull-wheels and draw up the slack until the sinker-bar rises, the "play" of the jars allowing it to come up 13 inches without disturbing the auger-stem. They watch for the coming together of the cross-heads, which will be plainly indicated by a tremulous motion communicated to the cable, and by the additional weight of the auger-stem. When the jars come together they slack back about four inches and the cable is in position to be clamped in the temper-screw.

If now the vertical movement of the walking-beam be 24 inches—when it starts on the up stroke the sinker-bar first moves; it rises 4 inches—the cross-heads come together with a sharp blow, and the auger-stem is picked up and lifted 20 inches. On the down stroke the auger-stem falls 20 inches, while the sinker-bar goes down 24 inches to telescope the jars for the next blow coming up. This is the theory of the movement, but of course in practice the *spring* of the cable in deep wells and the weight of tools make many modifications necessary.

Some writers, in describing the manner of drilling, convey the impression that the sinker-bar is used as a *mall* to drive the auger into the rock; but this, we see, is entirely erroneous. A skillful driller *never* allows his jars to strike together on the down stroke. They are only used to "*jar down*" when the tools stick on some obstruction in the well before reaching the bottom, and in fishing operations.

An unskillful workman sometimes "looses the jar," (especially if the well be deep and nearly full of water,) and works for hours without accomplishing anything. The tools may be standing on the bottom, while he is playing with the slack of the cable, or they may be swinging all the time several feet from the bottom. If he cannot recognize the jar he is working entirely in the dark; but an expert will tell you the moment he puts his hand upon the cable whether the drill is working properly or not.

As the "jar works off," or grows more feeble, by reason of the downward advance of the drill, it is "tempered" to the proper strength by letting down the temper-screw to give the jars more play.

§ 534. *The Temper screw*, *l*, forms the connecting link between walking-beam and cable, and it is "let out" gradually to regulate the play of the jars, as fast as the drill penetrates the rock. When its whole length is run down, the rope clamps play very near the well mouth. The tools are then withdrawn, the well sand-pumped, and preparations made for the next "run." With the old fashioned temper-screw, a great deal of time was spent in readjustment, for it had to be screwed up thread by thread, by tedious revolutions of the clamps. But this delay is now obviated. The nut through which the screw passes is cut in halves, one half being attached to the left wing of the screw frame, the other half to the right wing. An elliptical band holding the set-screw, *l'*, passes around the nut. It is riveted securely to one of the halves, and the set-screw presses against the other half to keep the nut closed. The wings are so adjusted that they spring outward and open the nut whenever the set-screw is loosened. To "run up" the screw, the driller clasps the wings in his left hand, and loosens the set-screw; he then seizes the head of the temper-screw in his right hand, and, relaxing his grip upon the wings, the nut opens, when he quickly shoves the screw up to its place, again grips the wings and tightens the set-screw—the whole performance occupying less time than it has taken to describe it.

But as this is heavy work, even for a man of great strength, some inventive, and probably unmuscular driller has recently added a very clever improvement which merits a passing notice. In the top of the screw is fixed a small swivel, and in the crotch of the wings above it a small pulley; a cord passes from the eye of the swivel over the pulley, and thence over two similar pulleys placed on the under side of the walking-beam, and the end of the cord suspends a weight about equal to the weight of screw and clamps. As the screw runs down the weight rises, and when it is to be run up again, this counterbalance carries it up to its place, requiring but little assistance from the driller.

§ 535. *Dimensions of Drilling Tools, Plate XVI.*

Pins, each, 3″ long, 2⅝″ diameter, 8 threads to an inch.

Collars, each, 3″ long, 4⅛″ diameter.

Length of boxes—auger-stem, 10″; ring socket, 6″; others, 8″.

Diameter of boxes—auger-stem, 4½″; others, 4¼″.

Square shoulders, 3¼″×3¼″.

Diameter of auger-stem and sinker-bar, 3½″.

Length in detail.

Rope-socket,	Wings,	2′ 6″	3′ 6″
	Square shoulder,	0′ 4″	
	Box,	0′ 8″	
Sinker-bar,	Collar,	0′ 3″	18′ 0″
	Bar,	17′ 1″	
	Box,	0 8″	
Jars,	Collar,	0′ 3″	7′ 4″
	Links, (open,)	6′ 5″	
	Box,	0′ 8″	
Auger-stem,	Collar,	0′ 3″	30′ 0″
	Stem,	28′ 11″	
	Box,	0′ 10″	
Center-bit,	Collar,	0′ 3″	3′ 3″
	Bit,	3′ 0″	
Total length of "string" of tools,			62′ 1″

Temper screw.—The iron side pieces or wings are 1½″×⅝″ and 4′ 6″ long. The *screw* is 1⅜″ in diameter, 4′ long; square thread; two threads to an inch. Sometimes a double thread, three to an inch, is cut.

§ 536. *A wing rope socket* to be secured to the cable by rivets, is shown in fig. *d*. Other styles have been invented, which are tubular in form, and have a central opening passing through them smaller at the top than at the bottom. The end of the cable is passed through the tube and fitted into clamps, which wedge and hold it firmly without rivets, when it is drawn back into the tapering sleeve. Many contractors prefer to use the patent sockets, because they have suffered from loss of tools by breaking the wings or rivets of the other kind. Let me explain why these breaks occur. Usually the end of the cable to be inserted in the wings is simply wrapped with marline and forced into its place, when the rivets are hastily driven and clinched down on an anvil. This is all wrong, as a moment's thought will show. The end of a new cable is less firm, and contains more stretch than other parts of it, and being thus thoughtlessly *crowded* into the socket, the result is that the upper rivet must take all the strain alone, and bend or break before the stretch in the rope will allow the others to render it any effective support. To prove this, take a socket thus prepared for the rivets, and put in the lower one only. Fit it in one of the wrenches firmly secured behind the samson-post; attach the cable to the band-wheel shaft, and let two or three men put a heavy strain upon it, when it will be seen that the part in the socket has stretched an inch or two, and reduced so much in size that the coils of wrapping slip loosely upon it. The cable should be under a strain like this while it is being wrapped. Then after the *lower* rivet has been put in it should be again subjected to tension and held so while the *upper* rivet is being driven. After this it may be released, and the center rivets be put in and clinched in the usual way. I know from experience that a socket put on in this way can be depended upon under all circumstances.

§ 537. *Weight of drilling tools.*

Rope-socket,	80 pounds.
Sinker-bar, 3½″,	540 pounds.
Jars, 5½″,	320 pounds.
Auger-stem, 3½″,	1020 pounds.
Bit,	140 pounds.
Total weight when "strung up,"	2100 pounds.

The other parts of the set weigh as follows:

Temper screw,	145 pounds.
Jars for 8″ hole,	565 pounds.
Two bits for 8″ hole, (each 160 pounds,)	320 pounds.
Reamer,	180 pounds.
Two bits for 5½″ hole (each 140 pounds),	280 pounds.
Reamer for 5½″ hole,	140 pounds.
Ring-socket,	50 pounds.
Two wrenches, (each 105 pounds,)	210 pounds.
Total weight of complete set,	3990 pounds.

Cost of drilling tools.

Rope-socket,	$20 00
Sinker-bar,	38 00
Jars, 5½″,	110 00
Auger-stem,	60 00
Two bits, 5½″,	75 00
One reamer, 5½″	35 00
Two wrenches,	24 00
Temper screw,	40 00
Ring-socket,	15 00
Total cost for 5½″ tools,	$417 00

Additional for the 8″ hole at the top.

Jars, 8″,	$140 00	
Two bits, 8″,	85 00	
One reamer, 8″,	50 00	
		275 00
Total cost of complete set,		$692 00

§ 538. *Materials.*

The sinker-bar and auger-stem are made of rolled iron, collars and boxes of hammered iron, and pins of Norway iron.

The jars are faced with steel on the inside wearing surfaces and in the crotches, the other parts are of Norway iron.

The lower half of reamers and bits are made of the best steel, the upper half of Norway iron.

All of the above facts in relation to drilling tools were kindly furnished by the Ames Manufacturing Company of Titusville, Pa.

Preparing to drill and drilling.

§ 539. "*Spudding.*"—With rig put in complete running order and conductor sunk to bed-rock, the contractor is now ready to commence to drill. But the common boring tools are about 60 feet long and therefore cannot be operated by the walking-beam in the usual way until the hole is deep enough to allow them to sink beneath the derrick floor. He must "*spud*" the first sixty feet, then, without the aid of the walking-beam. To do this a short cable is run up over the crown pulley in the top of the derrick. One end of it is attached to the ring-socket and screwed to the auger-stem, the other is passed around the bull-wheel shaft two or three times and the end left free. The bull-rope is now put on and the engine started. A man stationed in front of the bull-wheels, seizes the free end of the rope coiled around the shaft, a slight pull causes the coils to tighten and adhere to the revolving shaft, the auger-stem rises in consequence until it hangs suspended in the derrick, when it is swung over the hole and lowered through the conductor to the rock. The engine is kept running and the bull-wheels revolve all the while, but the man holding the shaft-rope has full control of the tools. When he pulls on the rope, the coils at once "bight" the revolving shaft, the tools rise, when he gives his rope slack they fall, and so long as the coils remain loose upon the shaft it revolves smoothly within them and communicates no motion at all. Thus, then, alternately pulling and slacking the rope, this animated substitute for a walking-beam raises and drops the tools as much or as little as may be required, while the driller turns the drill to insure a round hole.*

§ 540. *Driving Pipe.*—When a conductor cannot be *dug* to the rock, and *drive-pipe* is to be inserted, a mall and "guides" must be provided for the purpose. The mall is made of any tough, hard log, that will dress 15 or 18 inches square, and 10 or 12 feet long. Two sides only are dressed; one end being rounded and encircled by a heavy iron band to prevent its splitting, the other having a strong staple driven into it to tie the cable in. Two pairs of wooden pins are put in each of the dressed sides, one pair near the top, the other pair near the bottom; they are two inches apart, and two inches long, and serve instead of grooves in the mall—the guides fitting in between them.

To erect the guides, draw a line on the derrick floor, through the center of the well and at right angles to the walking-beam; on this line place two 2-inch plank perpen-

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*Sometimes connections are made with the walking-beam at a less depth by using a short auger-stem and the jars without a sinker-bar above them, but a description of every variation from the general plan of drilling cannot be attempted. The intention here, is simply to describe the *usual modus operandi.*

dicularly and stay them securely at the bottom and from the sides of the derrick. They are to be 15 or 18 inches apart, according to the width of the mall to be used, and may be continued upward by adding two or three more plank, as circumstances require. They are strengthened by spiking a narrower plank on each side, leaving the center one projecting a couple of inches to enter between the pins in the mall.

After *spudding* awhile, as above described, to prepare the way for the drive-pipe, the drill is set aside—the pipe to be driven, armed at the bottom with a steel shoe, as shown in Fig. 3, Plate XIV, is put in place—the mall is attached to the spudding cable and let down between the guides, where it is alternately raised and dropped upon the casing or drive pipe by the man at the bull-wheels, precisely the same as in spudding. The casing used is of wrought iron, screwed together in thimbles the same as tubing. A heavy cap of iron is screwed in the top when driving, to prevent its being injured by the blows of the mall.

When two or three hundred feet of pipe are to be driven, as is frequently the case in some of our northern valleys, it requires a great deal of skill and judgment to put it in successfully. In these deep drivings, after a sufficient depth has been reached to admit of the introduction of a string of tools, they are put in and operated by the walking-beam in the usual way; the cable (a short one, furnished for the purpose) being coiled upon one end of the bull-wheel shaft, while the other end is left free to work the mall-rope on. To facilitate the necessary changes which must be made every time the drill is stopped and pipe driven, the lower part of the guides are cut and hung on hinges some 10 or 12 feet above the derrick floor, and when not in use may be swung up overhead out of the way of the workmen.

§ 541. *"Stringing" the Tools.*—When a sufficient depth has been reached by spudding to admit of the introduction of a full "string of tools," the spudding machinery is abandoned.

Now the coil of drilling-cable is rolled into the derrick and set upon end. The free end in the centre of the coil is tied by a connecting cord to the rope just detached from the ring-socket, and by it drawn up over the crown-pulley and down to the bull-wheel shaft, where it is fastened; the bull-rope is put in place; the engine started, and the men carefully watch and guide the cable as it is wound coil after coil smoothly and solidly upon the shaft. When this is done the end of the cable depending from the crown-pulley is secured to the rope-socket, as above described, and the full set of tools are attached and swung up in the derrick. After carefully screwing up all the joints, (the bull-rope having been unshipped,) the tools are lowered into the hole by means of the bull-wheel brake, *cc.* The band-wheel crank is then turned to the upper center; the pitman is raised and slipped upon the wrist-pin, where it is secured by the key and wedges; the temper-screw is hung upon the walking-beam hook; the slack in the cable is taken up by the bull-wheels until the jars are known to be in proper position; the clamps are brought around the cable (after a wrapper has been put on it at the point of contact,*) and securely fastened by the set-screw; the cable is slacked off from the bull-wheels, and the tools are now held suspended in the well from the walking-beam instead of from the top of the derrick, as before. Some fifteen or twenty feet of slack cable should be pulled down and thrown upon the floor to give free movement to the drill. When the drill is rotated in one direction for some time the slack coils around the cable at the well mouth; if it becomes troublesome the motion is reversed and it uncoils. Only by this constant rotation of the drill can a round hold be insured.

§ 542. *Drilling.*—Having now made all the necessary connections, it only remains to give the engine steam, and the drill will rise and fall with each revolution of the band-wheel, and commence its aggressive work upon the rocks below.

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* A small handful of untwisted strands of cable, say two feet long, is generally used for a "wrapper." It is quickly wound tightly round and round the cable with a greater thickness at the upper part of the clamps than at the bottom. This prevents their slipping and preserves the cable, which must be cautiously protected from harm above ground, or it will be unsafe to use when the defective parts have entered the hole.

From this point downward the daily routine of the work is very monotonous unless some accident occurs to diversify it. Day and night the machinery is kept in motion. One driller and one engineer and tool-dresser work from noon until midnight, (the "afternoon tour,") and another pair from midnight until noon, (the "morning tour.") Up and down goes the walking-beam, while the driller, with a short lever inserted in the rings of the temper-screw, walks round and round, first this way then that, to rotate the drill. He watches the jar, and at proper intervals lets down the temper-screw as the drill penetrates the rock. When the whole length of the screw has been "run out," or the slow progress of the drill gives warning that it is working in hard rock and needs sharpening, he arranges the slack cable upon the floor so that it will go up freely without kinks, and informs the engineer that he is ready to "draw out."

§ 543. "*Drawing the Tools.*"—After attending to the needful preliminaries, the driller throws the bull-rope upon its pulley, and quickly steps to the bull-wheel brake, while the engineer commands the throttle of the engine. The walking-beam and the bull-wheel are now both in motion, but at the proper moment one man stops the engine, and the other holds the bull-wheels with the brake—just when all the slack cable has been taken up, and the weight of the tools is thus transferred from the temper-screw to the crown-pulley. This is a performance requiring experience and good judgment, for should any blunder be made a break-down must certainly result. To loosen the clamps on the cable, and unlock the pitman from the wrist-pin and lower it to the main-sill, is but the work of a moment. Dropping the pitman raises the end of the walking-beam with the temper-screw attached to it, and throws them back from their former perpendicular over the hole, so as to allow the cable and tools to run up freely without interference with them. Steam is now turned on again, and the tools come up. When the box of the auger-stem emerges from the hole, the engine is stopped. A wrench is slipped on the square shoulder of the bit, and the handle dropped behind a strong pin fixed for that purpose in the floor;

another wrench is put on the shoulder of the auger-stem; a stout lever is inserted in one of a series of holes bored in the derrick floor in a circle having a radius a little less than the length of the wrench handle, it is brought up firmly against the upper wrench handle, thus making a compound lever of the wrench, and greatly increasing its power. Both men give a hearty pull on the lever, which "breaks the joint," or, in other words, loosens the screw joint connecting the bit with the auger-stem, so that the bit can be unscrewed and taken off by hand after it has been brought up above the derrick floor. The wrenches are then thrown off, steam is let on again, the bit rises from the hole. Now the driller throws off the bull-rope by operating a lever with one hand, * while with the other he catches the bull-wheel with the brake, holding the tools suspended a few inches above the derrick floor. At the same instant the engineer shuts off steam, or else suddenly relieved of its heavy work by unshipping the bull-rope, the engine would "run away" with lightning speed. It only remains now to hook the suspended tools over to one side of the derrick, and the hole is free for the sand-pump.

While the driller is sand-pumping, the engineer unscrews the worn bit and replaces it by one newly dressed, so that there may be no delay in running the tools into the well again when sand-pumping is ended.

§ 544. *Sand pumping.*—The "line" to which the sand-pump is attached (as before described) passes up over a pulley near the top of the derrick and thence down to the sand-pump reel, which is operated from the derrick by

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* A piece of plank five or six feet long, on one end of which three or four short pieces are spiked one on top of the other, until it has a thickness of about ten inches, with a hole for the pivot near the center, and another for a hand rope in the other end, makes a very simple contrivance for unshipping the bull-rope. A stout pin is put in the derrick floor, say two feet from the bull-wheel, and in a line toward the well mouth, and on this the lever is pivoted. As the rope plays near the floor, and travels toward the wheel, a pull on the hand rope presses the thick end of the lever against the bull-rope, and being thrown out of line, it runs off of its pulley and drops upon the bull-wheel shaft. When the bull-rope is thus thrown off, the weight of the tools would instantly reverse the motion of the wheels, and, therefore, the driller operates the lever with one hand and the brake with the other, catching the wheels with the brake at the instant the bull-rope falls.

means of hand-lever, *v* and connecting levers, *u* and *t*. While sand-pumping the pitman remains disconnected, the bull-rope lies slack on its pulleys and the band-wheel is kept constantly in motion. A slight pressure on lever *v* brings the friction pulley *w* in contact with the band-wheel, and the pulley immediately revolves, the slack sand-pump line is quickly wound up and the sand-pump, which is usually left standing at one side of the derrick, swings out to the center and commences to ascend, just now the lever is thrown back and the connection between the friction pulley and the band-wheel being thus broken the sand-pump commences to descend into the well by its own gravity. If it be likely to attain too great speed in its descent, a movement of the lever to bring the pulley either forward against the band-wheel, or backward against the brake post previously mentioned, will quickly check it, and thus the speed may be regulated at will.

As soon as the pump strikes bottom, additional steam is given to the engine, and the lever is brought forward and held firmly while the sand-pump rises rapidly from the well. The sand-pump is usually run down several times after each removal of the tools, to keep the bottom of the hole free from sediment so that the bit may have a direct action upon the rock.

§ 545. *Drilling resumed.*—After the hole has been sufficiently cleansed, the sand-pump is set to one side, the drilling tools are unhooked, and swinging to their place over the well mouth are let down a short distance by the brake, the wrenches are put on and the lever is applied to "set up" the joint connecting the replaced bit to the auger-stem. Then removing the wrenches, the tools are allowed to run down to the bottom under control of the bull-wheel brake. Connections are now made as before, the driller commences his circular march, the engineer examines the steam and the water gauges and the fire, and then proceeds to sharpen the tool required for the next "run," and thus the work goes on from day to day until the well is completed.

CHAPTER XXIX.

(Illustrated by Plates XIV, XIV bis, XV and XXXIX.)

Different methods of drilling and pumping oil wells from 1861 to 1878. Progressive improvements. Relative cost of wells, &c.

§ 546. *Every oil well shaft is naturally divisible into three sections: First*, unconsolidated deposits—surface clay and gravel. *Second*, stratified rocks containing more or less water—shales and sandstones. *Third*, stratified rocks seldom water bearing—slates, mud rocks, shales and sandstones, including the oil sands of the different districts.

The first division always requires a conductor-pipe or casing of some kind to prevent caving. It varies in thickness in different localities from four feet to four hundred feet, the deepest accumulations always being found in valleys.

The second division requires no support for the walls, but must be cased to prevent the water contained in it from following the drill down to the oil sand. Its thickness may be one hundred, or six or seven hundred feet, depending on location.

In the third division the bare rocks form the well-wall, and it is not an unusual occurrence to pierce a thickness of ten or fifteen hundred feet of these strata without encountering enough water to supply the ordinary demands of the sand-pump. In Watson's deep well at Titusville, 3300 feet feet of the wall was bare rock, but water had to be poured in at the top to moisten the drillings.

Therefore each of these divisions must be considered separately in describing the well shaft and its appurtenances.

§ 547. *On Plate XIV* the reader will find sectional drawings of three oil wells representing different periods and designed to show the improvements made in the style of drill-hole and also in its furniture since the year 1861.

As the horizontal and vertical scales of the drawings are the same, ($\frac{1}{20}$ of nature,) the sections necessarily show but a mere fraction of the total length of an ordinary well, for to thus fully represent one only 1500 feet deep, would require a roll of paper 75 feet long.

The "surface section" shows about 4 feet of the well shaft below the derrick floor, and 7 feet of the well fittings above it, and is intended mainly to explain the details above ground.

The "bottom of drive-pipe section" shows about 4½ feet of the well shaft at the junction of the superficial deposits with the bed-rock, being the termination of the *first* division mentioned at the head of this chapter.

The "seed-bag section" shows about 5½ feet at the junction of the water-bearing and non-water-bearing rocks, being the termination of the *second* division as aforesaid.

The "bottom section" shows about 10½ feet of the oil sand, being the termination of the *third* division and bottom of the well.

The artist's representations of shale, sandstone, &c., are merely illustrative, and not by any means typical.

§ 548. *The three cross sections of well mouths* drawn to natural scale (see Plate 14, bis.) will materially assist one in understanding the details of conductor, drive-pipe, casing, tubing, sucker-rods, &c., as seen in the wells on Plate XIV.

No. 1 belongs to the well of 1861, *No. 2* to the well of 1868, and *No. 3* to the well of 1878. As these drawings represent the actual dimensions of the drill holes and all the materials belonging to them that can be seen in cross sections of the well mouths, they present the facts in a very clear and comprehensible manner, and need no further comment.

Fig. No. 1.—Well of 1861.

§ 549. *The primitive style of drilling and tubing an oil well* is illustrated in Fig. No. 1, Plate XIV. It shows a simple wooden conductor* with a 4-inch "wet hole" continuing down below it to the oil sand, and a string of tubing having an old fashioned seed-bag attached to it.

By this method of drilling, as the hole was generally nearly filled with water from the gravel-beds, and kept so by it and accessions from lower water-courses, it was not possible to note exactly where the lowest water-vein was passed; consequently the point for seed-bagging became a matter of doubt, and frequently the tubing had to be drawn several times to change the position of the seed-bag, before the water could be effectually shut off.

It is desirable always to stop the water as near as possible to the bottom of the stratum where it enters the well, for if it be allowed to pass down the shaft below the impervious rocks immediately underlying its natural horizon, it may find access into some more porous stratum beneath it, and pass through into and flood adjoining wells which are seed-bagged in a higher geological plane.

§ 550. *In preparing to tube a "wet hole,"* the point at which the seed-bag is to be placed must first be decided upon. Suppose it to be 300 feet from the bottom. Then the tubing is carefully measured joint by joint, and 300 feet (less the length of the working-barrel, and whatever distance is to be left between it and the bottom of the well,†) is placed in a pile upon the derrick floor. The working-

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* The conductor plank in Fig. 1, is shown by scale as one inch thick. It should have been two inches.

† Sometimes the working-barrel was put 20 or 30 feet, or even more, from the bottom of the well, on the theory that the pump worked more effectively when placed as near as possible to the point at which the oil was supposed to come in. But this resulted in many expensive accidents, for if the tubing chanced to part above, it would be ruined by so great a fall. To prevent this an anchor, or piece of perforated tubing of the proper length should be put below the working-barrel, reaching to within three inches of the bottom, and thus, while the tubing hangs suspended from the top, (which keeps it much straighter than if it rested on the bottom,) it cannot fall to its injury if a break occurs in it.

barrel is first put in the well and held by clamps fitting under the thimble; then a swivel attached to the tubing cable, which runs up over the crown-pulley and down to the bull-wheels, is screwed into a joint of tubing, and it is elevated and screwed fast to the working-barrel; the clamps are opened to allow the thimble to pass, and the tubing is lowered into the well until the upper thimble rests upon the clamps; the swivel is unscrewed and put into another joint, which is manipulated in the same manner, and thus the work of tubing goes on until the point for seed-bagging has been reached. Now a pause is made and a leather bag like a boot-leg, two or three feet long, and when expanded exactly fitting the well bore, is slipped over the tubing and securely fastened to it by wrapping its lower end with cord. The wrapping is put immediately under a thimble, to prevent the bag from slipping up as it goes into the well, for if the bag be a little too large, or a contracted spot occurs in the shaft, the tubing may have to be forced down occasionally by levers at the top. After the bottom has been tied, the bag is packed with common flaxseed, and a ring having the same diameter as the well bore is passed over it to make sure that it is of proper size. The top is then tied like the bottom, but not so securely (for it is designed to break loose here and turn, when the tubing is to be drawn out,) and it is lowered into the hole by adding the remainder of the tubing joint by joint, as before, until the amount required to place the seed-bag in the position designed has been put in, when the head-block is screwed up, the clamps are permanently secured beneath the thimble by inserting the safety-bolt, and the tubing is ready to receive the sucker-rods.

§ 551. *The sucker-rods are introduced* in a similar manner to the tubing; but as the tubing is full of water, which the rods must displace and cause to flow over at the top as they descend, they can frequently be inserted the first time by hand, without the assistance of pulley-rope or swivel. Indeed, when they are dry and somewhat crooked they require considerable downward pressure to overcome the buoyancy of water and friction against the tubing. After the rods are in and connections with the walking-beam made, the well is left over night to allow the seed-bag time to moisten and swell so that it may fit sungly to the walls of the well.

§ 552. *When the pump is started*, it can draw its supply only from the well chamber below the seed-bag, if the latter is effective and accomplishes the purpose intended. Hence (provided there are no water veins below the seed-bag) the water is soon pumped out from the bottom of the well, the oil-rock is relieved from its pressure, and the oil and gas now meeting with no opposition, come into the chamber and pass up through the tubing as the water exhausts.

§ 553. *Very grave defects* were soon discovered in this method of managing oil wells. Ordinary wear and tear of machinery or accidental break-downs often made necessary the removal of the tubing before repairs could be made, and this could not be done without disturbing the seed-bag and again letting down the surface water in full force upon the oil-rock. In new wells and new territory this might be fraught with little damage; but in an old district, after large bodies of oil had been drawn from the sandrock, it often proved disastrous. Consequently some plan had to be devised whereby the tubing could be withdrawn at pleasure without disturbing the seed-bag, and the first one adopted was to shut the water off by inserting 3¼-inch casing, as will be described below.

Fig. No. 2.—Wells of 1868.

§ 554. No great changes were made in the style of drill hole or the methods of drilling between the years 1861 and 1868. All parts of the machinery and tools employed were made heavier and stronger, of course, for the shafts were larger and deeper, but the wells of 1868 were still drilled as before, through a simple drive pipe or conductor, the holes being full of water while drilling, and remaining so until the pumping machinery was put in motion.

Fig. 2 shows a cast iron drive-pipe* instead of a wooden conductor, through which a plain 5½ inch hole was sunk to the oil rock.

§ 555. *To introduce the* 3¼″ *inch casing* was the first step in preparing to tube a well of this date. On the bottom of it was affixed the seed-bag, and consequently the length of casing required depended upon the distance the base of the water bearing rocks lay below the suface. In some wells one hundred feet would suffice, in others three or four hundred were necessary. Sometimes an ordinary seed-bag was used, and sometimes a patent water-packer consisting of a heavy iron ring a quarter of an inch smaller than the size of the hole, supporting a leather cup similar to the leathers on the cup valve used in the pump barrel. The rim of the cup is thrown open and held against the walls of the well by static pressure as soon as the water below it commences to exhaust.

But as the casing was a *permanent fixture* intended to remain in place for years, or as long as the well lasted, many well owners preferred to put on both styles of seed-bags one above the other as shown in Fig. 2.

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*The following note from Report II, page 136, may very properly be reprinted here:

" Where it is suspected that the floor of the drift lies too deep to be reached by digging, cast iron "drive-pipe" is used. This pipe is cast in sections about 9′ long. A space of 4″ at each end is carefully turned in a lathe to a certain gauge, and the end is cut smoothly at right angles to the axis of the pipe, so that the joints will stand perpendicularly one upon the other. A joint of pipe is placed on end in the center of the derrick between two "guides," which have been temporarily erected for the purpose of driving it. A heavy "mall" working between these guides is raised and dropped upon the pipe, slowly forcing it into the ground, precisely as piles are driven for docks, bridges, &c. When the top of a joint has been driven to the level of the derrick floor a band of wrought iron, made to fit the turned ends of the pipe, and heated red hot, is quickly slipped upon the end of the driven pipe and another joint at once set up. The contraction of this band in cooling holds the two joints firmly together, and the driving process then goes on. In this way joint after joint is added and driven until solid rock is reached. As many as 23 joints have been used in a well. Great care is required when so long a "string of pipe" is driven to keep it straight and perpendicular, a broken bank, or a large bowlder encountered may cause the pipe to so far deviate from the perpendicular as to necessitate the abandonment of the well. To avoid this the pipe should be frequently cleaned out by the drill while being driven.

The casing-head was screwed to the top of the casing and formed a substantial head block for the tubing to rest upon. It was very similar to the one shown in Fig. *a*, Plate XXXIX.

§ 556. *Tubing.*—The work of casing completed, the next step was to insert the tubing. As the inside diameter of casing was 3¼ inches, and the outside diameter of tubing thimbles or collars 2¾ inches, the latter moved freely inside of the former, and could be put in quickly, there being no delay for seed-bagging, and no measurements necessary. An anchor was put below the working-barrel, and the tubing added on until it struck bottom, when a mark was made on the tube projecting from the well mouth, and the whole string drawn up again to the first thimble. After taking off the first joint, another of proper length, with the casing flange attached to its top was substituted for it, so that when lowered again into the well the tubing would be suspended from the casing head, and the anchor swing just clear of the bottom.

§ 557. *Pumping.*—If the seed-bag proved effective, the space between tubing and casing was quickly relieved of water when the pump was put in motion, and as its surface lowered in the well a partial vacuum formed above it, as was plainly demonstrated by the force with which the air rushed into the well chamber on opening the stop cock at the casing-head. When the water surface drew down below the oil vein, a reaction occurred; the well chamber quickly filled with gas and oil, the former turbulently seeking an exit at the casing-head, while the latter was drawn into the pump barrel as the water at the bottom exhausted, and gradually filling the tubing from the bottem expelled the water at the top, and made its appearance at the delivery pipe in due time.

§ 558. *Water Pump.*—In situations where water was needed for boiler use, a ¾ inch pipe and pump were run down between the casing and well-wall into the water chamber above the seed-bag. Its little sucker-rod of ¼ inch pipe or of iron rods was attached by a clamp to the polished rod* of the oil well, and thus by working constantly furnished all the water required.

§ 559. *Defects in these methods of managing wells.*—Although the well of 1868 was a great improvement over the well of 1861, still it did not meet all the requirements of the situation. In deep shafts the presence of water in the hole greatly retarded the speed of drilling, and it was realized that a column of water a thousand or fifteen hundred feet in height must have an injurious effect upon the oil rock. Experience proved also that many accidents were possible which necessitated the drawing of the casing before the wells could be put in running order; for the cased part being only 3¼ inches in diameter, and that below it 5½ inches, adequate fishing tools could not be introduced when any serious accident happened from dropping tubing, &c. And again, if the well needed to be cleaned out or sunk deeper only a 3⅛ inch hole could be drilled, and that with tools necessarily so light that the work was slow and unsatisfactory. These and other considerations naturally led to the experiment of drilling through large casing, and this was found to be so great an improvement over the old plan that it soon entirely superseded it.

No. 3.—Wells of 1878.

§ 560. This well differs from the last described in many particulars. Its drive-pipe consists of an eight inch wrought

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*The polished rod is a bar of cold rolled iron 12′ long and 1⅛″ in diameter, having on one end a box to fit the sucker-rod pins, and on the other a thread for a swivel. In conjunction with the adjuster, it affords a ready means for connecting the sucker-rods to the walking-beam without the delay of cutting the rods to the exact length required. The adjuster is attached by its bearing to the walking-beam, and by means of set screws can be clamped immovably to the polished rod at any point, when it becomes a cross head pivoted upon the walking-beam, and supporting and operating the sucker-rods in the well. After the sucker-rods are put in the tubing, and the working-valve rests upon the standing-box at the bottom, the upper joint of rods may project above the well mouth a few inches or three or four feet. The walking-beam is now put in position, and the polished rod is run up through the adjuster and screwed to the sucker-rods. Then by means of the sucker-rod rope and swivel on top of the polished rod, the whole string of rods is raised as much as is required to give the necessary play between the pump valves, when the polished rod is clamped in the adjuster, the swivel is detached and the well is ready to pump.

iron tube armed at the bottom with a steel shoe and driven to the rock as described in the previous chapter. The 8 inch jars, bit and reamer, mentioned among the drilling tools are employed while sinking this pipe. After it has been driven to bed rock the 8 inch hole is continued down to the base of the water bearing strata, one, two, or three hundred feet as the case may be, when drilling is suspended and another tube 5⅝ inches in diameter, (technically called "the casing,") is inserted. Before stopping to case, however, the bits are drawn down gradually to reduce the diameter of the hole from 8 inches to 5½ inches, thus forming a beveled shoulder for the casing to rest upon, into which the collar fitted to the bottom of the casing for that purpose, is ground and seated by revolving the casing a few times while it is resting on the bottom. This usually produces a water-tight joint, but if a little sand-pump sediment be thrown in between the casings it will settle at the bottom and make the joint still more secure.

After casing, the 8 inch jars and bits are laid aside for the regular 5½ inch tools, which pass freely through the casing and cut a hole of that diameter to the bottom of the well.

Quite frequently veins of water are encountered after a well is cased, and if it does not exhaust by sand-pumping, drilling is stopped, the casing drawn, the hole reamed out to 8 inches and more casing put in. In new territory where the depth of the water-bearing rocks is not known, this operation may have to be repeated several times. As wells are now drilled, a contractor is not allowed to continue his work unless he succeeds in effectually shutting off all water before striking the oil rock.

§ 561. *Deep "wet wells"* seldom give much show of oil either on tools or in the sand-pump while drilling, and it is only after they are tubed and exhausted of water that the oil makes its appearance. But in dry cased wells, the moment a vein of oil is tapped it gives notice of its presence and frequently flows out at the surface before the tools can be drawn. Thousands of dollars have been spent in testing hopelessly unproductive wells that were drilled "wet," because it could not be known until they were tubed and tested, whether they contained oil or not. But with dry casing the owner knows when the well is finished whether it will be productive or not, and all the testing required can be done with a sand-pump. Thus a considerable item of expense is saved to the operator who is so unfortunate as to get a genuine "dry hole" or "duster."

§562. *The average cost of drilling cased wells*, (especially if we take into account the reduced liability to accidents from tool sticking, &c.,) is probably but little if any greater than it would be if they were drilled wet. The additional expense of boring an 8 inch hole two or three hundred feet, and the increased cost for large casing, is often fully offset by the time and money saved in more speedily drilling the remainder of the well. Quite an item in the cost of fuel is also sometimes realized, for a vein of gas may be struck several hundred feet from the bottom of the well, which will fire the boiler until the work is finished.*

§ 563. *Some of the obvious advantages* which a cased well has over the well of 1868 are these:

Fishing operations can be successfully prosecuted, for the bore is of the same size all the way down.

A deep hole, five and a half inches in diameter, can be carried on down without letting the surface water in.

Torpedoes can be put in safely and with better efect.

The water-packer can be introduced on the tubing at

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* When gas is obtained from the upper rocks in sufficient quantity to furnish fuel for the boiler during the remainder of the drilling, it is conveyed to the boiler through a two-inch pipe, connected with the casing beneath the derrick floor, as seen in Fig. 3. Just before this gas-pipe enters the fire-box, a quarter-inch steam-pipe from the boiler passes into it through a tee, and terminates in a quarter-inch elbow, which is thus held in the center of the two-inch pipe. Another piece of quarter-inch pipe, with the opening in one end reduced to less than an eighth of an inch, is then screwed into the elbow with the reduced end pointing toward the fire-box. When steam is let into the small pipe, it vents in the center of the gas-pipe and forms an "injector," which forces a current of gas and steam into the fire-box, while the draft occasioned by it in the lead-pipe, draws in the gas from the well, although the well mouth is entirely open, and also prevents all danger from "back suction." Without an "injector" the burning gas is liable to run back through the delivery pipe to the well mouth, where it will explode and set the rig on fire.

any point desired, either to confine the oil and gas and induce them to flow, or simply to prevent the seepings of salt water which sometimes come in below the casing in quantities so small as to be scarcely noticed while drilling, from reaching the bottom of the well, to the detriment of its oil-production.

Geological Sections.—Plate XV.

§ 564. Placing this plate by the side of Plate XIV, we see that the geological structure of the areas operated upon at different periods has largely directed and influenced improvements in the methods of drilling and the appliances for pumping oil wells. The system of operating which met the requirements of the situation in 1861, would have been worse than useless in the deep territory of 1878. The problem forced upon the oil producers has been how to accomplish a greater depth of drilling without increasing the cost of his well; and it has been worked out with such success by the thousands of energetic, inventive minds, engaged in the business, that the average cost to-day of a well 1500 feet deep is less than one of 500 feet was in 1861, and our present wells are also much more fully equipped, and with a better class of machinery.

§ 565. *A little profile section* at the bottom of Plate XV shows that the additional depth of drilling was not required alone on account of a greater altitude of areas drilled upon, but was due mainly to the southwesterly dip of the oil sands.

§ 566. *Geographical positions of the vertical sections.*—Section No. 1 is typical of the geological structure on Oil creek, near the celebrated Noble well; No. 2, of the higher table lands at Pleasantville; and No. 3 is made from the record of Sutton well, No. 4, near Petrolia, in Butler county.

The distance from No. 1 to No. 3 is about 36 miles. The well mouth of No. 3 is only 324 feet *higher* above ocean level than the well mouth of No. 1; but the oil sand of No. 3 is 846 feet *lower* than the oil sand of No. 1. Therefore over 70 per cent. of the additional depth of drilling is occasioned by the dip of the oil sand.

Page Plate No. XXXIX.

§ 567. *Explanation of Figures*—Illustrating some of the details of oil-well machinery mentioned in the preceding pages:

	Cost.
a, Casing head for 5⅝ in. casing,	$7 65
b, Sand-pump pulley,	3 25
c, Working-barrel, extra heavy brass, 1¾″ dia. (for 2″ tubing), 5 feet long,	21 75
d, Upper valve for 1¾ in. chamber,	7 50
e, Lower valve for 1¾ in. chamber,	4 00
f, Water-pump and valves, 1 in. dia.,	14 75
g, Rivet catcher,	2 35
h, Bull-rope couplings, 3 holes, for 1½″ rope,	1 33
Bull-rope couplings, 4 holes, for 2⅛″ rope,	1 90
i, Armor's water packer,	21 35
k, Jars. See Chapt. XXVIII.	

The cuts and price-list are taken from catalogue of Jarecki Manufacturing company, dated 1876. It will be seen that some of these prices vary considerably from those given in "cost of well at Bradford," in 1878, when well fittings were down to their lowest figures.

§ 568. *The rivet-catcher* is a perforated cup, to be attached to the valve stem above the valve, and is designed to catch broken rivets, in case any should work out of the sucker-rod joints, and prevent them falling upon the working valve, where they would quickly wedge and score the working-barrel—spoiling it, perhaps, for future use, before the pumper was aware that anything was wrong.

§ 569. *The water-packer* only came into general use about the year 1875. It is one of the several improvements upon the old-fashioned seed-bag, made possible by and naturally following the use of dry casing in wells. Its design is to prevent any water that may seep into a well below the casing, from gaining access to the oil sand, and to stop the ascent of gas on the outside of the tubing. The oil and gas are thus confined in the well chamber, below the water-packer, and the diameter of the tube through which they must pass to reach the surface, is reduced from $5\frac{1}{2}$ inches to 2 inches. As a result, many wells flow when treated in this way, that otherwise would require pumping.

A number of patented packers are in use. The one shown above is simple in construction and effective in operation. It is made of malleable iron and rubber. The top piece, 1, is connected with the bottom, 3, by a slip-joint, the upper tube, 1, passing through the rubber band, 2, and sliding inside of the lower tube, 3. Fig. *i* shows the packer open; to close it as in the well, the top is shoved down so that the flange of 1, rests upon the rubber band, 2. This forces the cone into the rubber band and compresses it against the well walls, and causes the lower part of 1 to project below 3, and on this projecting end of 1 is affixed the working-barrel, when one is to be used. To 1 is attached the 2″ tubing reaching up to the well mouth, and to 3, the "anchor" extending down to the bottom of the well. The length of "anchor" decides, of course, the point at which the well will be packed, for when it strikes bottom the weight of tubing above the packer telescopes the slip-joint, expands the rubber and shuts off all communication between the annular space outside of the tubing above the packer and the well chamber below it.

§ 570. *The "anchor" is* made of a piece of perforated $3\frac{1}{4}$″ casing, say 6′ long (it must be long enough to receive the working barrel.) This is screwed on to 3. A reducer is inserted in the bottom of the casing, and a proper amount of 2″ tubing is added to make the anchor of the requisite length.

§ 571. "*Packed Wells.*"—A large number of wells in the Bradford district are "packed" in this manner at the top of the oil sand, and they flow periodically several times a day without requiring any attention, for months at a time, except to watch the receiving tank which quickly tells when a falling off in production occurs and an "overhauling" is necessary.

Cost of an Oil Well in 1878. Bradford District.

§ 572. An extensive oil producer in Bradford, McKean county, gives the following figures in detail to represent the actual cost of drilling and equiping an oil well in December, 1878. But it should be understood that this was a period when both labor and well machinery were at their lowest values:

Carpenter's rig, complete,	$350
Belt, bull-rope, engine "telegraph," water pipes, steam pipes and fittings to connect boiler and engine,	100
Boiler, (20-horse power,) and engine, (15-horse power,) on ground,	750
Contract for drilling, contractor to furnish fuel, tools, cable, sand, pump line, &c., at 65 cents per foot, say 1500′,	975
Casing say 300′, at 80 cents per foot,	240
Tubing, say 1600′, at 20 cents per foot,	320
Torpedo, (almost universally used before tubing,)	100
Packer,	25
Working barrel,	8
Casing head,	3
Tees and elbows to make tank connections,	5
One twenty-five barrel tank,	25
One two hundred and fifty barrel tank,	110
Tank house,	25
Expense of tubing and packing well,	20
Expense for hauling tubing, material, &c., say,	50
Total cost of well, flowing,	$3,106

In the above well no "drive pipe" was used, a short wooden conductor set by the rig builder being all that was required. In localities where from 100′ to 280′ of drive pipe casing, costing, $1 80 per foot is required, the cost of a well is increased accordingly.

§ 573. If the well is to be pumped the following items are to be added:

1500 feet of sucker rods @5½ cents,	$82 50
Valves for working barrel,	7 00
Polished rod,	2 50
Stuffing box,	1 50
Adjuster,	5 00
Tees and elbows, &c., say,	2 00
	$100 50

§ 574. The necessary tools and implements for handling the tubing and sucker-rods, are—

Large pulley block,	$11 00
Tubing elevators,	9 00
Three pairs of tubing tongs,	10 00

Tubing cable,	25 00
Sucker-rod rope,	11 00
Sucker-rod wrenches and elevators,	3 50

Cost of an Oil Well 1865-1872. Butler District.

§ 575. The following figures, taken from the ledger of a company which operated largely on the Butler belt, will convey a very good idea of the relative cost of drilling oil wells from 1865 to 1872:

Year.	*Well.*	*Depth.*	*How drilled.*	*Cost.*
1865	No. 1,	1120'	By day's work,	$11,069 84
1866	2,	1400'	do. do.	11,441 94
1868	3,	1111'	do. do.	6,116 16
1870	4,	1262'	do. do.	10,405 62
1870	5,	1105'	do. do.	7,827 88
1871	6,	1290'	Drilling contract, $3,500,	8,132 86
1871	7,	1414'	do. 3,500,	8,401 41
1871	8,	1345'	do. 3,600,	9,047 80
1871	9,	1065'	Everything furnished by contract,	5,750 00
1872	10,	1300'	Everything, $6,700; extras, $317 12,	7,017 12
1872	11,	1200'	Everything, 6,300; extras, 380 95,	6,680 95
1872	12,	1212'	By day's work,	6,557 04
1872	13,	1402'	do. do.	6,671 06

Nos. 9, 10 and 11 were put down by contract; the contractor in each case to furnish the rig, boiler, and engine, casing, tubing, and sucker-rods—and to drill the well to the oil rock and tube and test it for the price named. The extras are for drilling deeper after finding the oil sand unproductive.

Torpedoes.

§ 576. Torpedoes have been so often referred to in these pages, and they are now employed so generally in oil wells as soon as drilling is completed, and before the tubing is inserted, that it seems proper to close the details of drilling and pumping with a short account of the invention, and a description of the manner in which it is applied.

The following quotations from "The Early and Late History of Petroleum," by J. T. Henry, 1873, are presumed to contain the facts in relation to its early history, as the article was prepared under the eye of the inventor.

"In 1862, Col. E. A. L. Roberts, then an officer in the volunteer service, and with his regiment in the army of the Potomac, in front of Fredericksburg, conceived the idea of exploding torpedoes in oil wells, for the purpose of increasing the production. He made drawings of his invention, and in November, 1864, made application for letters patent. In the fall of the same year he constructed six torpedoes, and on the 2d of January, 1865, he visited Titusville to make his first experiment. Col. Roberts' theory was received with general disfavor, and no one desired to test its practicability at the risk, it was supposed, of damaging a well. On the 21st of January, however, Col. R. persuaded Capt. Mills to permit him to operate on the Ladies' well, on Watson Flats, near Titusville. Two torpedoes were exploded in this well, when it commenced to flow oil and paraffine. Great excitement of course followed this successful experiment, and brought the torpedo into general notice. The result was published in the papers of the oil region, and five or six applications for patenting the same invention were immediately filed at Washington. Several suits for interference were commenced, which lasted over two years, and decisions in all cases were rendered declaring Col. Roberts the original inventor.

"Notwithstanding the success of the first experiment, operators were still very skeptical as to the practical advantages of torpedoes, and it was not till the fall of 1865 that they would permit the inventor to operate in their wells to any extent, from fear that the explosion would fill them with rock, and destroy their productiveness.

"In December, 1866, however, Col. R. exploded a torpedo in what was known as the 'Woodin Well,' on the Blood farm. This well was a 'dry hole,' never having produced any oil. The result of the operation secured a production of twenty barrels per day, and in the following month, January, 1867, a second torpedo was exploded, which brought up the production to eighty barrels. This established for the torpedo, beyond question, all that Col. Roberts had claimed, and immediately the demand for them became general throughout the region."

This historical sketch is followed by a tabular statement showing the effects of the first thirty-nine torpedoes exploded, and giving the names and locations of the wells in which they were used. According to this statement, the flow of six of these wells was greatly increased—the smallest to the extent of 125 barrels, the largest 200 barrels—while the others ranged from four to ninety barrels. In the aggregate the thirty-nine torpedoes caused an increased production of 2227 barrels, or an average of over fifty-seven barrels per well. It must not be understood, however, that this increase was permanent; for although wells may flow or pump freely immediately after being torpedoed, in a few weeks or months, at most, they will drop back to their natural production again.

§ 577. The torpedo as first used consisted of a simple tin case or shell filled with gunpowder, and having a percussion cap fixed in the upper end of the case in such a manner that a slight blow upon it would cause an explosion. It was lowered into the well by a cord or wire, and held suspended at a point in the sandrock where the oil was believed to enter. When in proper position, a cylindrical weight through which the wire passed, was dropped from the well-mouth, and guided by the wire, fell upon the cap and exploded the charge. The water in the hole acted as tamping, confining the effects of the explosion to the immediate vicinity of the torpedo, and thus excellent results were obtained.

Since then every kind of explosive has been employed, and every device which ingenuity could invent has been tried by parties endeavoring to introduce rival torpedoes without infringing upon the first patent. But all these efforts have failed. The Roberts' patent has been sustained in every contest in the courts and the original torpedo with such improvements as practical experience has suggested is the only one now in use.

But nitro-glycerine has been substituted for gunpowder, dynamite, and other explosives, it being more easily introduced and more certain in its effects. The charges exploded in deep wells to-day are enormous when compared with those of a few years ago. Formerly a shell holding from two to ten quarts was considered a good shot, but now from thirty to sixty quarts (100 to 200 lbs.) are required. The shells or cases containing the explosive are sometimes over twenty feet long; but large charges are generally inserted in sections. If, for instance, the oil sand is thirty feet thick, and it is desired to cover the whole of it with one explosion, the process will be something like this: Take a case, say fifteen feet long, and attach an "anchor" on the bottom corresponding in length to the depth of the well-pocket below the oil sand. Introduce the case into the hole, and holding it suspended at the well mouth, fill it with water. Then pour in the nitro-glycerine until the water has been displaced and the shell is full. Lower this carefully by the torpedo wire to the bottom of the well and unhook from it, thus leaving it standing upon the bottom and covering the lower fifteen feet of the sandrock. Now fill another shell in the same manner, and in the top of it affix the device containing the percussion cap to explode the charge. Lower this also into the well, and when it rests upon the one already put in, unhook the wire and withdraw it.* Nothing now remains to be done but to drop into the well a weight made for that purpose and—*run;* for sometimes these explosions, even at a depth of 1800 feet or more, are followed by a discharge of water, oil, mud, and broken rocks—some pieces of which are nearly the full size of the well-bore—which shoots up higher than the top of the derrick, and makes it disagreeably exciting to those who happen to be too near when the miscellaneous shower comes down. With nitro-glycerine the firing of one charge explodes all the others in the well, and hence a large surface of rock can be covered by it with more ease and certainty than it could if any other explosive were used.

§ 578. The simplicity of the torpedo, and the method of introducing and exploding it, and a desire to evade the payment of the large profit or royalty demanded by the

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*In cased holes containing but little fluid, it is necessary to withdraw the wire before the shell is exploded, otherwise it is driven up into a wad and destroyed. In this shape it may lodge somewhere in the well and cause considerable delay in removing it before the tubing can be inserted.

Roberts' Torpedo Company, (but which royalty, after all, does not seem so extortionate when the immense advantage the invention has been to the oil producer and the extremely hazardous nature of the business are taken into consideration,) have induced many well-owners to buy the materials and prepare their own torpedoes. These are secretly put into the wells at night by professionals called "moonlighters," who follow the business of inserting them, charging from five to ten dollars for their services. But this kind of work generally ends in an injunction from the court, and a costly settlement with the torpedo company.

Another shrewd way of defrauding the patentee has been practiced to a considerable extent by using what has been appropriately named a "sleeper." An operator orders from the torpedo company a small ten-quart shot, to be put in on a certain day, "just to stir up the well a little." He then procures a case and say thirty quarts of nitro-glycerine from some of the "moonlight manufacturers," and secretly lowers it to the bottom of the well some time during the night previous to the day appointed. When the company's agent arrives everything is in readiness for him, and he quickly shoots off his ten-quart shell and goes away, little thinking that he has exploded forty quarts of nitro-glycerine in the well, while the company receives their royalty only on ten.

CHAPTER XXX.

On the Glacial Drift.

§ 579. Many curious and interesting facts relating to the *Drift deposits** of northwestern Pennsylvania presented themselves to notice at the commencement of the present survey.

Heavy surface accumulations were frequently met with by oil miners where least expected, both on ridges and in valleys. The beds of streams north of the main range of outcropping carboniferous conglomerate were found to be more deeply filled with Drift than their southern outlets; and it often happened in these northern valleys that a conductor hole could be *dug* to bed rock in one well, while a hundred feet or more of *drive-pipe* would be required in another but a few rods from it.

What might be the significance of these facts, with others bearing upon the topography and drainage of the country, no one could tell; for they were then too meager and disconnected to be intelligently discussed or understood. Since that time I have embraced every opportunity offered for studying these phenomena; but as my observations have been necessarily restricted to a very small portion of the drift-covered area stretching across the continent at this latitude from the Atlantic to the Mississippi valley, the conclusions based upon them may not always be in accord with those drawn from a larger field of experience. Still, I trust that some of the local details about to be presented may be found to be of sufficient novelty and interest, even to those who possess a wider knowledge, and who have had enlarged opportunities for investigations in this branch of

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* We use the term "Drift," in a very general way in these chapters—and perhaps rather improperly sometimes—to designate any and all of the unconsolidated deposits lying above bed rock.

our science, to secure for them a thoughtful consideration, and for my effort in their presentation, however faulty it may be, a charitable criticism.

§ 580. A synopsis of some of the principal inferences which appear to be reasonably deducible from a study of the topography, drainage, and drift deposits of northwestern Pennsylvania, may be given in a few brief paragraphs in advance of the detailed facts.

1st. That a system of drainage was here inaugurated by the post-carboniferous uplift, the *main features* of which are still preserved; although many important changes have since occurred, by which some of the old outlets have been closed and new deliveries established, so that certain streams which formerly ran north now fall in an opposite direction, and the drainage of large areas has thus been transferred from the great valley of the lakes to the Gulf of Mexico.

2d. That there was a triplicate water-shed then, as now; one portion contributing to the Lake Erie basin, another to the Mississippi valley, and the third to the Susquehanna valley.

3d. That the pré-glacial conditions of sub-aerial erosion must have been in operation for long ages, seeing that some of the ancient streams are found to have cut out channels for themselves at least 1200′ in depth and of regular gradient, notwithstanding the varying structure of the rocks over which they flowed.

4th. That then succeeded a *glacial epoch*, during the continuance of which the whole northern country was covered with an unbroken canopy of ice, and the gorges of the Lake Erie slope were partially filled up (indeed some of them were entirely obliterated) with disrupted fragments of mountain-top and cañon-wall, intermixed with immense burdens of foreign detritus, brought down on the crystal currents from the Azoic highlands of the north. This also was an age of very great duration; and to be studied properly, it should be divided into 1, a period of accumulation and advance, 2, a period of maximum development and intensest cold, and 3, a period of recession and decay.

5th. That during the Ice Age the basins of the Great

Lakes were formed by the widening and deepening of old river valleys through the agencies of ice and sub-glacial water; the northeastern outlet was obstructed, holding back the sub-glacial waters and throwing the overflow across the low spots in the ridge at the south, where new avenues of drainage were brought into operation at different points and at various elevations, and maintained for unequal periods of time—dependent upon the accidents of northeastern obstruction and the topography of the country where the outlets occurred. That during the age of recession, while some of the ancient channels were being widened and enlarged, others were being partially or completely filled with glacial detritus; while some of the southern outlets were being abandoned by reason of lowering water-levels to the north, others were still kept in operation; so that, when the ice finally disappeared, a new system of drainage had been established, according to which the waters of the four basins shown on Plates 1 and 2 were diverted from their former outlets into the valley of the Lake Erie basin, (as seen on Plate No. 2,) and made to deliver through the Allegheny and Ohio rivers into the valley of the Mississippi, (as seen on Plate No. 1.)

6th. That since the Ice Age, atmospheric agencies of erosion have been effectively at work upon indurated rock and glacial debris; deepening outlets and bursting barriers have drained nearly all of the lakelets left in the trails of receding glaciers, and lowered, by successive stages, the whole water-surface of the basin of the lakes. Thus the mixed foreign and local detritus of the ice age has been rearranged and modified in its character, according to the measure of these accidental conditions to which it was subjected, and the rugged pre-glacial orographic features of the country have been sculptured into more graceful outlines, while the truncated sub-structure remains to point out the probable topography of the country anterior to its envelopment by ice.

7th. That no phenomena have thus far presented themselves to notice in this district, which *absolutely require* for their explanation the hypothesis of submergence beneath ocean level since the close of the Carboniferous period. Changes of levels may and probably have occurred; but the present outlines of topography and drainage do not demand such a supposition; and the deposition of the alluvions appear to be as susceptible of explanation without them as with them.

§ 581. It may be well to add here, also, that I have studied the phenomena of ice-action, as they are exhibited in this district, on the theory that the natural laws which govern the movements of water are not abrogated by its congelation, but merely modified and retarded in their action; that owing to the properties of plasticity, viscosity and regelation possessed by ice, there may be different currents of it, as we know there may be of water, moving with different velocities, one above the other, and gliding either in parallel lines, or at divergent angles; the laws of velocity, gravity, and friction operating the same in ice as in water, but not with equal degrees of activity.

Drainage of the Chautauqua Basin.

§ 582. All the drainage of the Chautauqua Basin now centers in the Allegheny river at Irvineton, in Warren county, Pa., as described in Chapter 1, and delineated on Plate No. 1. But, that this channel could not have been the outlet for the pre-glacial basin, which varied but little from this in outline (See Plate No. 2) without intermediate unequal or contorted elevations and depressions of the earth crust, of which there is now no evidence, seems to be decidedly apparent from a study of the following facts:

§ 583. The valley of Tunangwant creek, a stream rising in McKean county, Pa., and trending northerly until it joins the Allegheny river at Carrollton, in Cattaraugus county, N. Y., has been very thoroughly pierced by oil well shafts within the last three years, thus affording a good opportunity for making actual measurements of the thickness of drift lying between the present water-plain and the bottom of the ancient valley.

§ 584. The table below shows the maximum thickness at stated points between De Golier and Irwin's Mills, a distance of 14 miles; and the borings over this section have been so numerous that the results obtained cannot be questioned.

§ 585. Elevation above ocean of the present and ancient valley-floors of the Tunangwant creek, with the thickness of drift now found in the valley.

	Well mouth.	Drive pipe.	Old floor.
De Golier,	1490	155	1335
Bradford,	1440	218	1222
Tarport,	1425	240	1185
State Line,	1415	255	1160
Limestone,	1405	270	1135
Irwin's Mills,	1400	280	1120

Supposing the water-plain slope to very nearly represent the slope of the water surface, we get the following:

§ 586. *Approximate fall in present stream.*

ELEVATION.		Total fall.	Dist. miles.	Rate per mile.
1490	De Golier to Bradford,	50	3	16′ 8″
1440	Bradford to Tarport,	15	1½	10′ 0″
1425	Tarport to State Line,	10	2½	4′ 0″
1415	State Line to Limestone,	10	3	3′ 4″
1405	Limestone to Irwin's Mills, (1400,)	5	4	1′ 3″
	Average:			
1490	De Golier to Irwin's Mills, (1400,)	90	14	6′ 5″

§ 587. *Slope of Ancient Valley-floor.*

ELEVATION.		Total fall.	Dist. miles.	Rate per mile.
1335	De Golier to Bradford,	113	3	37′ 8″
1222	Bradford to Tarport,	37	1½	24′ 8″
1185	Tarport to State Line,	25	2½	10′ 0″
1160	State Line to Limestone,	25	3	8′ 4″
1135	Limestone to Irwin's Mills, (1120,)	15	4	3′ 9″
	Average:			
1335	De Golier to Irwin's Mills, (1120,)	215	14	15′ 4″

§ 588. It will be observed in the above tables that the superficial deposits in the bottom of the valley thicken as they are followed down stream or northward, from 155 feet to 280 feet in a distance of 14 miles; and that the old valley floor has more than twice as rapid a fall as the bed of the present stream.

As the bordering hills rise abruptly from the modern water-plain to the height of 800 feet or more, it follows that the ancient current which eroded this valley must have flowed through a cañon not less than 1100 feet deep, (saying nothing about the degradation which the hilltops may have suffered,) excavated entirely by its own and atmospheric agencies.

§ 589. At Irwin's mills our chain of closely connected vertical measurements ends; but we have already caught a glimpse of the underground structure of drift-filled valleys in studying the preceding brief tablet of geologic history, as thus interpreted by the drill, which will be of great assistance in our further investigations of the subject.

The Tuna joins the Allegheny river at Carrollton, three miles below Irwin's* mills. In view of the above exhibit, it seems safe to say that here will be found at least 300 feet of drift, which puts the old valley floor at 1100 feet above tide.† Now, from this starting point, (since all of the upper branches of the Allegheny must deliver their waters here in any event,) let us trace the ancient stream and see if an outlet can be found.

If the water flowed down the present valley of the Allegheny, then, provided no changes in levels have occurred, that valley must contain about 300 feet of drift-filling all the way to Pittsburgh, and below; for the old stream could hardly have had less fall than the present one. And it should be expected, also, that the general topographic features of the valley throughout the whole distance would afford unmistakable evidences of the former existence of this deep cut and important artery of drainage.

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* This is the popular abreviation for the aboriginal Tunangwant.

† Round numbers are sufficient for the purposes of a general discussion of this kind.

§ 590. Following the lead of the current from Carrollton and examining the characteristics of the valley as we proceed, a broad river flat, sometimes a mile or more in width, and with every appearance of being deeply underlaid with drift, is found to extend all the way to Great Bend, 43 miles from Carrollton (and nine miles above Warren), in Warren county, Pa.

At Great Bend the side-walls are high and rugged, standing only about 1200 feet apart, and the stream is contracted to a width of 350 feet. Here, in an attempt to put down an oil well, the floor of the old valley is said to have been reached at an elevation of 1170 feet above tide; but with only the record of one well at our command we cannot be sure that this represents the deepest part of the old excavation. The surroundings, however, do not indicate any great depth of drift-filling at this bend.

From Great Bend toward Warren, for five miles, the flats continue narrow, with high, steep side-walls, lined on their slopes and at river level with huge blocks of conglomerate and sandstone, derived in many places from cliffs still scarped near their summits in massive layers from 20 to 40 feet thick. Then the valley widens again, assuming the same aspect as that presented above Great Bend; and thus it continues down to Warren and Irvineton, and further on for several miles towards Tidioute.

In the vicinity of Thompson's station, steep side-walls again encroach upon the river, and from this point southward the bottoms occupy a comparatively narrow defile, exhibiting a marked contrast to the broad valleys at the north.

From Tidioute, in Warren county, to Parker's, in Armstrong county, the river terraces and islands have been thoroughly drilled upon, disclosing not more than from 30 to 50 feet of Drift below water-level, at any point; by which it is shown that the *old* river bed runs nearly parallel with the *new* one, through all this portion of the valley, and that the *new flood plain* lies approximately about 40 feet above the old one. The following table will further illustrate this:

§ 591. *Altitude above Ocean Level, of the Ancient Floor of the Allegheny River.*

	R. R. levels.	Depth of Drift.	Ancient floor.
Carrollton, Cattaraugus Co., N. Y.,	1400	300±	1100±
Cold Spring, " " (est.),	1330	315±	1015±
Great Bend, Warrren Co., Pa.,	1230	60	1170
Warren, " "	1200	100	1100
Irvineton, " "	1168	60	1108
Tidioute, " "	1113	50	1063
West Hickory, Venango Co., Pa.,	1092	45	1047
Tionesta, Forest Co., Pa.,	1060	50	1010
President, Venango Co., Pa.,	1048	40	1008
Henry's Bend, " "	1035	45	990
Oleopolis, " "	1032	45	987
Walnut Bend, " "	1023	40	983
Rockwood, " "	1016	50	966
Oil City, " "	1008	50	958
Franklin, " "	988	40	948
Cochran, " "	982	40	942
Fosters, " "	970	40	930
Scrubgrass, " "	945	40	905
Emlenton, " "	905	45	860
Parkers, Armstrong Co., Pa.,	889	50	839

The depth of drift, as shown in the second column, has been obtained from a careful examination of well records, and the borings have been so numerous that the figures cannot be other than reliable.

The railroad elevations in the first column are generally from 20 to 30 feet above low water in the river.

§ 592. Let us now compare the present river fall with the ancient channel floor, as far as it has been revealed by the drill.

Present fall of the Allegheny River.

		Total fall.	Miles.	Average fall per mile.
1376	Carrollton to Warren,	200′	52	3′.11″
1176	Warren to Tidioute,	78′	21	3′. 8″
1098	Tidioute to Oil City,	113′	35½	3′. 2″
985	Oil City to Parkers,	125′	49½	2′. 6″
860	Parkers to Pittsburgh (699),	161′	82½	2′. 0″
1376	Carrollton to Oil City,	391′	108½	3′. 7″
985	Oil City to Pittsburgh (699),	286′	132	2′. 2″
1376	Carrollton to Parkers (860),	516′	158	3′. 3″
1376	Carrollton to Pittsburgh, (699),	677′	240½	2′.10″

The height above ocean level, of the Allegheny river at low water at the places named, is given in the first column.

§ 593. *Fall of the Ancient Valley-floor.*

		Total fall.	Miles.	Average fall.
1100	Carrollton to Warren, ...	00	52	00
1100	Warren to Tidioute, ...	37′	21	1′. 9″
1063	Tidioute to Oil City, ...	105′	35½	2′.11″
958	Oil City to Parkers (839), ...	119′	49½	2′. 5 ′
1100	Carrollton to Tidioute (1063), ...	37′	73	0′. 6″
1100.	Carrollton to Oil City (958), ...	142′	108½	1′. 4″
1100	Carrollton to Parkers (839), ...	261′	158	1′. 8″

§ 594. Supposing that the deepest part of the ancient channel may not yet have been discovered at Great Bend and Warren, it is nevertheless evident from the above showing, that with the present status of levels, the waters of the upper Allegheny at Carrollton could not have been drained through the channel at Tidioute, for it is unreasonable to suppose that a mountain stream of this character would cut out for itself a bed for a distance of 73 miles having an average fall of only about six inches to the mile.

§ 595. A difficulty of the same character, and equally insurmountable, is encountered in attempting to find a drainage towards the south for the waters of ancient Conewango creek.

At Warren, where the Conewango joins the Allegheny, the old floor lies at 1100 feet above tide. Two miles north of Warren, (North Warren,) its level is 1111 feet above tide; and probably the deepest part of the old valley has not been drilled upon. Seven and a half miles north of Warren (Sloan farm) it is 1024 feet. Thirteen miles north (Fentonville, on the northern line of the State) it is 964 feet. These figures show a slope in the old valley towards the north, of 136 feet in about 13 miles and a corresponding increase in the thickness of the superficial deposits, from 100 feet at Warren, to 276 feet at Fentonville.

CHAPTER XXXI.

The northern outlets.

§ 596. A consideration of the facts noted in the foregoing chapter and others of like nature observed in the *Oil creek* and *Conneaut* basins, plainly indicating that the superficial deposits occupying the valleys north and northwest of the principal line of outcrop of the carboniferous conglomerate were very much thicker than those south of that line, and that they increased in thickness as they were followed northward (showing a northerly slope to the floors upon which they rested) induced me in 1877 to begin the search for some northern outlet for the old Allegheny waters.

At first I suspected that the ancient drainage of the Chautauqua basin centered at West Salamanca, and passed thence northward through Little Valley into Cattaraugus creek. But an examination of the surroundings soon proved that this could not have been the case; for the bed of *Little Valley* rises rapidly going north and soon shows evidences of indurated rocks in place and lying in such positions as must necessarily have prevented any drainage in that direction, even if we admit that great changes of levels have occurred in comparatively recent times.

I then proceeded down the river to *Steamburg*, near the headwaters of the southerly branch of Conewango creek. Here lies an irregular and rudely triangular flat, containing a superficies of more than four square miles and walled in by hills seven or eight hundred feet in height. The Allegheny enters this alluvial tract through a wide gap in the hills at its *eastern angle*, making at once a sharp bend toward the south; and then hugging its southeasterly highlands, passes out through a broad flat at its *southern angle.* This broad valley continues down to the mouth of Kinzua creek, near Great Bend. The remaining opening at the *northwestern angle* of the triangle is now occupied by

Cold Spring, an insignificant stream when compared with the broad valley through which it flows. These lowlands, curving around toward the west, connect directly with the great valley of Conewango creek, so that the Drift deposits of the latter and of the Allegheny valley are continuous through this now obliterated channel, while a low divide, not 50 feet higher than the general surface, determines the direction of drainage toward the Conewango in one direction and toward the Allegheny in the other.

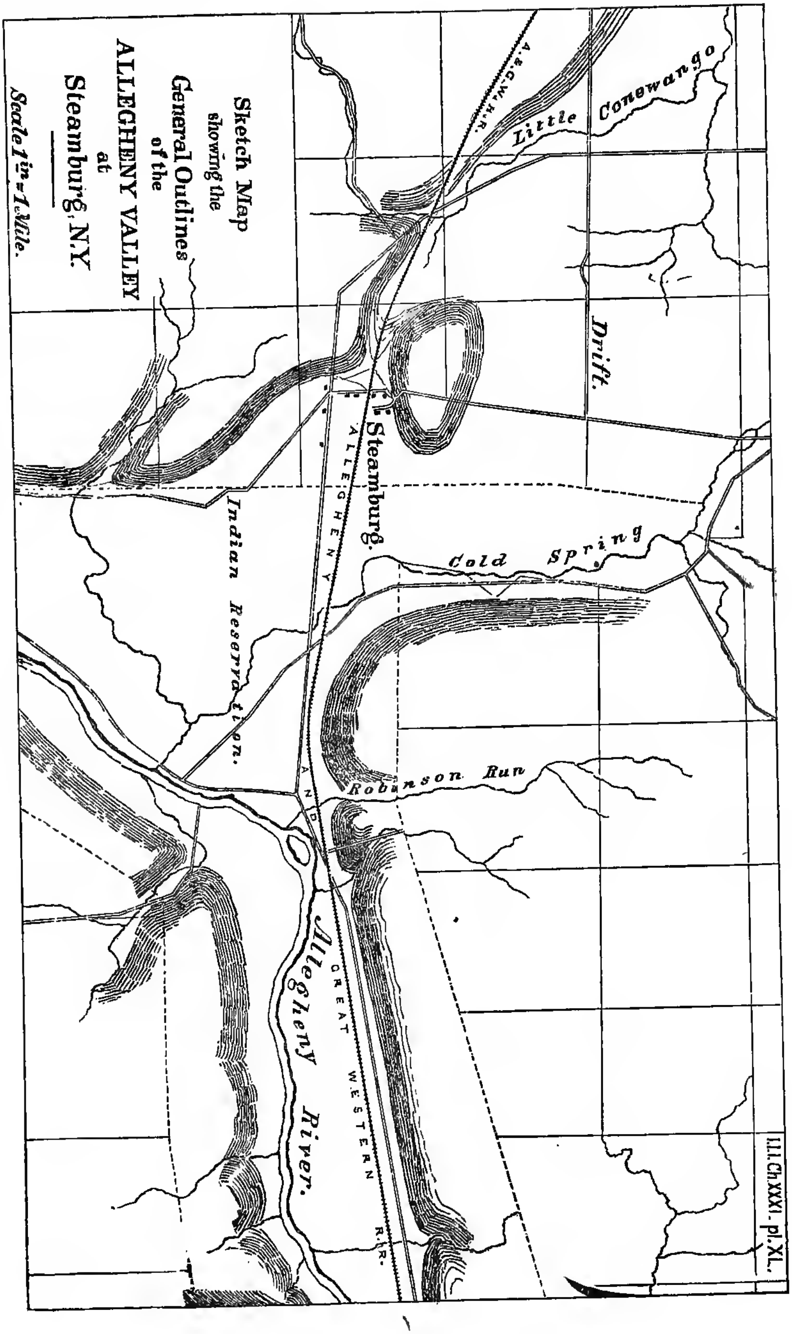
The Atlantic and Great Western railway passes in a westerly direction along the *northern side of the triangle*, and goes out at the west, (with a moderate rise of grade and just cutting down to bed-rock,) through a narrow new gap, opened no doubt during the glacial epoch.

This interesting cut, which may be noticed by anyone in passing along on the cars, leaves to the north an isolated, elliptical, truncated hill, 470 ft. in height and several hundred acres in extent, around which sweeps the broad valley, (now partly occupied by Cold spring at the east, and by the sources of Conewango creek on the north and west,) showing plainly that this was once a bluff point connected with the highland at the south of the railway at a time when the ancient stream which lined out these broad valleys had a northward sweep.

The sketch on Plate XL will more clearly explain the situation.

§ 597. Cold Spring is about 17 miles from Carrollton; and allowing a fall of 5′ per mile to the ancient stream, its bed would here be 85′ lower than at Carrollton, or 1015′ above tide, (1100—85=1015.) The altitude of the present water-plain is about 1330′, which gives 315′ as the depth of drift to be looked for here, on that supposition of ancient slopes. The character of this valley and its surroundings indicate that this is not an unreasonable thickness of superficial deposits to expect in this locality.

§ 598. At Falconers, Chautauqua county, the north-south valley from Cassadaga lake to the Allegheny is crossed by the east-west valley occupied by a portion of Conewango creek and the outlet of Chautauqua Lake. Here the waters


Sketch Map
showing the
General Outlines
of the
ALLEGHENY VALLEY
at
Steamburg, N.Y.
Scale 1in.=1 Mile.
Little Conewango
A. & G. W. R. R.
Drift.
Steamburg.
ALLEGHENY AND GREAT WESTERN R.R.
Indian Reservation.
Cold Spring
Robinson Run
Allegheny River.
III.Ch.XXXI. pl.XL.

of Conewango creek from the east, of Cassadaga lake and creek from the north, and of Chautauqua Lake and its feeders from the west all converge, and, after uniting in one stream, turn southward and flow as the main trunk of the Conewango into the Allegheny river at Warren.

Falconers is about 20 miles west of Cold Spring. Now, on the supposition that the old valley-floor descends to this point with a slope of 5 ft. per mile, it would here be found 100′ below its level at Cold Spring; that is, at 915′ above tide. The altitude of the present surface is 1260′. Consequently, on this supposition there should be 345 feet of superficial deposits here.

We have no means of knowing what the actual thickness may be; for no oil wells have been attempted in the immediate vicinity; but at Levant, about a mile to the northeast and on the northerly side of the old valley, a number of flowing water wells have been obtained by simply driving small wrought-iron pipes into the drift gravels. These wells are about 100 feet deep, and none of them have touched bed-rock.

As far as can be judged from the surface, everything indicates an unusual thickness of drift deposits at Falconers. The river bottoms are wide and the streams wander through them in an intricate net work of loops and bows, as if bewildered in attempting to select channels where so many opportunities offer themselves. The side hills are low, and rise from the plain with moderate slopes and curving outlines, as would naturally be the case supposing the more rugged sculpturing of their bases to be concealed.

§ 599. At Fentonville, nine miles south of Falconers, the State line crosses the Conewango valley; and here (in 1877) the Weeks' well was drilled. It commenced on the water-plain, at an elevation of 1240′, and reached fixed rock only after driving 276 feet of pipe, through blue clay and gravel. This puts the old valley floor, by actual measurement, at 964′. From this point an assumed slope in the old floor of 5′ per mile would bring it down to 919′ at Falconers.

There is thus only *four feet* difference between the results of the two calculations, viz: From Cold Spring to

Falconers, and from Fentonville to Falconers; the one making the old valley bed 915′, the other 919′ above tide.

§ 600. We have shown in § 595 that the waters which excavated the valley at Fentonville could not have drained into the old Allegheny at Warren; they must needs, therefore have passed northward; and in doing so they could not possibly have turned out of the Conewango valley before reaching Falconers; neither could they have flowed to that point unless the old floor lies at about the elevation here claimed for it.

It seems probable then, that the ancient drainage from the east and south centered near Falconers; and if so, then there were but two *possible* outlets for it; one northward through the Cassadaga valley; the other westward through the valley at the foot of Chautauqua Lake.

§ 601. The elevation of *Chautauqua Lake* is 1299 feet, and its maximum depth is said to be about 100 feet. Its present outlet has cut for itself a narrow channel about 50 feet deep through solid rock, at a point between Jamestown and Dexterville; but there can be no doubt that this is a post-glacial excavation, and that an ancient channel, deeper than the present lake-bed exists to the north of it.

Jamestown is built on a cluster of drift-hills which have been dumped into the old valley at this point in consequence of its peculiar position in relation to the different currents of ice-flow. The obliterated channel seems to have crossed the narrow neck of drift near the cemetery at the northly edge of town, and swept around into the Conewango valley through the broad dry basin north of Dexterville.

There is no evidence, however, of a northern ancient outlet through the valley of Chautauqua Lake into the Lake Erie basin; for all the surrounding hills are high, and stratified rocks appear in such positions as to preclude the possibility of any old valley being concealed from view. The slope from the divide toward Lake Erie is abrupt; and if an old channel had ever been cut there it must have left some witnesses of its existence in the present topography.

If the old current passed westward across the foot of

Chautauqua lake, it must have entered the Little Brokenstraw valley at Grant, and followed it down to the Allegheny river.

This is rendered improbable, by the fact that Grant is 138 feet higher than the surface of Chautauqua Lake; and it would require a cut of about 500 feet to convey the water from Falconers in this direction. Even then it could not flow down the Allegheny river, because, as we have seen, the old floor lies at Tidioute at 1063′, which is 148 feet *above* our starting point at Falconers.

From Grant the current could not have gone westward into French creek, near Corry, because a high ridge intervenes, through which the A. and G. W. Ry finds a passage only by following the windings of a narrow valley after passing over a summit very close to bed rock at an elevation of 1550′.*

§ 602. We see from the above facts that the drainage from the west also centered at Falconers; and now our only alternative is to seek for an outlet to the north through the valley of *Cassadaga Lake.*

Starting then with our calculated elevation of bed-rock at Falconers, and continuing the 5 feet slope for 18 miles, to Cassadaga Lake, *bed rock should be found under the lake* at (915′—90′=)825.′ As the lake elevation is at 1305′, and as the drift-hills north of it are about 20 feet higher, the old valley should therefore contain about 500 feet of drift-filling.

Five hundred feet of drift seems like an immense thickness of superficial deposits. At first thought we are startled at its magnitude, being hardly willing to accept a train of reasoning which leads to such conclusions. But on a further study of the premises, guided by analogy and the light thrown upon the subject by actual experience in other places, imaginary difficulties vanish, *possibilities* present themselves which can only be entertained unchallenged, and *probabilities* approximate so closely to certainties that a growing conviction is the result.

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* On Plates 1 and 2 the summit elevation a little southeast of Corry should read 1800′ instead of 1500′.

Five hundred feet of filling beneath Cassadaga lake does not presuppose an extraordinary depth of old valley in this instance, for the side hills rise only about 150 feet above the lake surface ; so that if the valley were again freed from drift, it would be not more than 650 feet deep ; while, as we have seen above, the Tunangwant would be more than 1100 feet deep under the same circumstances. There is no improbability then on this score. But this of course is making no account of the extent of erosion the hilltops have suffered since the old valleys were excavated; whether more or less in one or other of the situations we cannot tell.

Moreover, the calculation is based upon a projection of the ancient river-fall along a hypothetical slope of 5 ft. per mile, when it may have been perhaps not more than 2 feet.

The distance from Fentonville, where we have a measured elevation of the old valley-floor to Cassadaga lake is 28 miles. A slope of 2 feet, instead of one of 5 feet to the mile as calculated above, would place the old floor beneath the lake 84 feet higher, and reduce the drift-filling to about 400 feet.

§ 603. *Cassadaga Lake*, a very irregularly outlined body of water, five lakelets connected by narrow channels, nestles among a cluster of drift-hills on the lowest part of the divide separating the Chautauqua basin from the Lake Erie slope. At the north end of the lake the tops of the sand hills are only from ten to thirty feet above its surface. These hills stretch across a *sag* in the crest of the divide, perhaps a mile or more in width, and overlap upon the stratified rocks of the ridges lying to the east and to the west of it.

Looking southward from the lake, the valley of Cassadaga outlet, which is so wide and level, and merged by such insensible gradations into the sloping side-hills, as to deserve rather the appellation of a plain—stretches away, and loses itself in the distant landscape in such a manner as to leave the beholder in doubt whether he is looking down stream or up.

In the opposite direction, towards the north, the landscape changes in a remarkable manner ; first a steep declivity almost at one's feet; then an apparently level plain, and the broad expanse of Lake Erie. Ragged drift-hills and basins rapidly falling in successive steps, are seen occupying the whole width of what seems to have been an ancient valley. Through these yielding clays and gravels the rainfall of ages has cut deep and intricate gorges, plunging at the rate of more than 150 feet per mile towards Canadaway creek, the stream which now usurps the lower portion of the old valley.

§ 604. At Laona, five miles north of Cassadaga lake, we have descended 500 feet below its surface; and here the Canadaway is flowing in a rocky channel; although this may not be the channel of the ancient stream.

The probabilities are that the old valley passes down through Dunkirk harbor; whereas the Canadaway now debouches at some distance to the west of it. Light-house point, on the west of Dunkirk harbor, seems like a remnant of the western old channel walls; striated rocks also appear in places on the east; all between is a mass of waveworn Drift.

If it be conceded that the fixed rock exposed at Laona (from this point up to Cassadaga, nothing but Drift can be discovered in the center of the valley) be the deepest part of the old excavation, we still have sufficient fall to deliver the water from Falconer's basin, where we have already seen reason to believe that the upper drainage all converged, thus:

Probable elevation of old floor at Falconer's,	915′
Bed rock seen at Laona,	800′
Total fall,	115′
Distance,	23 miles.
Fall per mile,	5 feet.

This is more than twice the rate at which the Allegheny river now falls from Oil City to Pittsburgh.

Three classes of valleys.

§ 605. We pass to a consideration of another class of facts bearing upon the subject.

At the commencement of my researches it appeared to me a reasonable supposition that the present topographic features of the country would assist in tracing out these ancient streams. The facts noted and the comparisons made with this idea soon became fruitful in pointing out a distinction between three kinds of valleys, classified as follows:

1st. Broad valleys, deeply filled with Drift and occupied by streams still flowing in their original directions.

2d. Broad valleys, deeply filled with Drift, where the present streams apparently run in a direction opposite to that taken by the streams which excavated them.

3d. Narrow valleys, with abrupt and steep side-walls, and slightly drift-filled; these being the *new outlets*, cut in glacial times, at points where the former lines of drainage were reversed from north to south.

§ 606. The contrast between a valley of *normal current*, where the stream has always flowed in the same direction, and a valley of *reversed current* is plainly discernible, and in several ways.

In regard to the former it will be noticed that lateral streams generally fall into the main valley so as to point in the direction of its water-flow; and in case the after current of ice-flow moved also in the same direction, then the *upper* bluff-point between the two valleys, where the streams meet at an acute angle, is drawn out into a long, tapering, prismatic wedge; while the *lower* point is rounded off obtusely.

In regard to the latter, where the stream has been reversed, the tributaries often come in from an opposite direction to the present course of the main channel; the acute angle of the original upper bluff-point is rounded off; and the lateral current (now flowing over the deep alluvions of the modern valley, far above its ancient floor, and with a possible water-plain widened by so much as the depth of filling and slope of original valley walls may allow,) wanders hither and thither through the broad bottoms, and finally enters the main stream perhaps a mile or more from its former junction. For example, the tributaries of the Allegheny between Steamburg and Great Bend, and of the Conewango between Warren and Falconers exhibit this peculiarity.

Another observation may be noted. Where a sharp bend occurs in a stream of rapid fall the current sweeps constantly against the outer arc of the circle; the banks are undermined and falling, leave perpendicular bluffs. As the stream cuts deeper into the bed-rock it also carries the curve forward, down stream, always hugging the cliff. Hence the eroded channel at this point is not cut down vertically, as it might be on a tangent, but at an angle to the horizon dependent upon the force of water and upon the quality of materials wrought upon. The effect is to leave a sloping and sometimes terraced point of highland on the inside of the curve; and steep bluffs, covered with falling masses of hill-top rocks, on the outside. It is evident, in situations of this kind, that *erosion* originally commenced at the top of the sloping inner point of upland; and that it has cut down by stages; shifting laterally as it sank vertically to its present plane of activity. Illustrative examples are numerous along the Allegheny river below Franklin.

Let us now suppose a stream checked in its operations after having cut out a chasm through horizontal measures to a depth of five hundred or a thousand feet. Let us next suppose this chasm filled with loose materials to a height of one, two or three hundred feet; so that a wide level bottom be left between the sloping sides of the valley. Finally let the drainage be reversed. How will the new stream act?

Certainly the new stream, flowing, not like the old stream at the narrow bottom of a rock gorge, but over a wide level bottom of loose materials, will be free to select a new channel; and the same laws which directed the old stream flowing in one direction, *against* the cliffs, should direct the new stream flowing in the opposite direction, *away from* them. New cliffs should be formed in other places, leaving the old ones unwashed by the stream and silent witnesses of the change.

Cliffs of this character may be seen at Stoneham in Warren county; on the Allegheny between Irvineton and Warren, and between Great Bend and Steamburg, on the Conewango, and in many other places.

§ 607. Without dwelling on these facial characteristics which may be excellent guides in the field, but cannot be made intelligible descriptively without the aid of a contour map of the country, we will note one more piece of circumstantial evidence for a northern outlet to the Chautauqua Basin, and then proceed to indicate what appears to have been the shape of the water-tree of the upper Allegheny in pre-glacial times.

The Tionesta drainage.

§ 608. In Mead township, Warren county, at an elevation of a little more than 1400′ lies *Cranberry Swamp*, underlaid and surrounded by drift-deposits similar to those found about the several lakes and swamps which are scattered along the crest of the Lake Erie divide, and they are the most southerly accumulations of the kind in the region.

Tionesta creek heading southwest of Cranberry swamp, in Limestone township, Warren county, (and but a few miles from the Allegheny river at Tidioute,) flows northeastward to it and through it. After issuing from the swamp, the Tionesta turns sharply to the south, and flows to Sheffield, where it is re-inforced by Two Mile run coming from the east. Thence it flows on to Barnesville, where it meets the south branch of Tionesta full in the face.

Here the swollen stream turns squarely to the west, passing out of a broad and terraced basin, through a narrow gorge between high hills, and enters the main creek which flows in a devious southwesterly direction into the Allegheny river, at Tionesta Bend, in Forest county.

Just north of Cranberry Swamp, (and perhaps receiving some of its drainage,) heads *Dutchman's Run*, a rapid but inconsiderable stream occupying a broad old valley which opens northward into the Allegheny river just above Warren.

A glance at the curious windings of the upper Tionesta, as shown on any map, would be sufficient to awaken a suspicion in the mind of a fluvialist that these peculiarities were due to unusual causes; and a few hours spent in the field would satisfy him that his suspicions were well founded. There seems to be scarcely the shadow of a doubt that *all of the upper branches of the Tionesta once delivered through Dutchman's Run into the Allegheny.*

For proof of this proposition we need only point to 1. the clear evidences of a new cut at Barnesville, furnishing an outlet to the south ; 2. to the equally clear evidences of a deep fill of drift at Clarendon, (Cranberry Swamp,) constituting a divide or water shed to the north ; and 3. to the abandoned curve-cliffs at Stoneham once washed by the north-flowing stream, but now high and dry on the drift-filled divide.

Moreover, a well sunk at Sheffield (in 1865) and requiring 110 feet of drive pipe, shows that the old floor there is *lower* than the floor of its present *Tionesta outlet*, but *higher* than its former *Conewango outlet.*

Old floor in Sheffield well, above tide,	1215′
" at Warren,	1100′
" at Foxburg, Forest county,	1260′
Thickness of drift in valley at Sheffield,	110′
" " " Warren,	100′
" " " Foxburg,	25′

Foxburg is situated on the Tionesta, nine miles belc Sheffield.

§ 609. The following tables will assist in a comparison of the average fall of the present streams with the slopes of the ancient channel:

Altitude of Old Valley-floors.

At Carrollton, above tide,	1100′
At Cassadaga Lake, (calculated,)	815′
At Sheffield,	1215′
At Warren,	1100′
At Fentonville,	964′

Fall of the Ancient Valley-floor.

		Total fall.	Dist.	Average.
1100	Carrollton to Cassadaga Lake, (815′,)	285	60	4′ 9″
1215	Sheffield to Warren,	115	11	10′ 5″
1100	Warren to Fentonville,	136	13	10′ 6″
964	Fentonville to Cassadaga Lake, (815′,)	149	28	5′ 4″

Present fall of Cassadaga and Conewango Creeks.

		Total fall.	Dist.	Average.
1305	Cassadaga Lake to Fentonville, ...	80	28	2′ 10″
1225	Fentonville to Warren, (1176′)	49	13	3′ 9″
1305	Cassadaga to Warren, (1176′,)	129	41	3′ 2″

Drainage Maps.

§ 610. Two maps of the Summit water-basins of northwestern Pennsylvania accompany this volume. The first, Plate I, is designed to show the drainage system as it now exists. The second, Plate II, is intended to indicate the probable shape of the pre-glacial water-tree.

A comparison of the two sheets will disclose the points where the physical changes have occurred which resulted in transferring the overflows of the several basins from the valley of the St. Lawrence to the valley of the Mississippi.

§ 611. It will be noticed (Plate II) that the blue rim of the Chautauqua basin is broken through by a stream only at one point—at Cassadaga lake, in Chautauqua county. In pre-glacial times all the water from this basin, containing probably 4,000 square miles of surface, appears to have been delivered through this one outlet; and it will be observed by referring to the hilltop summits along the rim, that the outlet occurs in the very spot where we should look for it, on the supposition that it was opened under the influences of atmospheric erosion alone; for that portion of the crest between Mayville and Dayton is much lower on the average than any other part of it.

The only outlet through the rim of the Chautauqua basin noticeable on the map (Plate I) is at Thompson's station, in Warren county, Pa., where the Allegheny river now carries the accumulated drainage of all this summit area. Another outlet through the ancient rim was cut near Barnesville, in Warren county, but only the waters derived from a small area tributary to Tionesta creek now pass through that gap.

§ 612. The principal points of difference between the two maps are these:

On map No. 2 pre-glacial ridges of indurated rocks extend across the stem of the present Allegheny at Thompson's and at Great Bend, and also across the present Tionesta creek, near Barnesville, all in Warren county.

On map No. I, barriers of glacial debris obstruct the ancient Cassadaga valley at Cassadaga Lake, and at Steamburg, in N. Y., and a similar deposit at Stoneham, in Warren county, has in like manner obstructed and reversed the ancient stream formerly flowing northward into the Conewango.

It is here claimed that the cutting through of these three pre-glacial ridges and the building up of the three glacial barriers accomplished during the Ice-age through the agencies of water and ice, as hereinafter to be explained, would result in the re-alignment of drainage lines as shown on the two maps; the status of levels remaining meantime unchanged; and that therefore we have no need of resorting to the hypothesis of warpings and oscillations of the earth-crust, or of submergence beneath ocean and subsequent elevation, to account for the accomplishment of any of the effects observed in this basin.

Allegheny river drainage.

§ 613. The upper Allegheny waters appear to have flowed in pre-glacial times as they now flow, as far south at least as Steamburg; where meeting the waters of Kinzua creek and its tributaries from the south, they swept around to the northwest into the Conewango. That part of the Allegheny valley, between Steamburg and Kinzua, was then a portion of Kinzua creek. The present Kinzua valley, for some distance above Kinzua village, is a counterpart in width and general appearance of the portion of its old bed now occupied by the Allegheny. Near where Kinzua village now stands, a small stream came in from the south, taking its rise in the highlands trending across the country in the vicinity of Great Bend. This ridge capped with the massive conglomerates and sandstones of the coal measures still maintains its superior elevation above the surrounding country, and has preserved several patches of good coal (Quaker Hill, &c.,) notwithstanding its prominent exposure to erosive agencies during and since the Ice-age by reason of its peculiar position and altitude. It was also the source of several streams flowing in a westerly direction, one of which, a branch of Hook's Run, appears to have taken its rise quite near the Kinzua branch above referred to. These two branches became connected during the Ice-age, and their channels deepened and adjusted to grade, now form the Great Bend cut connecting the broad valley north of Kinzua with the broad valley west of Hook's Run.

The following facts appear to sustain this conclusion: (1) The narrowness of Great Bend cut as compared with the valleys both above and below it. If the ancient current which excavated the deep and broad valleys above and below passed through the bend, why this contraction of the valley at this point where there is no conspicuous change in structure to cause it?

(2) Northeast of the bend the lateral streams come in from a southerly direction corresponding with a northerly flow of the Kinzua, (now a part of the Allegheny,) and the contours of the hills at their intersection with the main valley, point in the same direction.

(3) West of the bend, features of a similar character indicate a westerly flow for the drainage in harmony with the present current.

That the other new cuts of the Tionesta near Barnesville, and of the Allegheny at Thompsons, have originated in a similar manner to the above, that is by the joining together of two streams originally flowing in opposite directions, can hardly be doubted. The proofs are plain, but it is unnecessary to adduce them here, for they would only be a repetition of those already given above.

§ 614. The Allegheny in pre-glacial times, according to these views of the situation, took its rise on the southerly side of the high lands between Irvineton and Tidioute, and no water north of that point entered its channel. This ridge, it will be noticed, forms the southerly rim of Chautauqua basin. Down its northerly slope ran a small stream into the Brokenstraw, at Irvineton. The Brokenstraw flowing eastward to Warren, there met Hook's run and turned north through Conewango creek. At Falconer's the stream was greatly enlarged by the waters of Chautauqua from the west and those of the Kinzua, northern Allegheny, and Cassadaga from the east, and still flowing northward through the Cassadaga valley entered the Lake Erie basin.

That portion of the Allegheny valley between Steamburg and Thompson's has had a very different history from the portions above and below those points. The Allegheny, as now flowing, may be said to be a modern stream occupying portions of the valleys of several old ones. From Steamburg to Great Bend it has usurped the trough excavated by the ancient Kinzua and its branch, and reversed the direction of their former currents—from Great Bend to Warren it has absorbed Hook's run and its branch, but still carries them in their original course—from Warren to Irvineton it has robbed the Brokenstraw of its bed and sweeps back its waters through a former tributary, and thus effects a connection with the present trunk stream.

The water-tree of Chautauqua basin, as shown on Plate No. 2, is somewhat peculiar, but not at all unnatural. When this area emerged from the ocean we may suppose it to have been a nearly flat but somewhat warped and undulating basin-shaped plateau of mud and sand. It must have had a *lowest* point among its depressions—this seems to have been near Falconer's; and a *lowest* point in its periphery; this seems to have been at Cassadaga. The rain waters converging toward the lowest point of the basin would accumulate and overflow at the lowest point of the rim. An outlet once established would cut down rapidly in such soft and unconsolidated materials as we may suppose these to have been. The main lake would soon be drained, leaving smaller lakelets scattered about in the depressions, all in turn to be emptied into the common outlet, as the barriers cut down and the channels deepened. A system of drainage, whose outlines were first inscribed in this manner upon a soft and undulating plain, would be a striking prototype of that which we see the witnesses of in this ancient basin.

It is an interesting thought in this connection, that if the new cuts on the Allegheny at Thompson's and at Great Bend were to-day filled up to a height of 1350 feet above ocean, that is about 200 feet above the present water plain at Thompson's, and 120 feet at Great Bend, precisely analogous results to those indicated above would occur. The old outlet at Cassadaga lake would be re-opened; as it deepened the waters would all centre near Falconer's, and thus no doubt in the process of time the old valleys would be swept of their superficial deposits, and the ancient floors again be laid bare.

CHAPTER XXXII.

The Conneaut Northern Outlet.

§ 615. *The Oil creek* and *Conneaut water-basins* both present in their topographic features evidences of the existence of buried channels, drift-barriers, glacial cuts, and reversed streams, very similar to those of the Chautauqua water-basin.

As the old valleys are traced northward, the superficial deposits are found to increase in thickness; the old floor approaches nearer and nearer to tide-level; and the difficulties in the way, supposing that the waters, while excavating these ancient valleys, delivered through any southern outlet now discoverable, become quite insurmountable.

The present outlet of Oil creek water-basin, is Oil Creek, which joins the Allegheny river at Oil City; and that of the Conneaut water-basin is French creek, entering the Allegheny river at Franklin.

On Oil creek, the old valley floor is found at the entrance of the high lands, just below Titusville, at a tide-level altitude of 1125′. Nine miles further north, at Grey's well, near Clappville, it was not reached at 1034′.

On French creek the elevations are 948′ at Franklin, and 800′ at Canfield well, 23 miles above Franklin, (equal to about 780′ at the mouth of Conneaut outlet, 20 miles from Franklin.)

These figures afford proof positive that the old rock beds on these two streams, between the points named above, slope downward towards the north at a rate on Oil creek of at least 10 feet to the mile, and on French creek, (if calculated to Conneaut outlet,) of not less than 8½ feet.

A continuous and elevated range of hills heavily capped with conglomerate and sandstone, lying to the southeast of these two basins, forbids the supposition that other outlets than those named above might be found leading into the Allegheny. It is evident, from the shape of the surrounding country, that if these waters passed southward at any time during the pre-glacial period, they must have flowed through the channels occupied by the present streams.

The following tables, showing the depth of drift and slope of old floors along Oil creek and French creek, will throw light on this part of the subject.

Oil creek.—Elevations above tide and thickness of superficial deposits:

	Surface.	Depth of drift.	Old floor.
Oil City,	1008′	50′	958′
Rouseville,	1036	40	996
Petroleum Centre,	1089	40	1049
Pioneer,	1099	45	1054
Gregg farm,	(1115)*	50	1065
Miller farm,	1131	45	1086
Boughton,	(1157)	30	1127
Bissell farm, junction of Pine creek,	(1170)	45	1125
Titusville,	1194	94	1100
Grey well, 8 miles above Titusville,	(1260)	226+	1034—

French creek.—Elevations above tide and thickness of superficial deposits:

	Surface.	Depth of drift.	Old floor.
Franklin,	988′	40′	948′
Sugar creek,	1014	40	974
Canfield well,	1070	270+	800—

Note how remarkably the thickness of drift south of the Titusville flats, and between Sugar creek and Franklin, agrees with that on the Allegheny river, previously given; and how quickly it begins to thicken going northward from these points.

The figures show a change of slope in the ancient floors

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* The figures in brackets are close approximations.

of Oil creek and of French creek in the vicinity of the Conglomerate ridge before spoken of, which, aside from other considerations, makes it appear quite improbable that these two valleys south of the ridge were excavated by the currents which eroded the deeper valleys north of it. And if they were not thus excavated—that is, if the waters of ancient Pine creek and Upper Oil creek did not originally find exit through the present main trunk of Oil creek at Oil City,—then they must have flowed northward into French creek. If the waters of ancient French creek and its tributaries did not join the Allegheny at Franklin, they could only find a delivery northward through Conneaut lake and Conneaut creek into the Lake Erie basin.

§ 616. With the scanty materials at command let us attempt to trace these ancient valleys toward Conneaut lake, and see if it appears feasible to deliver their waters in that direction.

Oil creek and French creek elevations above ocean, and slope per mile of old valley-floors:

Old floor.		Fall.	Miles.	Rate.
1125	Bissell farm* to Titusville, ...	25	2	12′ 5″
1100	Titusville to Grey's well, ...	66	7	9′ 5″
1034	Grey's well to Canfield well, ...	234	35	6′ 8″

This shows that there is ample fall in the ancient valley-floor (if the valley be continuous, and of regular grade along the line indicated on Plate No. 2) to deliver the Pine creek and Upper Oil creek waters at Canfield well on French creek, three miles above the mouth of Conneaut outlet; and since this well is said to have been abandoned before reaching bed-rock, the fall is probably greater than that figured in the table.

Starting now at Grey's well on Oil creek, and distributing the ascertained fall *pro rata* according to distance, we get the following elevations above tide for the ancient floor at the points named.

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* This is where Oil creek enters the highlands at the mouth of Pine creek, below Titusville.

Grey's well, old floor above tide, ... =1034′
Summit between west branch of Oil creek and Muddy creek, 20′ lower, (dist. 3 miles, fall per mile 6′ 8″=20′)=1014′
Little Cooley, on Muddy creek, (3½ miles×6′ 10″ fall=24′)= 990′
Cambridge, on French creek, (10½ miles×6′ 8″ fall=70′)= 920′
Meadville, on French creek, (15 miles×6′ 8″ fall=100) = 820′
Canfield well, on French creek, (3 miles×6′ 8″ fall=20′)= 800′
Mouth of Conneaut outlet, (3 miles×6′ 8″ fall=20′) . . . = 780′

§ 617. From these elevations we may ascertain the probable amount of superficial deposits at each point, thus:

	Surface.	Drift.	Old floor.
Grey's Well, (measured,)	1260	226	1034
Summit, ...	1358	344	1014
Little Cooley, ...	1200	210	990
Cambridge, ...	1140	220	920
Meadville, ...	1075	255	820
Canfield Well, (measured,)	1070	270	800
Conneaut Outlet, ...	1065	285	780

Nothing improbable appears in the above exhibit. The depth of drift required to make this route available is in no place greater than what might reasonably be expected; for both on the summit where the branches of Oil creek and Muddy creek rise interlocking together among a nest of low drift hills, and also at Little Cooley, Cambridge and Meadville, everything betokens very heavy drift deposits. The valleys are broad, the side hills sloping, affording ample room for a grand old channel of the depth and width required; and all the surroundings favor the inference that such an one once existed there.

No one who examines the superficial features of the country can fail to conclude that all the drainage of Oil Creek basin and so much of the Conneaut as did not fall directly into Conneaut outlet, once centered in French creek and passed down as far as its junction with the Conneaut Lake outlet.* From this point then it must either have gone

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* In 1877, before the idea of a northern outlet to the Oil Creek basin had been entertained, Prof. Chas. E. Hall, who had been giving considerable attention to the drift-deposits in eastern Pennsylvania, came out to inspect the drifts in the vicinity of Titusville. After a thorough examination of the singular deposit lying basined in the hills south of Titusville flats, and nearly op-

southeasterly into the Allegheny river, or northwesterly into the Lake Erie basin. These are the only two possible channels for it; which one did it follow?

We have very good evidence that the *ancient valley floor at the Conneaut outlet junction* is not *higher* than 780′ above tide. At the best then it is 168′ *below* the bottom of the mouth of French Creek at Franklin, and 60′ *below* the old floor of the Allegheny at Parker's, 60 miles further south. There could have been no outlet, therefore, in this southward direction with the present status of levels.

But the northward outlook is more favorable; for, the bed rock at the junction lies about 207′ *above* the surface of Lake Erie; and this free delivery can be reached by the valleys of Conneaut outlet and Conneaut creek in a travel of about 43 miles; which gives an average fall of 4 feet 10 inches to the mile. The distance would be greater, following the present windings of Conneaut creek, but the probabilities are that the old stream did not wander to westward as far as the present one does; but rather, that

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posite the mouth of Caldwell creek, we became convinced that it filled an old valley—that it had been transported from the north through Crouse run and Caldwell creek—and that there could not possibly be any continuation of the buried channel leading into Oil creek toward the southwest. Then, knowing the fact that the old floor beneath Oil creek on Watson's flats was from 50 to 60 feet *lower* than it was a mile further south where the stream enters the gorge cut through the highlands, we concluded to look for a *northern outlet.*

Procuring a conveyance we drove up Oil creek to Clappville; passed over the divide to Muddy creek, thence to Little Cooley, and so on to Cambridge on French creek. Down to this point there was no apparent difficulty in the way, either in levels or in the width of valleys and probabilities of drift-filling, and we felt confident that we had been following the course of the ancient stream.

From Cambridge a very broad valley extends northward to Conneautee Lake, which lies about 70 feet above French creek. It looked as if the ancient stream had found its way into the Lake Erie basin through this depression—but on arriving at Conneautee we were met by a broad ridge of stratified rocks through which it was evident no buried channel could extend. We then drove northeasterly to Waterford, on Le Boeuf creek, where the R. R. elevation is only 30 feet above Cambridge. The width of valley and great accumulation of drift here seen, made an outlet in this direction seem possible. We then turned north toward Lake Erie, but on reaching the summit swamp on the divide, at an elevation of 1260 feet above tide, became satisfied that this route was also impracticable, and consequently abandoned all expectations of finding an outlet except through the southwesterly continuation of French creek.

it flowed through a more direct but now obliterated or concealed channel leading from the big bend into Lake Erie.

§ 618. There is no necessity for confining this fall within the narrow limits afforded by the present Lake Erie surface, for the old valley-floor may have been far below the present water-level of the Lake. It has been demonstrated that the bottom of ancient Cuyahoga valley at Cleveland lies at least 228′ below the present level of Lake Erie; and other streams entering the lake are known to be flowing far above their former beds.*

There is no difficulty, then, in obtaining ample fall to carry the French creek waters into the great valley now occupied by Lake Erie, provided the old floor could be shown to have an uniform slope. This unfortunately cannot be done, for no wells have been sunk along the course of the old stream. But having seen that the waters could not have had an outlet towards the south, and that this is the only *other* available outlet for them, we are warranted in concluding, in the absence of positive evidence to the contrary, that the old stream-bed was adjusted to proper grade; and more especially so, if we shall find that this grade would not require an extraordinary amount of drift-filling on the supposition that the old stream has been obliterated and the current reversed.

From French creek to the head of Conneaut lake is a distance of about 15 miles. By adopting a slope of five feet per mile from our ascertained elevation of bed-rock on French creek, 780′, we get a fall of 75′ to Conneaut lake, which puts the old valley-floor there at 705′. The present surface water-level of Conneaut lake is 1082′; consequently (1082′—705′=) 377′ is the required thickness of filling un-

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* "All these streams [Grand river, the Cuyahoga, Black river, the Huron, Portage, Maume, &c.] now enter the Lake from one hundred to two hundred feet above their ancient beds, and when they flowed in their deeply buried rocky channels, Lake Erie had no existence as a lake, but was a valley traversed by Detroit river, which flowed north of Point Pelé island, at least two hundred feet below the present lake level, and received the streams I have mentioned as its tributaries."—Dr. J. S. Newberry, in Geology of Ohio, Vol. II, p. 199.

derneath it, and not extraordinary, considering the character of Conneaut outlet and the surroundings of the lake.*

§ 619. The surroundings of Conneaut are similar to those of Cassadaga lake; and here also a low barrier of drift prevents the Conneaut water from flowing northward. But the descent from Conneaut lake to Conneaut creek is not nearly as great or as abrupt as it is from Cassadaga lake to Canadaway creek; consequently the drift-filling is not

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* It should not be inferred from the methods above pursued in tracing the old valley-floors by relative levels above ocean, that we are attempting to give actual profiles of the beds of pre-glacial streams. This could not be done, even if all our valleys were as thoroughly perforated by drill-holes as parts of Allegheny river, Oil creek, and the Tunangwant have been, for the present contours of the old floors do not represent what they were at the *commencement* of the Ice Age, but what they came to be long subsequently, when the conditions had become such as to allow them to begin to retain the drift deposits now found lying upon them. I have no doubt whatever that these channels were greatly altered and modified during the continuance of the Ice Age, some of them having been considerably and regularly deepened, and others, owing to some peculiar action of the ice and under-ice-currents, (operating in a manner which, as yet, seems obscure,) having been actually excavated in long basins or sink-holes considerably deeper than their outlets.

The point in discussion is, not what were the precise physical conditions of cut and slope in these old valleys, but did our streams always flow in the directions they now flow, or have some of their currents been reversed? Did the immense amount of excavated material from these deep old valleys of the north, draining an area of more than 7500 square miles, all pass out in one turbid stream through the Allegheny river below Franklin, or did they flow northward by several channels into the valley of Lake Erie?

In preparing to answer these questions, one would naturally be led to first examine the Allegheny river below Franklin, where it must have received and forwarded all of these concentrated waters, to see if the depth and width and topographical aspects of the valley were such as might be expected in one through which had passed the currents of ages, carrying many cubic miles of sediment eroded from the mountains and valleys to the north; and which, consequently, must have furnished a free avenue for the unobstructed flow of glaciers during the whole of the Ice Age. And if, upon such examination, he became satisfied that the channel did not present satisfactory evidences of having been subjected to the tremendous wear and tear of the mechanical agencies belonging to such currents of water and ice, he would then look elsewhere, not only for other outlets to convey the waters, but for additional facts to support his conclusions in relation to the inadequacy of the Allegheny channel for the performance of the work required of it, if it had always been the only outlet.

In the pursuance of these latter objects the above levels are given, and they are to be taken for what they are worth, as collateral aids to assist in weighing the probabilities for or against the theory of northern drainage in preglacial times.

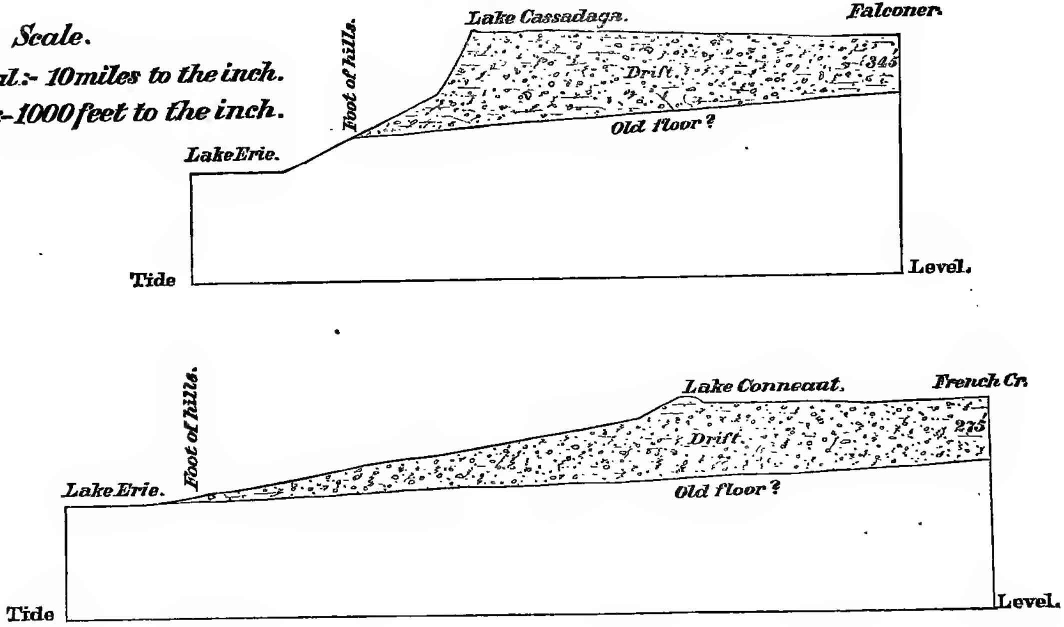
Sections showing the calculated depth of the Drift in N.W. Pennsylvania.

By J. F. Carll.

Scale.

Horizontal:- 10 miles to the inch.

Vertical:- 1000 feet to the inch.



so well exposed below lake level at the north. *Conneaut barrier* lies like a core in the old valley, with a surface sloping quite gradually both north and south from its point of maximum thickness; while *Cassadaga barrier* slopes very gradually to the south, but cuts off abruptly on the north, as seen in the following sketches, Plate XLI:

The shape of the trough receiving the deposit, necessarily determines the shape of the core within it. Cassadaga lies so high above Lake Erie (1305′—573′=732′) and so near the lake plain bordering it, (being only about five miles from Laona, where the elevated side-walls of the old valley terminate,) that there is not length enough in the excavation for such materials as these to form a permanent, gradual slope. They could not stand at a surface gradient as steep as one hundred and forty-five feet per mile if any considerable volume of drainage passed over them.

The waters of Canadaway creek entering the old valley from the east, about midway between Cassadaga and Laona, have carried out a large amount of material and reduced the slope of the drift-filled valley below that point. But above this a natural dam stretches across the valley, rising steeply to the height of 350 feet and holding Cassadaga lake upon its top. This steep slope is subject only to the wash of the rainfall received upon it; and how quickly the barrier would be removed if once broken by a stream of water passing over it, may be judged from the following circumstance:

Some thirty or forty years ago the mill owners on Canadaway creek desiring to increase their supply of water during dry weather, cut a small ditch through the low gravel hills at the head of Cassadaga lake, thus allowing lake water to flow north into Canadaway creek. The stream, small at first, soon began to cut. It quickly excavated a gulley fifty or sixty feet deep on the steep slope of the loose materials which formed the dam, and cut back towards the lake so alarmingly that the people of the neighborhood were called out in haste to fill up the ditch, that the lake might be preserved from drainage and the country below from inundation.

§ 620. But the situation of Conneaut is quite different from that of Cassadaga lake in important respects. It is 223′ lower than Cassadaga (being 1305′—223′=1082′; or 509 feet above Lake Erie) and the old trough below it to the north is protected by side-hills for a distance of about 20 miles. In addition to this, Conneaut creek, on emerging from the hills forming the Lake Erie escarpment, turns shortly to the west, and after a very devious course enters Lake Erie in Ohio; thus adding materially to the length of its channel. As the current runs, this stream must be about 60 miles in length. I have not examined that part of it north of Crawford county line, but suspect that it leaves the old valley near where it turns westward. The conditions of this ancient valley, therefore, favored the retention of the glacial debris swept into it. It filled in deep and broad between the protecting hills, and, having been leveled off on a natural slope as the waters lowered in the lake basin to the north, has not been materially altered by subsequent erosion.

How deep the drift of this valley between the lakes may be, we have no positive data for determining. It has every characteristic of the oil region valleys, where actual measurements show from 200 ft. to 450 ft., and is unquestionably very deeply filled.

About a mile from Conneautville and eight miles north of Conneaut lake, an oil well was sunk in which 112 ft. of quicksand and gravel were found above bed-rock. The well mouth is 150′ below Conneaut lake, and it does not appear to be located in the center of the old valley.

Conneaut lake was the summit reservoir of the old Beaver canal, supplying water for locking down both north and south. To increase its capacity, an aqueduct about twenty-one miles in length was constructed, through which the water of upper French creek flowed directly into the lake and raised its water-level about eight feet.* This open ca-

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* The elevation herein used for Conneaut lake (1082 ft. above ocean) is the old canal summit level. Since the abandonment of the canal and aqueduct and the dredging of the lake outlet, the water surface has been lowered from 10 to 12 feet.

nal tapped French creek at Bemustown, two and a half miles above Meadville, and following the east side of the creek to its junction with the lake outlet, there crossed over the stream in an aqueduct and then followed along the north-east side of the outlet to the foot of the lake.

It is here interesting to note, as showing the relative levels of different localities, that if this canal were cut through to Titusville on the alignment of the ancient stream, as shown on Plate No. 2, all the waters of upper Oil creek, Pine creek, and their tributaries would flow into Conneaut lake, instead of passing to the south down the main trunk of Oil creek as they do at present; and the current would have a total fall of about ninety feet between Titusville and the lake.

§ 621. We might go on now to speak of the evidences of a new cut, made during the Glacial epoch, on Oil creek, between Titusville and Petroleum Centre, and of another on French creek, between Utica and Franklin; and call attention to the trend of lateral valleys and the aspects of their terminal bluffs, on that part of Oil creek between Titusville and Clappville, and on French creek, where the streams seem to have been reversed—but it would only be a repetition of what has already been said in describing similar features in the Chautauqua basin. A reference to the map will show where the ancient dividing ridges and more recent glacial-barriers are located, as indicated by a study of the topography of the country.

While it is to be regretted that more abundant and positive proofs in confirmation of the hypothesis of a former northern drainage for these basins cannot be offered, it must be admitted that the facts already presented are sufficient to make it appear not only possible but very probable, for in no other way can the phenomena observed in connection with the drainage and the drifts be satisfactorily accounted for.

CHAPTER XXXIII.

Excavation of Lake Erie.

§ 622. Ancient valleys, similar to those mentioned in the preceding chapter, are known to enter the lake-basin in Ohio, as shown in the extracts before quoted. The drift-filling in them, like that in those of our own State, is an unimpeachable witness of pre-glacial excavation; and the direction in which they all trend proves plainly the former existence of a main channel of delivery to ocean through the present Lake Erie basin, and an ancient divide between the water-sheds of the Mississippi valley and the lakes. How did the crest of that divide compare, geographically, with the present one? In Pennsylvania, if the above expressed views regarding the pre-glacial flow of the upper Allegheny and its tributaries be correct, the old crest must necessarily have been many miles south of the present one, and have had quite a different trend. From the lack of requisite data, the old ridge cannot be located with so much assurance in New York and Ohio as in Penn'a; but I have endeavored to trace it approximately both east and west, on contour map, Plate No. 2 bis., in order that the continuity of the divide might be preserved to illustrate what is to follow.

That such a ridge existed somewhere in this region cannot be doubted, and the reasons for locating it, as seen on the map, will be apparent as we proceed. It was the barrier between two systems of river drainage and the source of their supplies—one delivering to the north of it, and the other to the south. The table-lands of its summit may have had considerable width, and the head-water streams may have interlocked, some of those flowing south rising north of its average medial crest, and some of those flowing north rising south of it, as we frequently observe in similar cases now; but it was an unbroken divide, extending from the Catskill mountains in New York, sweeping around the head of Lake Erie, and thence northwardly through Michigan to the vicinity of the straits of Mackinaw, and had sufficient altitude to originate the two systems of drainage referred to, and prevent any inter-communication between the waters of the one series and those of the other.

§ 623. What was the actual elevation of the country above ocean at that time, who can say? It would appear that it could hardly have been lower than at present; for the old floor of Cuyahoga river at Cleveland is now 228 feet below lake level, or only 345 feet above ocean; and the bottoms of lakes Superior, Huron, Michigan, and Ontario in some places are known to be from 200 to 500 feet below the present ocean level. It might have been higher, (and indeed it seems quite probable that it was,) but inasmuch as any change that did not materially alter relative levels, would not affect our argument; and as there seems to be nothing discoverable in relation to the old streams of Pennsylvania which requires a supposititious change of elevations for its explanation, we prefer to continue our discussion on the basis of the present status of levels; for, by so doing we shall avoid unnecessary complications, and be able to present more concisely the facts and inferences to which they lead. We want it distinctly understood, however, that we are not attempting to advance a *new theory*, but only aiming to record some conclusions (and they are largely tentative) drawn from local observations in northwestern Pennsylvania, hoping that they may prove suggestive, at least, and be of some assistance to others in a more comprehensive study of the drift phenomena of this latitude.

Judging then from the present configuration and altitude of this divide it is inferred that, at the commencement of the glacial-epoch, its summit could not have been less than 900 feet above ocean in its *lowest* part—which was in northwestern Ohio; and 2600 feet in its *highest* part—which was in northern Pennsylvania; and considering the extent of erosion accomplished since that time, on mountain top as well as in valleys, it may safely be assumed that it was much higher. In any event it was high enough to originate the streams flowing northward into the basin of the lakes, and southward into the Mississippi valley—the buried channels of which still remain on both sides of the divide as witnesses of the fact.

At that time, we may picture the country north of the divide (and that to the south must have been very similar) as a region of sharp and broken ridges, traversed by profound gorges, some of them no doubt more than 1500 feet deep, and occupied by rapid streams, all delivering into a grand trunk river which probably swept around somewhat centrally through the basins of lakes Erie and Ontario into the St. Lawrence*—the drainage and detritus of a vast area being thus poured into the ocean through a single channel, and this stream meeting tide-water in latitude more than eight degrees north of some of its sources of supply.

This is the situation as it presents itself to our view before the country was invaded by ice. Then, probably owing to cosmic causes, an arctic climate supervened. But the

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* Whether this stream headed in Lake Huron basin or on the southeastern slope of the Cincinnati anticlinal, is left an open question. *Possibly* the connection between Erie and Huron was made through the anticlinal *during* the Ice Age, and that previously the waters of Huron basin flowed out through the Maumee, and those of Michigan through the buried channel connecting it with the Mississippi.

In the absence of positive knowledge to the contrary, and because no other avenue seems feasible, I have assumed that the St. Lawrence valley must have been the ancient ocean outlet for the pre-glacial waters. A buried channel several hundred feet in depth, beneath the present bed of the Mohawk, has frequently been referred to as a probable connection between Lake Ontario and the Hudson. But a brief study of the gap at Little Falls, in Herkimer county, N. Y., ought to satisfy any one that no buried channel exists there, whatever the conditions may be to the east or to the west of that point; and I can see no possibility of there being an *abandoned* channel either to the north or to the south of it. Here the metamorphic rocks come up at a sharp angle and form not only the bed of the stream, but a considerable portion of the side-walls. The cut can scarcely exceed 100 rods in width—the side hills rise abruptly at least 300 feet in height—and the elevation of the top of the falls is about 380 feet above ocean, or *130 feet above* the surface of Lake Ontario. Another gap of about the same width, and cut through similar rocks, may be seen at the "Nose," near Yost, about 24 miles east of Little Falls. These facts induce me to regard the Mohawk valley only as an auxiliary outlet, opened during the Ice Age by the overflow of ice and water from the great central *mer de glace*. It has neither the depth nor the width that we should expect it to have, if it had been opened anterior to that time.

glaciers did not come down at once from their northern fastnesses like an irresistible avalanche, plowing up everything before them—scooping out the lake basins, filling up old channels, scaling the dividing ridge, and re-sculpturing the Mississippi slope as they passed on with a grand sweep towards the south. Ages on ages were consumed in accomplishing all this, and the specific methods by which the transformations were wrought varied at different periods and in different places, as the relative relations varied between the eroding agents and the eroded rocks. In one place, advantage of position saved soft rocks from destruction; in another, direct exposure insured the degradation of the hardest. We may study now on the surface only the particular features resulting from the concluding portion of the work—the faint marks, as it were, of the sculptor's finishing-chisel upon the statue; what the different stages were in the process of quarrying the block and outlining the figure in the rough, and just how the work progressed from time to time may be conjectured, but cannot with exactness be described, for the petrographic inscriptions by which alone this detailed history could be read have mostly disappeared with the wasting rocks upon which they were written; the last tablet alone remains to be studied.

§ 624. But in imagination we may look back into the abysmal past and attempt to briefly outline some of the sequences which would probably result from the natural advance, occupation and retreat of a continental glacier in a district presenting the features above described.

On the hypothesis of a gradual increment of ice proceeding from a northern nucleus, and a steady southward progress of arctic conditions of climate, we should expect to see the great ice wall from the north creeping down slowly partly by a movement of its own, but more sensibly by the accumulations of new materials along its face and in front of it. Step by step it advances—it stretches across the mouth of the St. Lawrence, travels onward, occupying more and more of its valley and soon seriously impedes the delivery of its waters, which now can only find an outlet beneath the ice, or through a channelway which the ice-movement tends to constantly fill and obstruct. Meantime the increasing rigors of the climate begin to produce their effect along the great divide to the south. The snow and ice of winter, which at first barely melted before another crop appeared, now remain over and accumulate from year to year. They slip from the steep hill-sides, carrying with them large masses of disintegrated rocks, and fill up the deep gorges. Thus the process goes slowly on until the whole basin draining into the St. Lawrence becomes one grand *mer de glace* whose overflows of ice must now necessarily be toward the south.

Through all this period, and indeed during the entire duration of the Ice Age, immense quantities of water must have been accumulating beneath the ice sheet. The under-ice-currents conforming to the general outlines of drainage already established, all converged toward the common trunk-stream, and this channel by reason of its trend to the northeast, was the first one to be seriously obstructed by solid ice. No doubt the ocean-seeking currents still flowed through crevasses, and in ice-arched channelways beneath the glacier, but the capacity of the aqueducts was inadequate to the delivery required. The water accumulated as in an ice-filled lake, until the surface level rose and another outlet was established through the Mohawk valley; but even with this auxiliary in operation the sub-glacial waters still increased, finally filling the basin and overtopping the rim at several low places in the crest at the south.

But these results were accomplished only through the greatest irregularity in the operations of the physical agencies combining to produce them. The peculiar situation of the basin induced and perpetuated a continual antagonism between the dynamic forces of the ice and water centering toward or contained in it. The main *shove* of ice was toward the south—while the only egress for the sub-glacial and crevass waters was to the northeast. Where a glacier and its under-water drain move in the same course, we may suppose that the ice-arch will be kept open with comparative ease; but where the ice-movement is at right angles, or approximately so, to the water-flow, a frequent settling of the ice-roof and obstruction of the channelway must occur.

Imagine an unbroken sheet of ice, say 2000 feet in thickness, gliding down the Canadian slopes into and across the old valleys of Erie and Ontario and impinging with tremendous power upon the southern cliffs. See the struggling waters beneath, impelled by a static pressure of from 300 to 600 feet, (varying at different times and in different places according to the fluctuating height of the water surface above the valley floor,) seeking an outlet in the direction of the old channel through a labyrinth of ice-arches supported largely by pillars and walls of soft rock left between the eroding sub-glacial streams.* The cross-movement of the ice current would undoubtedly topple over and crush down these combination supports of ice and rock, shifting the currents to new channels, and repeating the operation again and again. By the crushing and grinding of the rock the material was prepared for easy removal; by the changing channels the bottom was broadly excavated; by the letting down of the ice-roof the water and ice were kept constantly at work upon the rocks; and thus the valleys were gradually widened and deepened.

May not some of the lake basins have been partly excavated in this way? Erie and Ontario are situated precisely where agencies like these may be supposed to have operated most actively.

§ 625. To recapitulate, it seems clear that a system of preglacial valleys and streams existed in this region; that their accumulated waters reached the ocean either through the St. Lawrence or the Mohawk and Hudson, most probably through the former; that the great divide at that time could not have been less than 600 feet above the ancient valley-floor near the present head of Lake Erie, and 2000

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* It may be questioned whether the depth of water in the basin was not sufficient at some stages of the growth and decline of the ice sheets, to float large fields of it. But even if the mass was too thick to float, we may be sure that it was buoyed up by the water beneath it and rendered more susceptible to the guidance of the influences which were propelling it forward.

feet near the head of Lake Ontario; that there is no evidence of a change of levels *at any time* sufficient to throw the waters, (if they were free from ice,) from the *bottom* of this old channel backward or southward over the old divide into the Mississippi valley. We cannot avoid the inference, therefore, that causes similar to those described above bore an important part in the excavation of the lake basins, whether they were competent to the performance of all the work that has been done or not.

§ 626. It is also clear that at some period subsequent to the erosion of the ancient river valleys, several important gaps were cut through the crest of the great pre-glacial divide, between streams previously taking their rise upon it and flowing in opposite directions.

One of these cuts may be found near the head of Seneca lake, opening a communication with the Susquehanna river; present elevation above ocean 880 feet.

There are five others in Ohio, as follows:*

1. Between Grand river and the Mahoning, elevation . .	. 936′
2. Between Cuyahoga river and the Tuscarawas, elevation	. 968′
3. Between Black river and the Tuscarawas, elevation .	. 909′
4. Between Sandusky river and the Scioto, elevation . .	. 910′
5. Between Maumee river and the Miami, elevation, . . .	940′

Still another gap, the lowest in elevation, the broadest and most important one of all, connects the valley of the Maumee with the valley of the Wabash, the summit elevation being only 790 feet.

It will be noticed that these southern outlets to the lake basin are cut down to varying levels, being precisely of such a character as might be expected to result from the conditions above described. They appear to have been surface outlets for the *overflow* of the under-ice waters following the moving glaciers during the period of greatest accumulation of ice—intermittent streams dependent upon the fluctuating levels of the interior sub-glacial lake. These water levels, I imagine, were very inconstant. When the sub-glacial streams were delivering freely to the northeast the water line would fall; when they were obstructed, it

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* Geology of Ohio, Vol. II, page 47.

would rise. There were sudden, partial stoppages in the main channels, periodic accessions to the quantity of water accumulating, diversion of currents by crevasses in the ice, and barriers formed by the tortuous movements of ice cores which projected down into the old valleys hundreds of feet below the free-moving ice-sheets of the surface in such a manner as to practically separate, for a time, different parts of the basin one from another. The area of the basin was so large, the water communication so retarded and exposed to so many accidental conditions, amounting at times to almost complete stoppage of inter-communication, that temporary outlets to relieve these possible contingencies might be maintained intermittently in this place at one elevation, and in that at a different level until time was afforded for an equilibrium to be restored.

It may be said that I have laid too much stress upon the accumulation and action of sub-glacial water (*a*). But witness the facts. The idea that the Ice Age was a period of cold so intense that it was not possible for water to remain in a fluid state beneath it, is evidently an erroneous one. Arctic glaciers to-day are the sources of immense water-flows. The cold producing glaciers is atmospheric, not terrene. A non-conducting ice-sheet, by preventing radiation and induction must necessarily increase the temperature of the earth's surface beneath it, and to a greater degree, probably, under a continental glacier than under one of restricted dimensions, where numerous avenues of ventilation or radiation exist around its edges (*b*). The luxuriant growth of vegetation in close proximity to the ice-wall of a glacier is a proof that the soil is as warm there as at points remote from it (*c*).

The following quotations may be given to sustain the views above advanced:

(*a*) "Our progress on the 5th [Sept.] was arrested by another bay much larger than any we had seen since entering Smith's Straits. It was a noble sheet of water, perfectly open, and thus in strange contrast to the ice outside. The cause of this, at the time inexplicable phenomenon, was found in a roaring and tumultuous river, which, issuing from a fiord at the inner sweep of the bay, rolled with the violence of a snow-torrent over a broken bed of rocks. This river, [Mary Minturn river,] the largest probably yet known in North Greenland, was about three quarters of a mile wide at its mouth, and admitted the tides for about three miles; when its bed rapidly ascended and could be traced by the configuration of the hills as far as a large inner fiord. Its course was afterward pursued to an interior glacier, from the base of which it was found to issue in numerous streams, that united into a single trunk about forty miles above its mouth." * * * * *

"Some seven miles further on, a large cape projects into this bay and divides it into two indentations, each of them the seat of minor water-courses, fed by the glaciers."—*From "Arctic Explorations in the years 1853, '54, '55—By Elisha Kent Kane." Vol. I, p. 97.*

"The glacier was about seven miles across at its 'debouché;' it sloped gradually up for some five miles back, and then, following the irregularities of its rocky substructure, suddenly became a steep crevassed hill, ascending in abrupt terraces. Then came two intervals of less rugged ice, from which the glacier passed into the great *mer de glace.*"

"The discharge of water from the lower surface of the glacier exceeded that of any of the northern glaciers except that of Humboldt and the one near Etah. One torrent, on the side nearest me, overran the ice-foot from two to five feet in depth, and spread itself upon the floes for several hundred yards; and another, finding its outlet near the summit of the glacier, broke over the rocks, and poured in cataracts upon the beach below."—*Vol. II, pp. 270–272.*

(*b*) "A body of ice, resplendent in the sunshine was enclosed between the lofty walls of black basalt; and from its base a great archway or tunnel poured out a dashing stream into the lake, disturbing its quiet surface with a horse-shoe of foam. * * * The stream which tunnels its way out near the glacier-foot is about ten feet in diameter; and I was assured that it never completely suspends its flow.

Although the tunnel closes with ice, and the surface of the lake freezes for many feet below, the water may still be seen and heard beneath, even in midwinter, wearing its way at the base of the glacier."

"This fact is of importance, as it bears upon the temperature of deep ice-beds. It shows that with an atmosphere whose mean is below zero throughout the year, and a mean summer heat but 4° above the freezing-point, these great Polar glaciers retain a high interior temperature not far from 32°, which enables them to resume their great functions of movement and discharge readily, when the cold of winter is at an end, and not improbably to temper to some extent the natural rigor of the climate. Even in the heart of the ice nature has her compensations."—*Vol. II, p. 207.*

"I have found in midwinter, in this high latitude of 78° 50′, the surface so nearly moist as to be friable to the touch; and upon the ice-floes, commencing with a surface-temperature of—30°, I found at two feet deep a temperature of—8°, at four feet+2°, and at eight feet+26°. This was on the largest of a range of east and west hummock-drifts in the open way, off Cape Stafford. The glacier which we became so familiar with afterward at Etah yields an uninterrupted stream throughout the year."—*Vol. I, p. 267.*

(*c*) "The glaciers are moving masses, urged down the inclined planes upon which they are situate by the mutual pressure of their parts, a movement which the seasons accelerate or retard, according to their character. This motion gives rise to the extraordinary spectacle, of summer productions and winter formations being sometimes in immediate contact with each other, the ice-fields obtruding into flowery meadows, and gradually forcing their way into the regions of cultivation. According to Professor Forbes, the very huts of the peasantry (in the range of the Alpine glaciers) are sometimes invaded by this moving ice, and many persons now living have seen the full ears of corn touching the glacier, or gathered ripe cherries from the trees with one foot standing on the ice."—"*The Gallery of Nature,*" *by Thomas Milner, page 208.*

CHAPTER XXXIV.

The Canadian mer-de-glace, and the Appalachian mer-de-glace; their encounter, and movement westward; northern drift, and southern drift; local erosion; erratics, and local deposits.

§ 627. Two movements of ice over the highlands of northern Pennsylvania and southern New York will be described in this chapter; one from the north and the other from the south.

§ 628. After the formation of the great *mer-de-glace* on the Laurentian mountains of Canada, and its progressive envelopment of the Adirondack mountains of New York, and of the entire region of Lake Ontario, southward, to the highlands which enclose the Chautauqua basin of the upper Allegheny river in Pennsylvania (described in the preceding chapters,) this continental sheet of ice, always augmented in thickness, continued to rise and advance, and finally overtopped and flowed over those highlands.

To what height above tide its surface attained we have no means of ascertaining, but reasons will be given further on for believing that the sheet upon the highlands was comparatively thin; for, the main body occupying the lower country evidently parted into two lobes, one of which was deflected southeastward down the Susquehanna valleys, the other southwestward over the lower highlands and through the river gaps of the State of Ohio.

§ 629. On *Plate No. 2, bis*, I have endeavored to show, with sufficient approximation to exactness, the geographical position of *the Chautauqua highland divide* and its continuation to the east and west; defining it, as closely as our scattered and imperfect data will permit, by contour lines 200 feet apart (vertically) from the 800′ tide level upwards.

These contour lines, of course, are only intended to represent the *general topographical features* over which the ice moved, all the minor details requisite for a detailed topographical map of the region being omitted, many of which are indeed still wanting.

§ 630. It will be noticed that the *area of the 2400′* summit is small. It is however most important, from the fact that it forms a water-shed with three slopes, contributing to the St. Lawrence through the Genesee river, to Chesapeake bay through the Susquehanna river, and to the Gulf of Mexico through the Allegheny and Ohio river valleys.

West and northwest of this solid *continental summit* there are several isolated knobs and ridges of equal or superior altitude; but they all drain into the valley of the Allegheny.

§ 631. It will be noticed also, that *inside of the 2000′ contour line* there are both elevations 2500 feet above tide, and valleys with buried bottoms not more than 1100 feet above tide. In other words, erosion has here cut down through a vertical section of surface rocks at least 1400 thick.

This deeply and broadly trenched plateau deserves particular study; for, as it was the last to be covered by the growing glacier, so it was also the first to be relieved when the great ice-sheet melted. It probably supported an *independent mer-de-glace* both before the advance and after the retreat of the greater northern ice-sea, which in the interval of time overflowed it; and to the agency of this local *Appalachian mer-de-glace* both the sculpturing of its hills and the drift-filling of its valleys may in the main be referred.

Its greatest average height is in the southeastern portion, where the Allegheny river takes its rise; and it is split into two unequal areas by the deep valley through which the Erie R. R. passes (the larger area lying to the south of that valley) which receives the drainage of streams coming in both from the north and from the south.

§ 632. I have discovered no evidences that the great *Northern* ice, so far as its *Drift bearing* part was concerned, ever passed over this highland. Indeed ample evidence to the contrary exists in the following facts:

1. No *northern Drift* is observed to the south of it; nor in any of the streams which rise upon its southerly slope; but large quantities of foreign detritus have been swept around to the east into the north branch Susquehanna waterways. Similar drift deposits are also piled up in immense quantities all around its northern slope and fill the waterways of the upper Allegheny and its western branches.

2. No *northern Drift*, as far as I have observed or am informed, can be seen in the upper reaches of the streams falling north from its southerly rim. Such Drift has indeed intruded into it, through low spots in its northerly rim, and has descended the southerly flowing streams as far as the east and west Erie R. R. valley before mentioned. But this valley is practically the limit of the Drift. The ice current which bore it appears to have been met here by ice-currents from the south.

It is plain to be seen from the lithology of the Drift alone, that in this valley two ice streams encountered, joined and flowed out together towards the west. The upper branch valleys of the Allegheny river in Potter and McKean counties are excavated largely in measures lying beneath the Pottsville conglomerate (No. XII), viz., in the Mauch Chunk (Umbral, XI,) Pocono (Vespertine, X) and Catskill (IX) formations; and the conspicuous *red sands and shales* of these formations are plainly traceable along the valleys of the north-flowing streams and on the river flats as far as Olean and Allegany, where they mingle with the Northern Drift swept down the opposing streams from the north. Now, as there is no red rock in the northern branch valleys and no northern detritus in the southern branch valleys,—as every feature in the main valley shows the movement of a glacier *toward the west*,—as every feature in the Allegheny valley south of Olean shows an ice movement *toward the north*,—and as every feature in the northern branch valleys shows an ice flow *toward the south*,—it follows that the northern ice-flow, southward, met a southern ice-flow, northward, and both moved westward side by side.

§ 633. But although the *Drift-bearing* portion of the northern ice sheet may not have passed over this summit land, nevertheless the sculpturing of its surface and the character of the streams falling from it toward the south make it almost certain that at one time the upper *non-Drift bearing clear ice* did flow over it. This seemingly paradoxical statement needs explanation.

§ 634. I intimated in Chapter XXX my belief that ice flows in different currents, at various horizons, with unequal velocities and in divergent lines, dependent upon circumstances controlling its movements. To illustrate:

Suppose the surface of the front of the Northern Mer-de-Glace to have been 2600 feet above ocean, and the land elevations in northern Pennsylvania to have been the same then as now. If the average height of the Chautauqua basin highland summit was at 2500′, then the 100 feet of ice which overtopped that summit would have no impediment to its southward flow at any point along the whole front of the glacier; no inducement to turn either to the right or to the left except as it might be slightly influenced by the draft of side currents in the general mass.

The next stratum of 500 feet (from 2500′ down to 2000′) would strike the headland and must either rise up and go over it or split and pass around it. Of course it would not ascend so long as it had free passage sideways.

The next 500 feet, (from 2000′ down to 1500′) encountered a broader and still more preventive barrier, along which it would necessarily be compelled to flow, and could do so, since a free exit at that level (1500′) existed towards the east; while in northwestern Pennsylvania and Ohio there were probably only a few isolated knobs higher than 1500′.

But the next 500 feet (from 1500′ down to 1000′) was checked in many places; and now moreover *ice moved upon rock* instead of *ice upon ice* as was the case with the ice strata above. But still this stratum also had many avenues of escape to the south even at a level of 1000′, as may be seen on Plate 2, bis.

Considering now the ice from 1000′ down to 750′, it is probable that its lower strata met an unbroken mural obstruction along its front which it could not pass around to the right or to the left, but must either scale or breach to make any further progress southward.

From the 750′ level down to the bottoms of Lakes Erie and Ontario the ice must have lain in a closed trough, and could have had no possible outlet to the south without ascending a barrier which at the present day is nowhere breached to a level less than 500 feet above the bottom of Lake Erie and 950 feet above the bottom of Lake Ontario.*

§ 635. Obviously, then, both in central Ohio and in central New York, the ice-sheet would have had (with an empirically adopted surface level of 2600′) unobstructed flow for its upper 1600 feet; but on the Chautauqua basin summit, only for its uppermost 100 feet. The strongest and most rapid currents would, therefore, be where the greatest volume found freest movement, and the broad, unobstructed upper strata would undoubtedly have a more rapid motion than those at a lower level, because these, impinging upon the barrier divide, would be deflected along its face if they could not ascend to pass over its crest.

The free movement which the upper zones of the glacier had in central Ohio would increase the velocity of its currents there, thus somewhat concaving its upper surface and necessarily inviting all the other currents in that direction; while the same thing would happen to the east, although not to so noticeable a degree, because the overflow through central New York would not be so wide and free.

§ 636. While these upper currents were thus flowing freely by east and west movements towards the south, the lower ice in the deep old valleys would be moving more slowly in quite different directions, impelled by the weight of the upper ice, aided by the drainage water beneath, and directed by the trend of the gorges from which they could not escape.

Thus, after a southwestern outlet for the lower strata of

***The breach in Trumbull county, O, is 936′ above tide; that in Summit 968′; that in Medina county 909′; that in Wyandot county 910′; that in Auglaize county, near the Indiana State line, 940′; that in Allen county, Indiana, near Fort Wayne, 790′.**

ice and the under ice currents of water had been established through the Maumee and Wabash valleys (with their present low divide of about 800′) the Lake Erie ice-core would slowly advance southwestwardly along the face of the great divide, while the upper and freer ice would pass over the crest in a southerly direction across the lower level highlands of Ohio. The melting of its base would keep the glacier always at work upon the rocks beneath; its pressure toward the south would keep it constantly grinding along the face of the escarpment in front of it as it moved southwestwardly, and the result would be the production of a somewhat abrupt and sharp cut northern face to the Pennsylvania divide. This feature of its form has, in fact, been reproduced in detail, but on a smaller scale, in many places in southwestern New York and northwestern Pennsylvania, along the larger streams which run approximately parallel with the lake shore.*

§ 637. We may form some idea of the trend of these ice currents by studying the topography which they have carved out, and noting the geographical positions and physical characteristics of the principal lines of northern drift deposits; but it seems fairly questionable whether these deposits necessarily represent the lowest southern reach of the continental glacier. Let us examine this question.

§ 638. The first piece of Drift that left the northern highlands had of course a point of departure, a time of starting, and a certain average rate of speed for its journey.

It could not start until the ice which bore it had accumulated to a certain height over it, and commenced to move; and this movement implies the advance, also, of all the ice in front of it, which of course contained no Drift.

If it commenced its journey 200 miles north of the glacier front, then 200 miles of clear ice free from this kind of detritus must pass on to the south in advance of it. Its move-

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[* It must not be overlooked, however, that aerial erosion, in the absence of glacial action, would accomplish the same result, seeing that the dip of the rocks constituting the great divide is universally towards the south, so that their basset edges face northward; and consequently, the northern escarpment (if so irregular a country can be said to have one,) should be steep, whether ever touched by ice or not.—J. P. L.[

ment was slow, and the possible distance it could travel would be measured by the time allotted to its journey. Suppose it advanced at the rate of one foot per day; it would then consume 3000 years in traveling 207 miles. It may have journeyed that distance, or it may have traveled farther; it may have moved faster or slower, we do not know; but in any case, there would seem to have been time enough for great modifications of climate to have taken place between the inauguration of the ice age (which must have been long before the Drift commenced its journey) and the moment when this first emigrant of foreign rock plunged into some crevasse along the Pennsylvania divide, or melted out of the southern ice front of the glacier.

The advance sheet of clear ice formed during the period of snow, nevé and ice accumulation, and during the succeeding period of intensest cold, may have spread many miles to the south, and then been cut back again many miles by an amelioration of climate, before the *Drift-bearing* bottom ice reached the glacier's front.

This hypothesis is suggested, however, merely as furnishing a possible explanation of some of the traces of ice action apparently discoverable beyond the southern limits of these northern Drifts.

Other causes might have had, and no doubt did have, an important influence in limiting the Drift-deposits to certain areas.

§ 639. If these ideas regarding the movement of ice be correct it would naturally follow that the upper ice-currents, those which reached the farthest south, would contain but little, if any, Drift. For, by the constant underwaste of ice the debris which it received and bore from the Canadian hills would drop lower and lower as it crossed the lake basin; and the upper ices, formed from atmospheric accumulations and carried forward by more rapid currents near the surface, would pile up above it.

The glacier north of the barrier-divide and below its crest was moving in a southwesterly direction and struggling to overtop the summit; while to the south, in many places, there was a natural slope to the rock surface which induced an accelerated movement in the ice passing over it. Crevasses resulted, and into these the northern debris was freely poured. Such primary deposits have been greatly modified both in position and structure by the various agencies which have wrought upon them during succeeding ages.

The pre-glacial divide being as we have viewed it, a broad and deeply trenched plateau, certainly from 30 to 60 miles wide, the ice-movement was again checked when it reached the southerly rim of the summit basins, and here other crevasses occurred and more debris was dropped.

§ 640. All the low areas of these basins are covered by mixed Drift-beds, some of the valleys being filled to the known depth of 450 feet. These were the grand glacial dumping grounds; and it would seem that the *currents bearing northern material* never passed beyond them, except as local glaciers creeping down through the several gaps already referred to. Here, during the immeasurably long ages of the *recession period* (when the ice-sheet had become so much reduced in thickness and power that it was scarcely able to overtop the hills in front of it) the southern lip of the great glacier lay and wasted, and its heterogeneous burden of foreign and local rocks was promiscuously dropped, to be re-worked and re-arranged by the peculiar agencies which control the movements of ice and water in such situations as these.

§ 641. If we pause here to consider the *location* and *surroundings* of the *Summit basins*, we shall see that they must have been, during the final retreat of the Continental glacier, under climatic and dynamic influences quite different from those obtaining in districts both to the north and to the south of them.

If the ice-front was cut back by a gradual amelioration of climate, the southerly slope of the divide would first be sensibly affected by it; and here the ice-sheet, (being comparatively thin and thoroughly under-drained,) would waste rapidly from the higher grounds, leaving only local glaciers, urged down the valleys from the *mer-de-glace* behind or north of them.

But when the ice-front had been melted back to the southerly crest of the Chautauqua divide, the battle between the elements of heat and cold commenced in earnest. North of the barrier, the ice-king had massed his forces; lake Erie basin was full of ice, and all the reserves of the north were freely moving down into it. As fast as one skirmish line on the summit was repulsed, another was thrown forward; and thus alternately advancing and retreating the contest raged for ages before the invading ice was forced back and permanently confined within the limits of the present lake basin.

§ 642. During this period the surface of the summit basins was wrought upon by almost every possible combination of the powers of ice and water. In some of the valleys there were *local glaciers;* in others, *inter-glacial lakes.* There were temporary *ice-dams* and *ice-gorges;* intermittent deliveries of ice and water, now in one place, now in another, as accidental obstruction or free delivery might direct;* and as a natural result, we now find almost

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*Avalanches of rock and earth, snow and ice from mountain heights frequently produce notable changes in the forms and deposits of the valley beds below. Damming the gorges they produce temporary and even permanent lakes. When such a dam bursts, either from the pressure of the water behind or after being weakened by the long erosion of its outlet, deluges and debâcles desolate the lower reaches of the valley for many miles; load it with a new covering of sand and gravel; and oblige the stream to adopt a new water bed.

A memorable instance, occurring in 1818, is described by Escher von der Linth. The Val de Bagnes is a rocky glen among the Alps, thirty or forty miles long, opening into the valley of the Rhone at Martigny. Its cliffs are covered with perpetual snow. At its head are two glaciers, out of which flows the little river Dranse, in a gorge between Mont Pleureur (the mournful) and Mont Mauvoisin (the bad neighbor), which has often been blocked by huge masses of ice falling from the end of the glaciers. By April, 1818, the accumulated obstruction of previous years had grown into a cone a hundred feet high, behind which the Dranse began to form a lake. The cantonal authorities employed M. Venetz to engineer a tunnel through this conical dam of ice. The tunnel was begun May 10th and completed June 13th. The lake already contained 800,000,000 cubic feet of water In three days the new outlet reduced the amount to 530,000,000; but the swift outrush melted the ice, widened the mouth of the tunnel, hurled forward masses of the adjoining glacier, and reduced the length of the floor of the tunnel from 600 to only 8 feet. The torrent then attacked the dêbris at the foot of Mont Mauvoisin, against which the ice cone had rested, thus undermining the glacier itself, and making a water-way between it and the mountain wall.

At this moment the ice gave way, and the whole of the lake water precipitated itself in 30 minutes past the gorge down into the Val de Bagnes, carry-every variety of Drift-deposits within their limits—*finely levigated clays*, *pure sand-beds*, *beaches of lake shingle*, *coarse gravel banks*, *windrows of huge metamorphic bowlders*, and sometimes all of these promiscuously intermixed within a limited area.

§ 643. A similar disorder seems to characterize the deep deposits also, as shown by oil wells; in one locality quicksand predominates, in another clay, in another gravel; or they may all three be present, or repeated in layers in the same well; but they do not lie, as far as I have been able to discover in any regular order of superposition.*

§ 644. *The Chautauqua basin* appears to have been filled with bodies of ice and water possessing all the powers and motions requisite for lake-making. Under their actions *streams were cut together*, *valleys were broadened*, *bowl-shaped basins were formed* among the hills; and had not the processes been interrupted, either by the failure of ice

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ing off the Mauvoisin bridge, 90 feet above the ordinary level of the Dranse. It deluged the wider part of the Val below, poured through the next gorge, deluged the next open reach, and so on through a succession of basins and gorges it swept its burden of rocks and ice, forest timber, houses, barns, and the very soil itself, forward to Le Chable. Here the half solid deluge became banked between the piers of a stone bridge 50 feet above the level of the Dranse, and attacked the slope on top of which stood the church and houses of the town. Fortunately the bridge gave way, and only the houses at its two ends went down with the debâcle. The wide reach of valley from here to St. Branchier was then overwhelmed; houses, roads, fields and crops, orchards loaded with fruit disappeared in a moment into the long narrows between St. Branchier and Martigny, and were strewn on the plain of the Rhone Le Burg and Martigny were both ravaged, and the wreck of the spent flood was scattered along thirty miles to the Lake of Geneva.

M. Escher calculated that 300,000 cubic feet of water issued from the barrier per second, at the rate of 20 miles an hour. The Rhine at Bâsle delivers only 60,000 It reached the lake of Geneva (45 miles) in 6½ hours.

A new coat of alluvion, several feet thick, was spread over all the lower Val de Bagnes, but so irregularly that roads had to be cut through it as if through snow-drifts. Isolated masses of rock were carried great distances, one of which, hurled from the gorge on the plain below, measured 12′ by 12′ and 27 paces around. Still larger masses showed that they had been moved. The Dranse adopted, after some fluctuations, a wholly new water bed; and the whole plain of Martigny was changed in feature by the outspread of a layer of detritus. (See Gallery of Nature, by Rev. Thos. Milner, p. 412.

* Bowlders of metamorphic rock, and blocks of sandstone and conglomerate are quite frequently encountered, and trees a foot or more in diameter have been reported, at a depth of over 100 feet.

supply or by the wearing down of its outlet (which resulted in drainage) it is evident that the agencies at work would have here formed a lake, in the same manner as they formed one in the Lake Erie basin, where, owing to lower levels and a more favorable situation they continued to operate for a much longer period.*

As the glaciers did not withdraw from the basins with a steady and uniform rate of retrogression, but evacuated only after long periods of alternating advances and retreats, *moraines* were formed in many places; and hence, when the ice disappeared, *chains of small lakes* stretched all along the broad valleys north of the outlets. Periodical freshets, bringing down the waters accumulating from broad surfaces, eventually cut channels through the *moraine barriers;* and thus, one after another, the lakelets were drained; but their old outlines may be traced in many places by the *terraces* and *beaches* which surrounded them, and by the *lacustrine deposits* left in their beds.

§ 645. It is often remarked as a curious fact that *nearly all our small lakes lie on summits at the heads of streams.* But this should excite no surprise. They remain there as lakes to-day, because they have always received the drainage of but small areas, and have not been seriously affected by annual freshets; consequently their outlets cut down very slowly, and they have not yet had time to drain. We see evidences, however, in nearly all of them, that the water once stood at a higher level than it stands at present.

Chautauqua lake may be taken as an illustration; it has

[*This must not be taken in so large a sense as to make the whole valley now occupied by Lake Erie the work of the *Canadian mer-de-glace,* for the whole discussion of the subject of this chapter presupposes a topography existing before the ice age essentially the same with that which exists at present. To suppose Lake Erie excavated by ice, is to ignore all the knowledge we have acquired by forty years of study of the Appalachian topography from Canada to Alabama. The preglacial existence of the present basin of Lake Erie is as necessary to the argument of this chapter as the preglacial existence of the great Chautauqua barrier overlooking it.

It must also be remembered that an eminent difference in the two cases referred to in the paragraph above arises from the fact that the Lake Erie basin valley has a special and remarkable barrier to the north formed by the uplifted outcrop of the Niagara Limestone, &c., through which the Niagara outlet has been cut. J. P. L.]

cut down an outlet through about 50 feet of stratified rock. This has of course reduced its surface level by that much. What proportion of this cut was made during the ice age cannot be known; but the proofs are patent that a higher water level than the present has been maintained in comparatively recent times; and probably the lake area would not have been nearly as large as it now is, if, like other summit lakes, its outlet had been through Drift instead of through solid rock.

§ 646. *The southeastern limit of northern drift* is very closely defined by the Allegheny river valley in northwestern Pennsylvania; and the locations of the most noticeable deposits, when viewed in connection with the trends of the channels through which the materials must have been transported, and by the sculpturing of the hills surrounding the *mountain fiords* in which they lie, furnish good evidence in support of the hypothesis advanced in relation to the methods of ice movement on the divide.

From Olean in New York *to Smith's Ferry* on the Ohio line the Allegheny-Ohio river bed is strewn with rounded water-worn *pebbles of northern rock;* but the percentage and quality of foreign material varies quite materially at different points.

All the tributaries which come into the valley from a northerly direction, and which rise in or near the summit basins, are also strewn with Drift; while those flowing from opposite directions contain only such local deposits near their mouths as have been forced up stream, sometimes a mile or more, by the Drift-bearing glacier of the Allegheny.

§ 647. *At Olean*, heavy bodies of ice were forced in from the Genesee valley,* and meeting the ice-current of the Alle-

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*The manner in which ice-currents were forced into the summit basins through every available opening, may be profitably studied along the westerly branches of the Genesee River. All the larger ones which take their rise on the divide are flowing in broad and deeply cut valleys which connect directly with others leading to the Allegheny River. It may be noticed on the county maps that the highways frequently follow these streams, passing over the ridge from one river to the other. So continuous are these valleys, and so similar are the cuts at the summits to some of the passes below, that the ordinary traveler might pass over the road a number of times and not be able to tell where the waters divide. The cuts are generally characterized by pregheny, an *ice-eddy* resulted, which cut out a broad basin, and deposited heavy masses of Drift, partly foreign, partly local, which, however, was not carried southward far up the Allegheny river valley.

This action of the two currents is made manifest both by the shape of the basin, and by the position of the *eddy-hills.*

Across the river, southwest of the village, a very peculiar hill may be noticed, rising from the plain with a straight-cut side of almost bare rock, in appearance like the side of a truncated pyramid. This sharp-cut hill-face, so in contrast with the smoothly rounded slopes forming the other sides of the amphitheatre, would be hard of explanation on any theory of sub-aerial erosion; but as a result of ice-action it speaks for itself. Here was an elbow in the ancient-river; and when the ice came in southwestwardly from the Genesee valley, it struck the current coming down the Allegheny almost at right angles and held it against this point until its projecting nose had been ground squarely off.

A little north of this, the eddying ice has cut another point into a detached, elongated pyramidal hill, and formed several conical drift-hills in the valley basin.

§ 648. Between *Carrollton* and *Great Valley* the river has a northerly trend, and here the undercurrents of advancing ice were met and held in check by another important stream pouring down Great Valley. The upper strata of ice found outlets in several places across the hill-tops to the west. One of these waste-weirs between Great Valley and Little Valley was occupied long enough to cut down

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cipitous banks, a rather narrow stretch of creek-bottom, and an appearance of but little depth of Drift. They also usually occur at or near a considerable curve in the valley.

The Genesee valley is so located as to have received the full force of the ice-thrust, and its headwater streams rise upon the highest portion of the divide, through which no important southern outlets of overflow have been cut; hence the forward movement of the glacier was impeded and the ice crept through and deepened every possible avenue leading into the Chautauqua basin.

The summit divides of several streams inside the limits of the Chautauqua basin have been cut down in a similar manner, and they all clearly show the action of ice, for they are in situations where water alone could never have accomplished such results.

through a considerable thickness of rock, stopping at the *Salamanca Conglomerate*, a massive layer forty feet or more in thickness. When the ice-sheet wasted and the valley channel became able to carry the ice and water at lower levels, this outlet was abandoned; and now, the ice-cover having been removed, a mysterious "Rock City" remains perched upon a narrow ridge—the admiration and wonder of thousands of visitors, the subject of many artistic sketches and pen-pictures, and the suggestive prompter to many strange and some ridiculous hypotheses as to its origin.

South of Salamanca other cuts, but not so deep, were made, as attested by *elongated hill-tops* trending in an east and west direction and by deep *bowl-shaped basins* (now occupied by insignificant streams) into which the overflow has poured.

§ 649. At the mouth of Great Valley there are thick *gravel-beds* particularly deserving of notice, because they are composed of a large percentage of the hardest northern rocks, and the pebbles are unusually spheroidal, as if shaped by attrition under a rotary motion—facts which well support the other evidences of an ice-eddy at this point.*

§ 650. *At Steamburg* the old valleys were wrought into a broad basin; an elliptical, truncated hill was cut off from the point in the elbow of the ancient river (see Plate XL), and a number of conical ice-eddy Drift-hills were left upon the flats.

§ 651. *At Jamestown* the old Chautauqua outlet was filled up and a group of Drift-hills were stretched across the valley, completely closing the old outlet and forcing the pent-up waters over a point of fixed rock through which they have since cut a narrow channel 50 feet or more in depth.

§ 652. *At Warren* the eastern and southern walls of the

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*Not that ice itself is capable of grinding blocks into a spherical shape, for the characteristics of ice-débris are 1. angularity, 2. striation, 3. commixture, and 4. range of distribution. But, where glacial-water-streams can manage drift pieces in confined places, they are capable of rounding these in a remarkably symmetrical manner.

basin at the intersection of the Conewango with the Allegheny are faced with *gravel-banks*, from which I have made a collection of pebbles which can scarcely be distinguished from a similar one picked up from the strand in Dunkirk harbor.

As before explained, the ice-sheet here had a southward draft, one current having an exit through the Barnesville cut into Tionesta creek. This carried the Drift up to *Stoneham* and *Clarendon*, about three miles from the Allegheny, where it forms the present divide, at an elevation of about 1400 feet above ocean, and underlies the area covered by *Cranberry swamp*. More or less of it was also carried forward by the glacier into Tionesta creek. In no other locality has it penetrated so far to the south-east of the Allegheny valley as it has here. But the reason for this is obvious—no other stream had an outlet cut at the south, consequently the ice-flow elsewhere was checked and thrown back upon the main stream.

§ 653. *Brokenstraw*, west of Irvineton in Warren county, flows in an east and west trough occupied by the Allegheny river at its east end. This trough naturally received the full force of a number of ice currents from the north. Near *Spring creek*, just where such a result might be expected, the erosion has been very extensive. An isolated *pyramidal hill* has been carved out from one of the old points, and the valley after being widened and deepened was studded with gravel hills.

§ 654. *Opposite Garland* a stream comes in from the south (Crouse or Mullingar run) through which the ice-current pressed, effected a connection with Caldwell creek, cut down the divide to within 150 feet of the Garland level, and poured an immense amount of mixed debris into the Oil creek basin. It landed in the elbow where the old stream turned north, about three quarters of a mile from the present outlet of the basin, the high hills on all the outer circle of the curve preventing further progress. Here it filled in to the depth of 300 feet or more, when a new passage was opened leading more directly toward the present outlet. But this delivery from the Brokenstraw was only a temporary waste weir to the Chautauqua basin, and was abandoned as soon as the Allegheny channel at Irvineton became sufficiently enlarged to accommodate all the out-flow.

§ 655. *At Irvineton* the evidences of a long continued ice-gorge while the Allegheny was being prepared to convey the additional amount of drainage now forced into it, are plainly seen in the wide cut basin, in the topography of the hills and in the character and positions of the drifts

§ 656. *At Oil City* and *Franklin* other accessions of northern material were brought into the Allegheny valley. The contour map at the junction of French creek with the Allegheny (Plate XVIII) shows how the confluent glaciers have sculptured (or completed the sculpturing of) the topography there.

The Big Sandy is the last *northern* inlet of importance to the Allegheny. Below this little foreign matter has come into the valley until the *Big Beaver river* is reached, where, as may be noticed on Plate No. 2 bis, a short and quite direct avenue is opened up into a large area of low levels. As might be expected, therefore, here lie immense deposits of Drift, largely composed of northern rocks transported and dropped by the local glacier which must have crept down the Beaver valley and occupied it for ages.*

§ 657. Reviewing the above facts, we see that the most conspicuous *Drift-deposits* lie precisely where they should be looked for if the ice movement were such as we have supposed it to have been, and the relative surface levels the same as at present.

The glacial cuts in every instance have been made in curves in the hill-barriers where the full force of the ice-shove was concentrated; and, through those which were ex-

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*I strongly suspect that *Big Beaver river* is a glacial enlargement of a small ancient stream, formed in the same manner as those found in the summit basins; and that anterior to the Ice Age the Shenango and other head-water streams of the Beaver, *including the Connoquenessing*, delivered northwardly through the *Mahoning* and *Grand rivers* into Lake Erie basin: but having had no opportunity of verifying my suspicions I can say nothing further about it. The tendency of all the summit streams to flow southwesterly down the dip for a certain distance and then to swing round toward the north into the lake basin, is witnessed by the course of the *Cuyahoga*, and also by many of the modern streams along the lake slope.

cavated to a sufficient depth to remain as permanent southern outlets immense burdens of northern debris have been delivered, which the transporting glacier threw off at every sharp bend in the valley and on every nose where two confluent ice-streams met. For the sculpturing of the summit basins, the excavation of the glacial cuts, and the transportation of the gravel beds, we seem therefore to have a very plausible explanation.

§ 658. *The origin of river terraces* has been a much mooted question, which I do not feel prepared yet to discuss. There are peculiar difficulties in it to be encountered. While there can be no doubt of the passage of a valley glacier of great depth along the Shenango and Beaver rivers through the westernmost tier of counties, to within a few miles of the Ohio river,* and probably into the Ohio river valley, blocking up for a time the outflow of the Allegheny and Monongahela water basins, there is entire absence of evidence in the shape of striæ and erratics that a glacier ever filled the lower Allegheny river valley; and a complete lack of *northern* Drift in the Monongahela river valley.†

If the Allegheny and Mononaghela valleys before and during the retreat of the northern ice may be conceived as filled with two local ice streams, moving independently along those deep and narrow water ways, meeting at Pittsburgh and passing together (as one) northwestward down the Ohio river valley, cutting off in their deflection the point of highland and leaving the conical hill‡ in Allegheny city, now support-

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*See for the proofs Prof. White's Reports of Progress Q, QQ.

†See Prof. Stevenson's Reports of Progress K, KK; Mr. W. S. Platt's Report of Progress in Armstrong county, H.^{5}; and Mr. H. M. Chance's Reports of Progress in northern Butler and Clarion counties, V, VV.

[‡The explanation of such conical hills is still difficult. In my Manual of Coal and its Topography (1856) page 153, I give a sketch which I made some years previously, of two such eddy-hills projecting into the valley of Pine creek in Lycoming county; of another similarly half-attached to the sides of gaps in the Conglomerate of Broad Top in Huntingdon county; and of two others connected at gaps in the Bald Eagle mountain near Wilkes-Barre and Jersey Shore. Another occurs in a gap in Nittany mountain, southeast of Bellefonte in Clinton county.

No trace of ice-action has been remarked in the neighborhood of these eddy-hills. They are evidently features of the general topography of the country, due entirely to water-erosion in some one of its forms. Those in Pine Creek ing the soldiers' monument—the combined stream would encounter the Beaver river glacier in Beaver county.

Over or through such ice in the Allegheny and Monongahela valleys all the drainage of their water basins must pass, a drainage increased in volume in the melting epoch at the close of the ice-age. The thin upper edges of the ice-core in each valley would melt first and more rapidly, the lateral vales would become water pools, and violent water currents would set down the main valley between the ice and the hill sides whenever the under-ice water-way became obstructed. Thus the materials thrown off sideways by the valley ice would be rearranged, at various heights of 200, 300 or 400 feet above the valley bed, into terraces or flood-plains, like those which now cling to the hill sides.

The quality and structural arrangement of the materials composing the terraces and gravel banks, and the positions of the deposits, when studied in connection with the surrounding topography, seem to me to favor the view that they were formed by agencies immediately connected with the Ice Age, rather than that they are remnants of the silts of valleys which have been filled up three or four hundred feet and re-excavated since that time.

§ 659. *The distribution of erratic bowlders* remains to be referred to. The highest point at which I have myself seen large blocks of metamorphic rocks is on the table-land east

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valley have their summits—one of them on a level with an upper (horizontal) stratum of massive sandstone—the other (in front of it) on a level with a lower stratum of massive sandstone, as shown in the section accompanying the sketch. These two hills seem to me to show *progress of erosion*; the one in front being about half as high as the one behind it; and the higher one being two thirds as high as the tableland, which is about 1000′ above the bed of the valley. Their attachment to one another and to the tableland, their shape, and respective positions lead me to believe *now* that they were cut off from the point of tableland and from each other by accidental differences of hardness in the horizontal formations which run through all three; and that their quasi conical shape has resulted from the quaquaversal drainage of vertically descending rain water, and from the universal surface-erosion of frosts and winds; as in the case of all "pulpit rocks."

The other eddy-hills mentioned above are by no means so easily explained. But the Allegheny City hill may have owed its birth to ordinary river erosion when the bed of the Allegheny river was 300 feet higher than at present, and may have been receiving its present shape by the agency of river freshets from that time to the present.—J. P. L] of Chautauqua lake, at an elevation of about *1750 feet above ocean;* the lowest (that is, the lowest broad table-land summit), in Conneaut township, Crawford county, near the Penn'a-Ohio State line, at an elevation of about *1070 feet.* All along the divide and at any elevation between these points they may be found.

It has been asserted by some that they always lie upon the surface, and that therefore they must have been dropped by icebergs. That they do lie upon the surface in many notable instances will not be disputed; but it is well proven now that they also frequently lie imbedded in Drift many feet below the surface. Both on the surface and in the gravel-banks they have a vertical range of several hundred feet. The iceberg theory, therefore, in every aspect in which it may be viewed, seems to me to be entirely inadmissible; we must look for some other agency. For—

1. *The proportion which the erratics bear to the whole mass of glacial débris*, if it could be calculated, would be found to be very small indeed; consequently, where deep deposits of Drift occur they might be so sparsely scattered through it as to attract but little attention, while in exposed situations and in a thin Drift-sheet they would be very prominent.

2. We must consider also the peculiar manner in which they have been distributed. Where comparatively undisturbed along the divide they are almost always found *in colonies*, stretching in long and narrow lines, while for miles on either side of these rock-windrows scarcely a bowlder can be seen.

Probably they lie in a similar manner where buried in the Drift, and this would account for their absence in some gravel-banks and their presence in others.

They appear to have been thrown off from the glacier moving south-westerly through Lake Erie into crevasses along the summit. Those which came last, after the great ice-flow was checked and the ice commenced to melt back into the lake basin, remain where they were dropped. Many of them were covered at first to a considerable depth by glacial débris; but subsequent denudation has laid some of them bare, and others which lay within the range of frost-action have been brought up by degrees until all such now lie on the surface.

The tendency of large *blocks of local rock* to congregate along certain lines is finely illustrated in many places in the summit basins, where the sandstones and conglomerates have been taken up by the ice and dropped in reefs, exactly as the *azoic bowlders* have been dropped; and in some cases near the northern front of the divide the two kinds of rocks are promiscuously intermixed.

3. Another suggestive fact is that northern bowlders are only found in situations where a free movement of glacial ice has been possible. Thus at Cuba, N. Y., in the draft between the Genesee river and the Allegheny, they may be seen at an elevation of about 1600 feet, while at Wellsville on the Genesee, 100 feet lower, not a large bowlder can be found. In fact all the valley Drifts here are composed mostly of local materials, the ice sheet in this stream having been held in check by the unbroken divide at the south, so that the Drift-bearing currents of the north could not intrude; or if they did force up this far, the older Drifts were afterwards covered up by new debris brought from the south when the glacier receded.

The conclusion that northern bowlders and Drift have been landed in noticeable quantities on the great divide, and south of it *only along certain lines* where the glaciers were not permanently checked but had a free southerly draft and delivery, is further sustained by the evidences of ice action in Tioga and Bradford counties over which part of the eastern lobe of the mer-de-glace passed after breaching the summit at the head of Seneca Lake. No attempt has yet been made to interpret the Drift phenomena of this region by the hypothesis of ice movement advocated in this chapter; but it is evident from the facts given in Mr. Sherwood's Report G, that the foot-prints of the same mechanical agencies which fashioned the summit basins lying further west are clearly traceable here. The present main trunk of Pine creek, in the southwestern part of Tioga county, looks like a glacial cut similar to those which I have been describing, and it is certain that in preglacial times upper Pine creek at least contributed its waters to Tioga river through the old valleys of Marsh creek and Crooked river, now cut off from Pine creek by a long moraine. See Report G, p. 53, &c., and accompanying maps.

It is highly probable that the Drift deposits of the North Branch Susquehanna basin when they come to be studied in detail will shed much light upon structural questions relating to the smaller lakes of the State of New York; for up along through the deep valleys in which these lakes lie came forward one section of the Drift-bearing northern ice sheet.

CHAPTER XXXV.

Well Records referred to on the plates accompanying this Report, as published in Appendix III.

	Plate	Fig.
Boyd Hill,	VII,	31.
Economy, No. 2,	IV,	7.
Summit,	V,	15.
Mahan,	V,	17.
Graff, Bennett & Co.,	V, VII,	18. 32.
Pine Creek, No. 1,	VII,	34.
Midland, No. 1,	VII,	35.
Cherry Run,	V, VII,	21. 36.
Griswold, No. 1,	VI, VII,	30. 38.
Rohrer, No. 2,	VI,	29.
Strotman,	VI,	26.
Hains,	VI,	22.
Iron Bridge,	IV,	8.
Cove Hollow,	IV,	9.
John Smith,	IV,	2 & 10.
Boyce, Rawle & Co.,	IV,	3.
Raymond, No. 6,	IV,	4.
Reliance,	IV,	12.

§ *660. Boyd's Hill Well.* (*Plate VII, Fig. 31.*)

1876–77.

This well is located in the city of Pittsburgh, on a platform overlooking the Pittsburgh steel works, near the north bank of the Monongahela river. A full history of it has already been given by Prof. Lesley, in Appendix E of Report of Progress L.

Below we give a catalogue and description of the specimens of sand-pumpings, which were regularly preserved in glass jars as the boring progressed, by Dr. Hunter, who was one of the owners of the well, and personally superintended the drilling of it.

These specimens were carefully taken from the original jars, brought to Pleasantville, put in separate bottles, numbered and arranged in order as below, for preservation in the State museum, the owners of the well having kindly made a donation of them to the Survey for that purpose.

The thickness of rock assigned to each specimen is that which was marked on the jar. As some of the intervals are large, of course it cannot now be positively known whether the single specimen preserved faithfully represents the character of the whole vertical distance covered by it or not.

It is fair to presume, however, that the specimens were taken carefully, as they were intended to exhibit a correct representation of the entire stratification when packed in the jars (one layer on top of another) as the sediment came from the well, and that therefore no material change in the constitution of the rocks was overlooked and no important specimen omitted by Dr. Hunter.

Spec No.				
	Well mouth above ocean in feet,			852
	Conductor,	8 to	8 =	844
1.	Shale, fawn color and blue, with layers of micaceous sandstone,	78 to	86 =	766
2.	Coal,	8 to	94 =	758
3.	Shale, sandy, dark, bits of lime,	211 to	305 =	547
4.	SS., light grey, micaceous, hard,	45 to	350 =	502
5.	Shale, fawn and lead color, some lime,	132 to	482 =	370
	SS., as given in record, but no specimens preserved, (see note 2),	100 to	582 =	270
6.	SS., light reddish grey, with white specks, soft, fine grained,	5 to	587 =	265
7.	Shale, slate, and brownish sand-shells; trace of lime,	25 to	612 =	240
8.	Coal,	3 to	615 =	237
9.	Slate, hard and firm,	6 to	621 =	231
10.	Sand-shells, grey and sandy-shale, dark,	21 to	642 =	210
11.	Shale, bluish-grey, slaty, micaceous, containing fragments of limestone. (*Ferriferous limestone,*)	15 to	657 =	195
12.	Shale, slaty, dove color, soft,	18 to	675 =	177
13 A. 13 B.	Shale, yellow-brown and black, micaceous, gritty, soft; Top (13 A) darker than bottom,	20 to	695 =	157
	(13′ A and 13 B′ same as above, but washed.)			
14.	Shale, slaty, micaceous, dark,	25 to	720 =	132
15.	Coal,	9 to	729 =	123
16 A.	SS., very fine, grey,	60 to	789 =+	63
16 B.	SS., very fine, white,			
16 C.	SS., fine, hard, iron stained,			

Spec No.		
17.	Slate, nearly black,	90 to 879 = — 27
18.	Limestone, very dark,	10 to 889 = — 37
19.	SS., white, very fine, and intermixed with particles of grey limestone,	25 to 914 = — 62
19′ 19″	Same, coarse and fine, separated and washed.	
20 A.	SS., white, very fine and hard. The specimen is iron stained,	80 to 991 = — 142
20 B 20 B′	(Sifted spec., lower part of rock.)	
21.	Slaty-shale, dark,	82 to 1076 = — 224
22.	SS., gray, with white specks, fine hard, micaceous, no pebbles, (sifted No. 22 fine, No. 22′ coarse.)	110 to 1186 = — 334
23.	Slate, micaceous, gritty,	154 to 1340 = — 488
24.	SS., light-gray, fine, flaky, (coal probably accidentally dropt in,) (sifted No. 24 fine, No. 24′ coarse.)	35 to 1375 = — 523
25.	Slaty shale, dark, micaceous, with gray sand shells,	30 to 1405 = — 553
26A.	Slate. shaly, lead color,	185 to 1590 = — 738
26 B.	SS., greenish and *red*, fine, flaky,	
27.	SS., olive-gray, soft, some pebbles, probably in layers of white sand, (sifted, No. 27 fine, No. 27′ coarse.)	110 to 1700 = — 848
28A.	SS., gray, fine,	40 to 1740 = — 888
28 B.	SS., gray-green, *red*, some slate,	
28 C.	SS., gray-green, *red*, some slate,	
29A.	Slate, shaly, dark,	20 to 1760 = — 908
29 B.	Slate, shaly, dark,	
29 C.	Slate, shaly, dark,	
30A.	SS., very fine and hard, gray, (specimens oxydized,) (Sifted No. 30B fine, No. 30B′ coarse.	15 to 1775 = — 923
31.	Shaly, gray and *red*, with thin sand shells,	70 to 1845 = — 993
32.	Slaty shale, with gray sand shells, *traces of red*,	15 to 1860 = —1008
33.	Slate, with thin white shells,	40 to 1900 = —1048
34.	Slate, common,	38 to 1938 = —1086
35.	Slaty, shale, *red*, green and blue, shelly,	12 to 1950 = —1098
36.	SS.. light-gray, fine, hard, flaky, (Sifted No. 36 fine, No. 36′ coarse.)	15 to 1965 = —1113
37.	Shells *red* green gray with black slate,	45 to 2010 = —1158
38.	SS., olive-gray, very fine, flowery, flaky, (Sifted No. 38 fine, No. 38′ coarse.)	25 to 2035 = —1183
39.	SS., white, very fine, flaky, some slate, ("3d SS ,")	15 to 2050 = —1198
40.	Slate, shaly, with sand shells,	40 to 2090 = —1238
41A.	SS., very fine,	27 to 2117 = —1265
41 B.	Slate with close thin layers of fine SS., (Sifted No. 41B fine, No. 41B′ coarse.)	
42.	SS., olive-gray, very fine and hard, flakey, mixed with slate, as if in thin layers, (Sifted No. 42 fine, No. 42′ coarse.)	21 to 2138 = —1286
43.	Slate, common, soft,	100 to 2238 = —1386
	Slate, common, soft to bottom,	122 to 2360 = —1508

NOTE 1.—Specimens marked A B and C are from the top, middle and bottom of the layers of sediment as originally packed in the large jars. The duplicate numbers have been washed and sifted, so that the true character of the rock may be more plainly exhibited.

NOTE No. 2. The following quotations from Dr. Hunter's letter to the State Geologist, dated March 20, 1876, no doubt gives a more correct description of the strata occupying the interval between specimens Nos. 5 and 6, than the record which was made after the well was completed, for then the facts were fresh in mind. He says:

"We have passed through 86 feet of sedimentary friable rock, at the bottom of which we found fresh water; then 8 ft. of coal; [the coal is *included in the 86 ft., according to the jars,*] followed by 211 feet of rock similar to the 86 ft.; then 45 ft. of close white sandstone, hard; then 132 ft. of slate, *tough;* then 25 ft. of sandrock, more porous than the 45 ft. rock, with a little show of gas; then 36 feet of slate; then 3 ft. of coal, which is some 546 ft. below the surface or starting point. We are now in slate at 600 ft."

Taking this version and commencing with the 45 ft. sandstone, we get the following section:

Specimen No. 4,	Sandstone,	45′ to 350′
Specimen No. 5,	Shale,	132′ to 482′
100 ft. specimens wanting.	Sandstone,	25′ to 507′
	Slate,	36′ to 543′
	Coal,	3′ to 546′
	?,	36′ to 582′
Specimen No. 6,	Sandstone,	5′ to 587′
Specimen No. 7,	Shale or slate,	25′ to 612′
	("We are now in slate at 600 ft.")	
Specimen No. 8,	Coal,	3′ to 615′
Specimen No. 9,	Slate,	6′ to 621′
Specimen No. 10,	Sand shells,	21′ to 642′
Specimen No. 11,	Shale. *Limestone.*	15′ to 657′

As specimen No. 11 contains traces of the *Ferriferous limestone*, the bed of coal reported above appears to represent the Kittanning Upper coal.

Economy Well No. 2. (Plate IV, Fig. 7.)

July, 1877.

§ 661. Located near the cutlery works of the Economy Society, at Beavor Falls, Beaver county. Authority J. W. Ramsey, well manager.

Spec. Nos.					
	Well mouth above ocean in feet,				730
	Conductor,		3 to	3 =	727
1.	SS., yellow-white,		53 to	56 =	674
2.	Coal, bright,		1± to	57 =	673
3.	SS., shaly, fine hard,		10 to	67 =	663
4.	Slate, dark,	25	40 to	107 =	623
5.	Slate, dark,	15			
6.	Calcareous iron ore,		2 to	109 =	621
7.	Shale, muddy, light-gray,		10 to	119 =	611
8.	Shale, slaty, dark-gray,		50 to	169 =	561

Spec. Nos.				
9.	SS., white with black seams,	35	41 to 210 =	520
10.	SS., white with slate and pebbles,	6		
11.	Shale, dark and muddy,		40 to 250 =	480
12.	SS., shelly, fine, micaceous, gray and brown,		24 to 274 =	456
13.	SS., fine, gray, with white specks,	5	26 to 300 =	430
14.	Mud rock,	1		
15.	SS., gray, white specks, no pebbles,	20		
16.	Shale, slaty, and shells of micaceous SS.,		40 to 340 =	390
17.	SS., fine, greenish gray and red,	5	15 to 355 =	375
18.	SS., fine, gray and fawn color, soft,	10		
19.	Slate, shale and mud rock,		75 to 430 =	300
20.	SS., flaggy, fine, hard,		40 to 470 =	260
21.	Shaly slate, with fine sand,		12 to 482 =	248
22.	SS., fine, hard, greenish and brown,		5 to 487 =	243
23.	Slaty shale,	25	43 to 530 =	200
24.	Slaty shale, somewhat sandy,	18		
25.	Sandy shale and mud,		7 to 537 =	193
26.	SS., gray, pebbly,	3	23 to 560 =	170
27.	SS., light gray, fine,	20		
28.	Slate, with sand from above,		10 to 570 =	160
29.	SS., yellowish, very fine,		20 to 590 =	140
30.	Slate, with sand from above,		5 to 595 =	135
31.	SS., gray, very fine,		15 to 610 =	120
32.	Sandy slate, dark,		4 to 614 =	116
33.	SS., fine, nearly white,		80 to 694 =	+ 36
34.	Sandy slate, dark,	10	235 to 929 =	— 199
35.	Sandy slate (specimen lost),	82		
36.	Slate,	143		
37.	Red clay and dark slate,		15 to 944 =	— 214
38.	Slate,		116 to 1060 =	— 330
39.	SS., light-gray mica, with white specks,		30 to 1090 =	— 360
40.	Slate and mud rock,	360	400 to 1490 =	— 760
41.	Slate and mud rock,	40		
42.	SS., gray, very fine, flaky,		100 to 1590 =	— 860
43.	Slate, (42 B mud at 1580,)		10 to 1600 =	— 870
44.	SS., whitish, very fine, hard, flaky,		10 to 1610 =	— 880
45.	Shale, muddy,		55 to 1665 =	— 935
46.	Slaty shale, sandy,		40 to 1705 =	— 975
47.	Mud rock,		75 to 1780 =	—1050
48.	SS., flaggy, very fine, micaceous,		30 to 1810 =	—1080
49.	Mud rock,		10 to 1820 =	—1090
50.	Sandy slate, very fine sand,	15	85 to 1905 =	—1175
51.	Sandy slate, very fine sand,	20		
52.	Slate and fine sand shells,	50		
53.	Black slaty shale, 5 per ct. of carbonaceous matter,		35 to 1940 =	—1210
54.	SS., very fine, flaky,		10 to 1950 =	—1220
55.	Slate,	50	150 to 2100 =	—1370
56.	Slate,	100		
58.	Mud rock,		50 to 2150 =	—1420
58.	Slate,	50	180 to 2330 =	—1600
59.	Slate,	130		

Work on the above well was commenced in May, 1876, and suspended about the 1st of July, 1877. At the solicitation of Prof. White who was making his survey of Beaver county in 1876, Mr. J. W. Ramsey, superintendent of the drilling operations of the Economy society, carefully preserved samples of the sand pumpings wherever a change in the composition of the rocks occurred. These specimens, 59 in number, were designed for the museum of the Survey and were consequently added to my collection at Pleasantville, so that all oil well specimens might be grouped together. The above record is made from the specimens and labels on the bottles, and is no doubt as specific as a record can be made under the circumstances, where a single specimen represents so great an interval as some of these do.

In January, 1877, I visited the well, then 1300 feet deep and from Mr. Ramsey received the following particulars relating to it.

A twelve inch hole was drilled to the depth of 557 feet and cased with 8¼ inch pipe (inside diameter) which effectually shut off all fresh water. A little gas was noticed at 430 feet. From the large casing an 8 inch hole was sunk to 820′ at which depth 5⅝ inch casing was put in to shut out a heavy vein of salt water encountered in the 80 foot sand at 614 feet. In this part of the hole gas was struck at 517 feet, sufficient in quantity to fire a 12 horse boiler, and this was still further increased by the gas coming in with the salt water at 614 feet. After inserting the inside casing the gas and salt water flowed constantly over the well mouth between the two casings. The water was very salt, yielding on a rough test made by Mr. Ramsey, seventeen ounces of salt to one gallon of water.

From 820 feet a 5½ inch hole, was drilled on down. At 1060 feet another salt water vein was struck but as it was small and could be kept down by the sand pump, drilling was not interrupted, until at 1280 feet another supply was tapped which proved to be so copious that it could not be exhausted and therefore at 1300 feet it was thought advisable to stop drilling, pull the casing and ream down the 8 inch hole to that point. After this was done and the 5⅝ inch casing inserted to 1300 feet, no further trouble was experienced from water, and the hole was then drilled on down to 2330 feet, where, meeting with neither gas nor oil, the work stopped.

Summit Well. (*Plate V, Fig. 15.*)

1876.

§ 662. Near Great Belt city or Summit, Summit township, Butler county. Authority, Kirk & Dillworth.

Well mouth above ocean, in feet,			1326
?,		120 to 120 =	1206
Coal,		— 120 =	1206
?,		205 to 325 =	1001
Coal,		— 325 =	1001
?,		223 to 548 =	778
Limestone,		14 to 562 =	+ 764
?,		778 to 1340 =	— 14
Large flow of gas,		— 1340 =	— 14
?,		152 to 1492 =	— 166
SS.,	"*2d Sand,*"	20 to 1512 =	— 186
?,		234 to 1746 =	— 420
SS.,	"*Stray,*"	16 to 1762 =	— 436
?,		10 to 1772 =	— 446
SS.,	"*3d Sand,*"	36 to 1808 =	— 482
?,		14 to 1822 =	— 496

Mahan Well. (*Plate V, Fig. 17.*)

1875.

§ 663. On Mahan farm, Middlesex township, Butler county. Hart & Conkle, owners. Authority, F. A. Conkle and C. E. Hart.

Well mouth above ocean, in feet:		
Conductor,	12 to 12 =	
?,	63 to 75 =	
"Bluff sand," followed by ?,	125 to 200 =	
Coal,	4 to 204 =	
?,	86 to 290 =	
Coal,	2 to 292 =	
Slate,	3 to 295 =	
Limestone,	20 to 315 =	
?,	85 to 400 =	
SS.,	60 to 460 =	
?,	180 to 640 =	
Coal and coal shales, water and gas,	8 to 648 =	
?, (cased at 660',)	27 to 675 =	
SS., very hard,	90 to 765 =	
?,	385 to 1150 =	
SS., shelly,	100 to 1250 =	
?,	90 to 1340 =	

SS., black; brackish water,	10 to 1350 =	
SS., fresh water,	50 to 1400 =	
Slates,	70 to 1470 =	
SS., black and loose,*	10 to 1480 =	
SS., grey,	50 to 1530 =	
Slate,	15 to 1545 =	
Red Shale,	10 to 1555 =	
Slate,	10 to 1565 =	
Bowlder,	20 to 1585 =	
Slate,	38 to 1623 =	
SS., "corn meal,"	37 to 1660 =	
Slate,	40 to 1700 =	
SS., Pink pebble,	25 to 1725 =	
?,	15 to 1740 =	
SS., fine white,	15 to 1755 =	
Shales and slates,	30 to 1785 =	
SS., white and pebbly,	17 to 1802 =	
Slate,	28 to 1830 =	
Shales and sand,	10 to 1840 =	
Shales, blood red,	90 to 1930 =	

This record is compiled from the record given by Mr. Conkle, in Report II, page 271, compared with the record given by Mr. Hart, in Report Q, page 81.

Graff, Bennett & Co.'s Well. Plate V, Fig. 18, and Plate VII, Fig. 32.

June, 1878.

§ 644. Located on west side of the Allegheny river, Tarentum, Allegheny county. Authority, James E. Karns.

Well mouth above ocean, in feet,			872
?,		418 to 418 =	454
SS., white, coarse "*40′ rock*,"		49 to 467 =	405
Slate, black,	[Brine and *red oil horizon*, see note,]	53 to 520 =	352
SS., white, hard, fine "*70′ rock*,"		75 to 595 =	277
SS., green, soft,	"*Mountain Sand*,"	95 to 690 =	182
SS., gray, hard,		85 to 775 =	97
SS., white, hard,		43 to 818 =	54
Slate, blue, shelly,		10 to 828 =	44
Slate, *red*, hard,		5 to 833 =	+ 39
Slate, dark, gritty,		128 to 961 =	— 89
SS., gray to white, hard,	"*1st SS.*,"	199 to 1160 =	— 288
Slate, dark, gritty, shelly,		58 to 1218 =	— 346
SS., dark to white,	"*2d SS.*,"	29 to 1247 =	— 375
SS., blue to white,		40 to 1287 =	— 415
SS., blue to white,		50 to 1337 =	— 465
SS., blue to white,		25 to 1362 =	— 490

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* Mr. Conkle says, "10′ SS., black and loose, with amber oil and salt water." Mr. Hart, 60′ SS., very white, amber oil, 5 barrel well. Whatever the "show of oil" may have been, it was not considered worth pumping, and the well was put deeper and then abandoned.

Slate, dark, gritty, shelly,		68 to 1430	=— 558
SS., *deep red*, hard,	*"50 rock,"*	15 to 1445	=— 573
SS., blue to gray,		35 to 1480	=— 608
Slate, dark, gritty, shelly,		27 to 1507	=— 635
SS., *light red*,		3 to 1510	=— 638
SS., black,		5 to 1515	=— 643
Slate, dark,		12 to 1527	=— 655
SS., blue, bottom pebbly,	*"30′ rock,"*	10 to 1537	=— 665
Slate, black,		5 to 1542	=— 670
SS., blue to white,		10 to 1552	=— 680
SS., *red*,		10 to 1562	=— 690
Slate, *pink* to white,		18 to 1580	=— 708
Slate, blue and shelly,		22 to 1602	=— 730
SS., bluish, very hard,	*"Blue Monday,"*	8 to 1610	=— 738
Slate, black,		12 to 1622	=— 750
Slate, *red*,		2 to 1624	=— 752
Slate, gray, shelly,		2 to 1626	=— 744
SS., gray,		2 to 1628	=— 756
Slate, *red* and black mixed,		36 to 1664	=— 792
SS., gray,		3 to 1667	=— 795
Slate, *red* to blue, shelly,		16 to 1683	=— 811
SS., gray to white,	*"Bowlder,"*	25 to 1708	=— 836
Slate, white,		2 to 1710	=— 838
SS., dark to light gray,	*"Stray 3d,"*	12 to 1722	=— 850
Slate, black, shelly,		40 to 1762	=— 890
SS., gray, pebbly at bottom,	*"3d SS.,"*	20 to 1782	=— 910
Slate, *red* to gray,		10 to 1792	=— 920
Slate, gray,		28 to 1820	=— 948
SS., gray, loose, pebbly,	*"4th SS.,"*	8 to 1828	=— 956
Slate, *purple* to black,		98 to 1926	=—1054
Sand-shells, gray and green,		7 to 1933	=—1061
Slate, gray,		25 to 1958	=—1086
Slate, black, gritty,		20 to 1978	=—1106
Slate, gray, no grit,		44 to 2022	=—1150
Slate, black, no grit,		120 to 2142	=—1270
Slate, blue, no grit,		30 to 2172	=—1300
Slate, *brown*, soft sand shells,		20 to 2192	=—1320
Sand shells, light-green,		10 to 2202	=—1330
Slate, dark, no grit,		25 to 2227	=—1355
SS., gray, flaggy, hard,		5 to 2232	=—1360
Slate, dark, no grit,		30 to 2262	=—1390
SS., light-gray, coarse,		8 to 2270	=—1398
Slate, dark, soft,		14 to 2284	=—1412

Findings in well:

1st.	Salt water, copious,	4°	at 454 ft.
	Mud vein,		at 451 ft.
2d.	Salt water, copious,	4°	at 461 ft.
3d.	Salt water, less in quantity,	8°	at 476 ft.
4th.	Salt water, small quantity,	14°	at 828 ft.
	Fresh water (brackish) and gas,		at 1247 ft.
1st.	Gas, small quantity,		at 634 ft.

2d. Gas, small quantity, with fresh water,	at 1247 ft.
3d. Gas, strong, flame 50′ high,	at 1287 ft.
4th. Gas, small but oily,	at 1705 ft.

On closing the well mouth the gas pressure has run up to 130 lbs. to the square inch, and would go higher if not relieved.

The well has been cased at five different points, thus enabling the testing of each product separately. It is now cased at 1328 feet.

Mr. Karns says in his letter accompanying the record:

"You will observe the brine marked 8°. This is always obtained (if found at all) between the 40′ and 70′ rocks, and with it comes the *red oil* of this district. We got the brine, but merely a show of oil."

"I commenced this record at the top of what is known in this county as the 40′ rock, the stratum which has furnished nearly all the salt which has been made in the county, although some brine has been got in the 70′ rock, the top member of the mountain sand series. The stratification above this 40′ rock was so well known that I only thought it necessary to see that this well coincided with it. Enclosed is a record of the Peterson well near by, which will explain it."

Peterson Well.

1861.

§ 665. Located near the West Penn'a R. R. about half a mile southeast of the Graff, Bennett & Co. Well, drilled for L. Peterson by F. W. Humes in 1861. Level of well mouth 100 below G. B. & Co. well.

Elevation of well mouth above ocean, in feet,	772±
Conductor,	50 to 50 = 722
Sandy flags,	25 to 75 = 697
SS., white, flaggy,	50 to 125 = 647
Coal,	1 to 126 = 646
SS., brown,	4 to 130 = 642
Slate, gray,	30 to 160 = 612
SS., white, sharp,	20 to 180 = 592
SS. and slate, dark,	16 to 196 = 576
Coal,	2 to 198 = 574
Slate, white,	26 to 224 = 548
SS., white,	16 to 240 = 532
SS., dark,	19 to 259 = 513

Limestone,	9 to 268 = 504
SS. and slate,	18 to 286 = 486
SS., white,	8 to 294 = 478
Slate, white,	28 to 322 = 450
Slate, dark,	27 to 349 = 423
Slate, white,	13 to 362 = 410
SS., dark,	3 to 365 = 407
SS., white, coarse, sharp, "40′ rock," [Brine, see note,]	42 to 407 = 365
Mud vein,	— to 407 = 365
SS., dark,	23 to 430 = 342
Slate, white,	50 to 480 = 292
SS., dark, top of 70′ rock,"	2 to 482 = 290

"The salt measures here have been worked since about 1832, the brine coming from a sandrock about 40′ in thickness, and lying about 380′ below the level of the West Penn. R. R. track. This rock contains salt water of 4°, and in some localities a pebble stratum below it yields brine of 8°, accompanied by oil and gas. Mr. Peterson sunk a well here in 1852 and not finding salt water in the usual place drilled down to 1237′ striking *fresh water and gas*. The well continued to flow fresh water, and is still flowing (June, 1878) just as when drilled. Two years ago the well was reamed out and cased at 600′ but no accurate record could be had of it, as the drillings flowed out with the water."

Graff, Bennett & Company's well produces a large quantity of water which is ejected with varying force as the gas pressure increases or intermits. It quickly forms a deposit in the delivery pipe, and every pebble, twig and blade of grass along the sides of the ditch dug to convey the water from the well is beautifully encrusted by it. A specimen sent to Mr. A. S. McCreath for analysis gave the following results:

"The deposit consists of a thin nodular material, filled with a light brown clay. The shell after being tolerably well separated from the clay contains:

Carbonate of lime,	53.910
Carbonate of magnesia,	11.351
Carbonate of baryta,	8.884
Oxide of iron and alumina,	3.640
Insoluble residue,	19.160

Pine Creek Well No. 1, (Plate VII, Fig. 34.)

1877?

§ 666. In Pine twp., Armstrong Co., east bank of the Allegheny river and a short distance above the mouth of Pine creek. Authority Col. Jos. D. Potts, per A. B. Howland.

Well mouth above ocean in feet, about				800
Drive pipe,	47 to	47	=	753
Bed, rock, surface sand,	33 to	80	=	720
Slate,	15 to	95	=	705
Coal,	1 to	96	=	704
SS.,	150 to	246	=	554
Slate,	5 to	251	=	549
SS., strong gas,	257 to	508	=	292
Slate, (cased at 512′,)	12 to	520	=	280
Red rock,	20 to	540	=	260
Slate and shells,	35 to	575	=	225
Sand shell, oil and gas,	4 to	579	=	221
Red rock,	21 to	600	=	200
Slate,	7 to	607	=	193
SS., gas,	20 to	627	=	173
Slate and shells,	43 to	670	=	130
SS., gas,	8 to	678	=	+ 122
Slate and shells,	142 to	820	=	— 20
Red rock,	4 to	824	=	— 24
Slate,	6 to	830	=	— 30
SS., gas,	10 to	840	=	— 40
Slate and shells,	10 to	850	=	— 50
SS., hard, gas,	20 to	870	=	— 70
Slate and thick shells,	30 to	900	=	— 100
SS., gas, sufficient to fire the boiler,	70 to	970	=	— 170
Slate,	20 to	990	=	— 190
Slate and shells,	18 to	1008	=	— 208
SS., pebble, heavy gas, salt water,	43 to	1051	=	— 251
Slate and shells,	39 to	1090	=	— 290
Red rock,	10 to	1100	=	— 300
Slate,	5 to	1105	=	— 305
Red rock,	15 to	1120	=	— 320
Slate and shells,	30 to	1150	=	— 350
Red rock and shells,	26 to	1176	=	— 376
Slate and shell,	4 to	1180	=	— 380
SS.,	2 to	1182	=	— 382
Slate,	7 to	1189	=	— 389
SS.,	1 to	1190	=	— 390
Slate,	2 to	1192	=	— 392
SS.,	2 to	1194	=	— 394
Red rock,	1 to	1195	=	— 395
SS.,	7 to	1202	=	— 402
Slate and shells,	13 to	1215	=	— 415
Red rock,	7 to	1222	=	— 422
SS., and shells,	10 to	1232	=	— 432
Slate,	8 to	1240	=	— 440

Red rock,	4 to	1244	=— 444
Slate,	4 to	1248	=— 448
SS., blue, white, and pebble,	9 to	1257	=— 457
Slate,	13 to	1270	=— 470
Red rock,	2 to	1272	=— 472
Slate,	5 to	1277	=— 477
SS., white and hard,	18 to	1295	=— 495
Red rock,	7 to	1302	=— 502
Slate,	6 to	1308	=— 508
Red rock, with shell of slate,	17 to	1325	=— 525
SS., gray,	2 to	1327	=— 527
Red rock, with 2 feet of sand shell,	11 to	1338	=— 538
Slate, dark,	12 to	1350	=— 550
SS., dark gray thin white and very hard,	18 to	1368	=— 568
Slate and shells,	10 to	1378	=— 578
SS.,	10 to	1388	=— 588
Slate,	8 to	1396	=— 596
Shell,	2 to	1398	=— 598
Slate,	32 to	1430	=— 630
Red rock,	40 to	1470	=— 670
Slate and shell,	30 to	1500	=— 700
Slate,	50 to	1550	=— 750
Shells and slate,	25 to	1575	=— 775
SS., pebble,	1 to	1576	=— 776
Slate and shell,	21 to	1597	=— 797
Red rock, very hard SS.,	15 to	1612	=— 812
Slate and shell,	18 to	1630	=— 830
SS., dark,	8 to	1638	=— 838
Slate and shell,	4 to	1642	=— 842
SS., light colored,	8 to	1650	=— 850
SS., *red,*	10 to	1660	=— 860
Shell, hard,thin slate,	20 to	1680	=— 880
SS.,	6 to	1686	=— 886
Slate,	4 to	1690	=— 890
SS.,	3 to	1693	=— 893

"The *Ferriferous limestone* is supposed to lie about 35 feet above the well mouth."

(69)

Midland Well No. 1, (Plate VII, Fig. 35.)

1876.

§ 667. On Jacob Brinker Farm, near Millville Clarion county. Authority Col. Jos. D. Potts, per A. B. Howland.

Well mouth above ocean in feet, about,			1080
Conductor, to,	8 to	8 =	1072
Limestone, *Ferriferous,*	2 to	10 =	1070

Coal,	1	26	to	36	=	1044
SS., black,	18					
Coal,	3					
SS., black,	4					
Slate,		40	to	76	=	1004
Shells,		2	to	78	=	1002
Slate,		33	to	111	=	969
SS., white,		3	to	114	=	966
Slate,		32	to	146	=	934
Coal,		1	to	147	=	933
Slate,		4	to	151	=	929
Coal,		2	to	153	=	927
Slate,		17	to	170	=	910
Coal,		4	to	174	=	906
Slate,		44	to	218	=	862
SS., gray,		10	to	228	=	852
Slate,		2	to	230	=	850
SS., white,		57	to	287	=	793
Slate,		24	to	311	=	769
SS., "*Mountain Sand,*"		251	to	562	=	518
Red rock,		15	to	577	=	503
SS., white,		10	to	587	=	493
Slate, shelly,		75	to	662	=	418
SS., white, gas,		20	to	682	=	398
Slate, with shells,		128	to	810	=	270
Pebble shell,		1	to	811	=	269
Slate,		10	to	821	=	259
Shell, white,		5	to	826	=	254
Slate,		12	to	838	=	242
SS., pebble,		10	to	848	=	232
Slate,		8	to	856	=	224
SS., white,		14	to	870	=	210
Slate,		2	to	872	=	208
SS., white,		80	to	952	=	128
SS., gray,		20	to	972	=	108
SS., and slate,		18	to	990	=	90
Red rock,		5	to	995	=	+ 85
Slate, shelly,		135	to	1130	=	— 50
Red rock,		22	to	1152	=	— 72
Slate and grey shells,		33	to	1185	=	— 105
Slate,		11	to	1196	=	— 116
Red rock,		4	to	1200	=	— 120
Slate, shelly,		10	to	1210	=	— 130
Red rock,		43	to	1253	=	— 173
Shell,		1	to	1254	=	— 174
Slate,		30	to	1284	=	— 204
Shells and slate,		24	to	1308	=	— 228
Shell,		3	to	1311	=	— 231
Red rock,		5	to	1316	=	— 236
Slate, shelly,		7	to	1323	=	— 243
SS.,		9	to	1332	=	— 252
Slate,		8	to	1340	=	— 260

Shells and slate,	10 to 1350	=— 270
SS.,	5 to 1355	=— 275
Slate, shelly,	40 to 1395	=— 315
Red rock,	45 to 1440	=— 360
Red mud,	5 to 1445	=— 365
Slate, blue,	105 to 1550	=— 470
Red rock,	60 to 1610	=— 530
Shells and blue slate,	100 to 1710	=— 630
Red rock, very pale,	5 to 1715	=— 635
Shell and blue slate,	10 to 1725	=— 645
SS., gray, "*Drillers' First Sand*,"	40 to 1765	=— 685
Slate and shells with *red* streaks,	110 to 1875	=— 795
SS., grey, (show of oil and gas) "*Second sand*,"	45 to 1920	=— 840
Slate, blue,	30 to 1950	=— 870
Sand shell, light gray,	4 to 1954	=— 874
Shells and blue slate,	56 to 2010	=— 930
Pebble shell,	1 to 2011	=— 931
Slate and shells,	21 to 2032	=— 952
Shell, gray,	4 to 2036	=— 956
Shells and blue slate,	27 to 2063	=— 983
Sand shell,	6 to 2069	=— 989
Shells and blue slate,	39 to 2108	=— 1028
SS., white,	10 to 2118	=— 1038
Slate, blue,	4 to 2122	=— 1042
Pebble shell,	2 to 2124	=— 1044
Shells and blue slate,	42 to 2166	=— 1086
SS., gas and oil show "Stray,"	60 to 2226	=— 1146
Slate, blue,	22 to 2248	=— 1168
Slate blue,	32 to 2280	=— 1200

Cherry Run Well. (Plate V, Fig. 21, and Plate VII, Fig. 36.)

70

1878 ?

§ 668. On Plyer farm near center of Toby twp., Clarion co. Authority, Col. Jos. D. Potts, per A. B. Howland.

Well mouth above ocean in feet		
Conductor, (Ferriferous eroded here,)	5 to 5	=
SS., and shells,	56 to 61	=
SS.,	15 to 76	=
Slate,	35 to 111	=
SS.,	150 to 261	=
Slate,	5 to 266	=
SS.,	185 to 451	=
Slate and shales,	130 to 581	=
SS.,	44 to 625	=
Slate and shale, (oil,)	283 to 908	=
SS., gas, Slate, 5 SS., gas, pebbles,	105 to 1013	=

Slate and shells, (*5 feet red,*)	35 to 1048 =
SS., blue,	12 to 1060 =
Slate, red, with sand shells,	30 to 1090 =
Slate,	5 to 1095 =
Sandstone bowlder, solid,	23 to 1118 =
Slate, *3 feet red,*	15 to 1133 =
SS., *red* brown and yellow, oil show at 1143′,	15 to 1148 =
Slate, blue, with hard shells,	28 to 1176 =
SS., black and yellow pebbles,	3 to 1179 =
Red rock and brown and olive sandy shale,	9 to 1188 =
SS., (pebbles, and oil show at 1193′)	15 to 1203 =
Red shales with white and blue flags,	32 to 1235 =
Red, olive and white shells and blue slate,	26 to 1261 =
SS., close white hard,	9 to 1270 =
Slate,	13 to 1283 =
SS., (oil show at 1287′)	9 to 1292 =
Slate,	10 to 1302 =
SS., loose, oily,	5 to 1307 =
Shells &c.,	11 to 1318 =
SS., oily all through,	19 to 1337 =
Slate, blue,	63 to 1400 =

The *Ferriferous limestone* is seen in place a short distance from the well. The conductor occupies its horizon, it having been eroded at the spot where the well is located.

Griswold Well No. 1. (Pl. VI, F. 30, and Pl. VII, F. 38.)

May, 1878.

§ 669. "This well is located on Rattlesnake gulch, north of Clarion; about one mile from the river and one mile east of Toby creek; on the property formerly known as the 'Penn Mill Tract,' and now owned by Wm. Griswold, of Philadelphia." Authority: John W. Griswold.

Well mouth above ocean, in feet,	
Conductor,	22 to 22 =
Shales, soft, dark,	26 to 48 =
SS., "bluff sand,"	52 to 100 =
Slate, dark, with gray sand shells,	10 to 110 =
Coal, trace,	— to 110 =
Slate, dark, with gray sand shells,	110 to 220 =
SS., gray, 20 SS., white, 110 } *Mt. sand,* SS., gray, 30	160 to 380 =
Slate and sand shells,	50 to 430 =
SS., (cased at 440′) "*salt water sand,*"	70 to 500 =
SS., some pebbles, 25 SS., white, 35	60 to 560 =
Slate,	185 to 745 =

SS., hard gray shell, 5	“*1st sand,*”	130 to 875 =
SS., yellow, 107		
SS., white, 18		
Slate, sandy,		15 to 890 =
Red rock,		5 to 895 =
SS., with gas,		5 to 900 =
Slate, with sand shells,		53 to 953 =
SS., “*2d sand,*”		42 to 995 =
Red rock, “*Big red,*”		90 to 1085 =
Slate, traces of *red,*		5 to 1090 =
Red shale,		5 to 1095 =
Slate,		5 to 1100 =
SS., “*Green bowlder,*”		3 to 1103 =
Slate,		3 to 1106 =
SS., “*Stray 3d,*”		3 to 1109 =
Slate and shells,		6 to 1115 =
SS., “*3d sand,*”		40 to 1155 =
Slate and shells,		21 to 1176 =
Red shale,		7 to 1183 =
Slate, with layer of gray SS.,		27 to 1210 =
Red rock,		5 to 1215 =
Slate,		4 to 1219 =
Slate, with sand shells, some pebbles,		11 to 1230 =
Slate,		8 to 1238 =

“Some gas, but not quite enough to fire the boiler. Only a ‘show’ of oil.”

Rohrer Well, No. 2. (Plate VI, Fig. 29.)

1877.

§ 670. On Deer creek 1½ miles S. of Shippenville, Elk township, Clarion co., Pa. “Well is located on the bank of Deer creek about half way between Black’s furnace and the old forge about 125′ below the level of the surrounding country.” Authority, C. E. Hatch, Edenburg.

Well mouth above ocean in feet.	
?,	660 to 660 =
1st *red rock* with layers of slate,	48 to 708 =
Shell, very hard,	4 to 712 =
Red rock, with small streak of slate,	24 to 736 =
Slate and shells,	20 to 756 =
Red rock, soft; hard shell at bottom,	44 to 800 =
Slate,	20 to 820 =
Red rock,	15 to 835 =
Slate; with one hard shell,	18 to 853 =
SS., (oil rock?) hard, blue to lighter color,	17 to 870 =
Slate; with hard shell,	34 to 904 =
SS., very hard, small flow gas,	16 to 920 =
Slate and hard shell,	50 to 970 =
Red rock and shell,	40 to 1010 =

Slate and shells,		95 to 1105 =
Red rock with very hard shells,		25 to 1130 =
Slate, with some shells,		170 to 1300 =
Slate; soft, *pale red*,		40 to 1340 =
Slate, with very hard sand shells,		50 to 1390 =
SS., hard and fine,		30 to 1420 =
Slate; soft and "milky,"		50 to 1470 =
SS., hard and shelly,		8 to 1478 =
Slate; soft and white, with shells,		112 to 1590 =
SS., strong smell oil,		12 to 1602 =
Slate; soft, with shells,		138 to 1740 =
SS., with heavy gas vein,		11 to 1751 =
SS., similar to cornmeal,		10 to 1761 =
SS., gray and coarse,		19 to 1780 =
SS., smells strong of oil, (lighter color,)		10 to 1790 =
SS., and shells, (50 ?)		40 to 1830 =
Shell, very hard,		4 to 1834 =
SS., with shells and some slate,	191′	42 to 1876 =
SS., with shells and some slate,		149 to 2025 =

"The last 149′ was a mixture of gray and blue sand with an occasional hard shell and a very little slate in thin streaks. The well is 2025′ deep and stopped in sand. Cased at 260′. No record kept of 1st and 2nd sands, but they were passed through in their proper positions."

The well is about half way between Black's furnace and the old forge. Unproductive.

Strotman Well. (Plate VI, Fig. 26.)

Summer 1877.

§ 671. Elk township, Clarion co., 2 miles N. E. of Berlin's Tavern. Peter Schreiber, owner. Authority, J. R. Smith, contractor.

Well mouth above ocean in feet.

?			573 to 573 =
Shells, gas,			7 to 580 =
Slate,			167 to 747 =
SS., pebble on top, gas,		"*1st sand,*"	58 to 805 =
Slate,			37 to 842 =
Sand shells, gas,			38 to 880 =
Red rock.			10 to 890 =
Sand shells,			10 to 900 =
Red rock,			14 to 914 =
Slate,			26 to 940 =
Sandy shells,			10 to 950 =
Slate,			34 to 984 =
SS., dark, few pebbles,	9	"*3d sand,*"	20 to 1004 =
" " and pebbly,	5		
" very dark and fine,	6		

Slate, gas,		15 to 1019 =
SS., coarse pebble, gas,	3	12 to 1031 =
" fine,	9	
Slate,		17 to 1048 =
Yellow pebble,		2 to 1050 =
Slate,		6 to 1056 =
SS. and yellow pebbles; gas,	2	8 to 1064 =
" white and hard,	6	
Slate and shells,		35 to 1099 =
Red rock and shells, "chocolate," in layers,		16 to 1115 =

Some little oil in top of 3d sand, but not in paying quantity.

Hains' Well. (Plate VI, Fig. 22.)

February, 1876.

§ 672. On Holliday run, near Oil City. Authority, Jos. D. Potts, per A. B. Howland.

Well mouth above ocean in feet.

Conductor,		18 to 18 =
?		242 to 260 =
Shelly rock,		39 to 299 =
SS.,	*Mountain sand*	44 to 343 =
Slates, &c.,		108 to 451 =
Red rock,		86 to 537 =
SS.,	*"1st sand,"*	37 to 574 =
Slates, &c.,		107 to 681 =
SS.,	*"2d sand,"*	28 to 709 =
Slates, &c.,		81 to 790 =
SS., gray,		14 to 804 =
Slates,		19 to 823 =
SS., oil,	*"3d sand,"*	18 to 841 =
Slate,		25 to 866 =
Shelly rock,		50 to 916 =
SS., dark,		39 to 955 =
Slate, dark and shelly,		115 to 1070 =

55

Iron Bridge or Chew Well. (Plate IV, Fig. 8.)

1876–7.

673. Located on hillside, 20 rods east of Slippery Rock creek, 40 rods south of Iron Bridge, Perry township Lawrence co., Penna., and 2 miles S. 20° W. of well at mouth of Cove Hollow. Authority, Geo. H. Nesbitt, owner, per Geo. H. Dimick, manager.

Well mouth above ocean in feet.

Bluff sand,	15 to 15 =
Slate,	10 to 25 =
Coal,	2 to 27 =

Slate,[*]	143 to 170	=
SS.,	67 to 237	=
Slate and sand shells (fresh water,)	50 to 287	=
SS., light gray and close,	21 to 308	=
Slate,	20 to 328	=
SS., (salt water,)	25 to 353	=
Slate,	213 to 566	=
SS,, a little amber oil,	30 to 596	=
Slate; 18″ sand shell at 690,′	194 to 790	=
Red rock, (stopped in it,)	1 to 791	=

Cased first at 237′ then at 267′ and finally at 370′.

Unproductive, very little show of oil or gas.

The record adds: "The lubricating oil rock was passed through from 287′ to 308′, and it is evident that the oil must be found in crevices, as this well is located on a line between two well known producers of 1865, and should have found either water from the old wells or a supply of oil, if the rock had not been too close for the movement of fluid through it."

The proximity of the old wells probably accounts for the fresh water in the shelly measure above this close sandrock. At 690′ a slight show of oil and gas was found in a sand shell about 18 inches thick.

Cove Hollow or Shaffer Well.[†] (*Plate IV, Fig. 9.*)

1876-7.

§ 674. Situated on Slippery Rock creek at the mouth of Cove Hollow, Slippery Rock township, Lawrence co., Pa. Two miles N. 20° E. of "Iron Bridge Well." Authority, Geo. H. Nesbitt, owner, per Geo. H. Dimick, manager.

Well mouth above ocean in feet.

Conductor,	8 to 8	=
Bluff sand,	30 to 38	=
Slate,	42 to 80	=
Blue limestone,	3 to 83	=
Slate,	12 to 95	=
SS., gray, "*60 rock*,"	75 to 170	=

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[*] The figures down to 170 feet do not agree with Prof. White's section of this well (QQ. page 89), but they are copied from Mr. Dimick's letter containing the well record in his own handwriting.

[†] This record like that of "Iron Bridge Well" disagrees with Prof. White's, (QQ. p. 154.) The disagreement illustrates the unreliability of oil well records even when they are given by the same party, but to different persons and at different times.

Slate,	340	to	510	=
SS., gray, (a little amber oil,)	40	to	550	=
Slate, with an occasional shell,	150	to	700	=
Red rock,	26	to	726	=
Slate, sand shell at 800′, black oil,	164	to	890	=
Red rock,	40	to	930	=
Slate and occasional shells,	343	to	1273	=
Conglomerate, black and *red slate* and pebbles,	10	to	1283	=
SS., brown or light gray, fine,	5	to	1288	=
SS., black, dark gray when dry,	32	to	1320	=
Slate dark, a few shells,	116	to	1436	=

Cased at 249 feet. Unproductive.

"At 800′ struck a shell yielding a few gallons of black oil of light gravity supposed from 46° to 48°."

John Smith Well. (Plate IV, Figs. 2 and 10.)

64

1877.

§ 675. On John Smith farm, Brady township, one and a quarter miles northwest from the Prospect bridge, over Muddy creek. Owners, Messrs. Phillips Bros. Authority, E. J. Agnew, per W. G. Power.

Well mouth above ocean in feet, (barometer,)						1325
Slate and fireclay,		230	to	230	=	1095
Limestone, *Ferriferous,*		15	to	245	=	1080
Slate and clay,		27	to	272	=	1053
SS.,		18	to	290	=	1035
Slate, black,		110	to	400	=	925
SS.,		65	to	465	=	860
Slate,		3	to	468	=	857
SS.,	*"Mountain sand,"*	100	to	568	=	757
Slate and shells,		72	to	640	=	685
SS., gray,		50	to	690	=	635
Slate and shells,		10	to	700	=	625
SS.,		30	to	730	=	595
Slate,		180	to	910	=	415
SS.,		26	to	936	=	389
Slate and shells,		119	to	1055	=	270
Red rock,		60	to	1115	=	210
Slate and shells,		15	to	1130	=	195
SS.,	*"1st sand,"*	60	to	1190	=	135
Slate,		85	to	1275	= +	50
SS., rotten, 20 Slate, 20 SS., 25	*"2d sand,"*	65	to	1340	= —	15
Slate,		55	to	1395	= —	70
Granite,		5	to	1400	= —	75
Slate,		31	to	1431	= —	106
SS., ("off color,")	*"3d sand,"*	19	to	1450	= —	125
Slate, black,		8½	to	1458½	= —	133½

The Third sand was poor, and quite shelly, and produced no oil.

This well was subsequently sunk to a depth of 1596′. A thick mass of *red rock* was found near the bottom.

633

Boyce, Rawle & Co.'s Well, (Plate IV, Fig. 3.)

Spring of 1877.

§ 676. At Sharon Furnace, 1½ miles above Sharon. Authority, Mr. Hall Sharon Furnace.

Well mouth above ocean in feet, (by barometer,)			900
Clay and gravel, Coarse gravel, Bowlders,	100 to	100 =	800
Shale, "soapstone,"	85 to	185 =	715
SS., white, sharp, "*Mountain sand,*"	75 to	260 =	640
Shale, light-blue and *some red,*	305 to	565 =	335
SS., gray, fine oil, "*1st sand,*"	30 to	595 =	305
Shales, lead color,	23 to	618 =	282
Shelly, oil and gas, "*Stray,*"	— to	618 =	+ 282
Shales, lead colored and brownish, turning to dark-blue near bottom,	607 to	1225 =	— 325
Shales, blue-gray and brown, with thin layers of fine grit,	375 to	1600 =	— 700

Fresh water at 46′, 175′, and 280.′

Gas at 485′ and 618′.

Cased $5\frac{5}{8}''$ casing, at 175′; cased $4\frac{3}{4}''$ casing, at 280′.

Traces of oil either in "1st SS.," or at 618′. Amber oil, heavy gravity; no salt water.

59

Raymond Well No. 6. (Plate IV, Fig. 4.)

1877.

§ 677. At Raymilton, Sandy Creek township, Venango county. Authority, A. K. Williams' note book.

Well mouth above ocean, in feet,			1196
Conductor,	19 to	19 =	1177
Slate, ?	51 to	70 =	1126
SS., (cased at 191′), ?	100 to	170 =	1026
Slate (shells and gas at about 360′),	262 to	432 =	764
Red rock,	100 to	532 =	664
SS., (oil,) 10 Slate, . . 19 SS., . . . 18 "*2d sand,*"	47 to	579 =	617
Slate, no "*stray sand,*"	259 to	838 =	358
SS., oil show, "*3d sand,*"	10 to	848 =	348

Slate,	152	to	1000	=	196
Red rock,	100	to	1100	=	96
Slate,	250	to	1350	=	—154
Shells and shale (oil show and gas),	20	to	1370	=	—174
Shells, mud and slate,	40	to	1410	=	—214

Reliance Well. (*Plate IV, Fig. 12.*)

1868.

§ 678. Located on land of A. W. Brown, near the corner of Myrick and Chestnut streets, in the borough of Pleasantville. Authority, E. S. Nettleton.

Well mouth above ocean, in feet,						1652
Sandy shale and surface clay,		141	to	141	=	1511
SS.,	*Second mountain sand,*	35	to	176	=	1476
Shale,		208	to	384	=	1268
SS.,	*Pithole grit,*	22	to	406	=	1246
Shale,		139	to	545	=	1107
Red rock,		55	to	600	=	1052
SS.,	*First sand,*	28	to	628	=	1024
Shale and slate,		113	to	741	=	911
SS.,	*Second sand,*	42	to	783	=	869
Slate,		71	to	854	=	798
SS.,	*Stray Third,*	11	to	865	=	787
Slate,		20	to	885	=	767
SS.,	*Third sand,*	37	to	922	=	730
Slate,		94	to	1016	=	636

Drilled wet. But little gas or oil.

CHAPTER XXXVI.

Gravel Pit Oil Wells.
Grey's Well and others in Ohio.

§ 679. The history of petroleum developments in Pennsylvania has been a record of wonderful incidents and repeated surprises. When Messrs. Eveleth and Bissel organized "the Pennsylvania Rock Oil Company"* for the purpose of collecting "Seneca oil" from a series of trenches and pits on Watson's flats near Titusville, where the strange fluid came up in globules and spread upon the water whenever a ditch was dug, they little thought what was to be the ultimate results of their enterprise. It was a suprise to them, therefore, when after nearly five year's ill success and discouragement with the pick and shovel, their first venture at drilling, the Drake well, yielded *barrels* of oil where they had only anticipated gallons. It was a surprise to the world when a couple of years later several wells along Oil creek started to *flow* at the rate of from one thousand to thirty-five hundred barrels per day. It was a surprise to the "experienced operator" when the highlands were found to be as good for oil as the creek bottoms; when the deep rocks of Armstrong, Clarion, and Butler proved to be so largely productive; and when the hidden treasures of Warren and McKean counties began to be revealed. It was also a surprise when it was announced that on the 6th day of April, 1877, a pit only fifteen feet deep had been dug on Watson's flats which was yielding by a common hand-pump thirty barrels of oil per day, and this within a few rods of territory which had been thoroughly operated upon ten or

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*This was the first oil company organized in the United States, the certificate of incorporation having been filed in the cities of New York and Albany on the 30th of December, 1854. The "Seneca Oil Company" operating under a lease from the above, and embracing several of the original stockholders, came into existence on the 23d of March, 1858, and under its direction the Drake well was drilled.

fifteen years before. At first many were disinclined to believe the report and for some time the novel development attracted but little attention. But the original discoverers Messrs. Herron and Potts kept quietly at work and opened several additional pits which added to their production, and it became clearly apparent that they were shipping considerable quantities of oil. An excitement on a limited scale then suddenly broke out which rivaled the liveliest days of Pithole or Pleasantville. Operatorsfrom every part of the oil regions flocked in to see the novelty. Crowded stages lined the highway leading from Titusville to "Grasshopper City," (so named from the singular manner in which the hand-pumps were coupled together and worked, at first by horse-power and afterwards by steam,) and it is said that from 1000 to 1500 visitors were daily upon the ground. But inasmuch as the extent of territory supposed to be good was limited to a few acres, at most, the excitement soon abated for want of something to feed upon.

§ 680. The following letter written for *Stowell's Petroleum Reporter*, and dated Pleasantville, August 28, 1877, is re-printed here as a part of the history of this remarkable development:

In August, 1859, just 18 years ago to-day, the quiet little hamlet of Titusville was electrified by the report that petroleum had been found in large quantities at a depth of 70 feet, in the Drake well. Since that time probably 30,000 oil wells have been sunk, and great improvement has been made in the art of drilling. An ordinary 1,500 foot well is put down to-day with more ease and dispatch than was this little 70 foot well in 1859. We are not even surprised to learn that the Watson well, within two miles and a half of this first venture, has been carried down to the great depth of 3,553 feet, for we have become prepared for almost any achievement of the drill.

But now appear new claimants for our notice. The pick and shovel step forward to take the place of the drill. A 15 foot gravel pit assumes to supersede the 1,500 foot drill hole. And curiously enough, this happens on the same creek-flat, and within a mile of the old Drake well.

The gravel-well district of Titusville is the latest wonder of oildom—at least it has been made such by the exaggerated reports and astounding theories in relation to it, that have gained currency through the daily press.

Let us see what are the geological facts concerning it, and what the relations it bears to the regular oil producing rocks of the district.

Titusville is situated in a broad irregularly outlined basin of erosion, between hills more than 300 feet high, at the junction of Pine creek and Oil creek. The "flat," or old water plain, contains perhaps 1,000 acres, having its greatest length in a N. W. and S. E. direction. Oil creek enters it at the N. W. angle and sweeping around to the east and south leaves it at its S. W. angle. Pine creek falling from the N. E. and east, enters at the S. E. angle, and joins Oil creek near the outlet. Church run from the north, Shaffer and McGee runs from the south, and several other minor runs likewise empty into it. "Watson flats," a locality renowned in the early history of petroleum developments is included within these outlines.

The new oil pits are near the Pleasantville plank road, which passes along the northeasterly side of the basin before crossing Pine creek. More than 100 oil wells have been sunk on these flats in the usual way since 1859, and by the length of drive pipe required to reach the bed rock, they conclusively demonstrate the fact that the channel of the old stream, once flowing between these hills, was a hundred feet or more below the present surface. Within a rod or two of some of these oil pits 53 feet of pipe was driven through these superficial deposits; a little further out towards the center of the basin 80 feet; and in the center about 100 feet. As the oil pits on the creek-flat are only from 15 to 18 feet deep it will be seen at a glance that the oil is not obtained from the stratified rocks, for the old wells referred to show that they lie much deeper, and have not been reached by the pick.

This basin, then, as it existed in pre-glacial times, must have been at least one hundred feet deeper than it is at present. It was occupied by a stream whose birth could scarcely have antedated the close of the carboniferous period, and whose great age can only be surmised from the evidences it has left behind in the magnitude of the work performed. At this point it had already cut down through the solid rocks to within fifty feet of the first oil sand. This would be equivalent (if the rocks originally lay here as they now lie at Pittsburgh) to a vertical excavation of 1,900 feet. It is quite probable that it flowed to the north (as did others of these northerly streams at that day) delivering its waters into the Lake Erie basin.

But now a great change occurs—the glacial epoch comes on—a thick ice-sheet covers all the northern country; slowly advancing and holding in its icy grasp fragments of rocks, gathered along its track, all the way from Northern Canada, it levels off the hilltops, widens out the valleys, and plunges into the old river beds its burden of mixed transported debris. The northern outlets of drainage are all covered with ice and obstructed, and when long afterward, under a modification of climate, a recession of the glacier commences, pools and lakes of water accumulate in front of it; they fill up and overflow at the lowest depressions in the hills at the south. As these new outlets gradually deepen, the lake surfaces lower, the lake bottom fills up with detritus brought in by the melting ice, and finally when the ice disappears, we find the old river beds at the north filled with hundreds of feet of Drift, the valleys almost obliterated, and a new direction given to all the drainage of this section of the State. This is but a brief and partial statement of the probable sequence of events during this epoch. It may serve to show, however, that the beds of gravel or sand from which these pick and shovel wells obtain their oil, could not have been deposited until near the close of the Glacial period, for they lie very near the top of the Drift.

Examination of the sand or gravel shows that it is composed of a mixture of water-worn comminuted particles derived from the Primary rocks, the Silurian limestones, and the Local measures of the surrounding hills. It is a comparatively recent deposit, filling up an old deeply excavated channel in the sedimentary rocks, which channel had previously been the bed of a stream ages before.

There is no marked difference between the deposit here and thousands of other Drift deposits scattered all across the country in this latitude. They were all laid down in the same era, and by similar agencies. The fact that this particular spot produces oil, while others apparently just as favorably located do not, seems to indicate that the oil is not indigenous to the gravel bed itself. It is evidently derived from some other source, the gravel bed acting only as a reservoir for its reception and storage.

Many stories are afloat concerning the bursting of a pipe line near these pits, and the leakage of storage tanks formerly located in this neighborhood; and some affirm that the oil has soaked into the gravel bed from these sources. Others contend that it has ascended from the regular oil sands below through the old abandoned bore holes on the flat. But we think a much more probable explanation of the phenomenon can be found in the operations of natural agencies alone, unaided by the accidents or interventions of men.

The gravel bed (the thickness of which is not at present known, as it has not been dug through,) is capped by a sheet of tough, impervious blue clay, varying from two feet to twelve feet or more in thickness. This clay seems to cover the gravel bed like a hood, and the retention of oil in the gravel bed is no doubt due to the peculiar shape of the clay sheet.

Oil formerly issued with the waters of springs, and through the gravel of the creek bottom, in many places along the valley of Oil creek. The Drake well and some others of the early wells struck oil before reaching the first oil sand. But it is now well understood that this oil came up from the first oil sand which was in these places surcharged with oil. In the same manner, no doubt, the gravel beds have been supplied with oil. The first oil sand lies, as has been stated, only 50 feet below the bottom of the drift deposit. For ages the oil has been slowly escaping into the drift and working its way to the surface. In the locality of the gravel pits it was obstructed in its passage to the present surface of the Watson flats by an impervious sheet of clay lying immediately over a good deposit of coarse sand or gravel. In this almost hermetically sealed reservoir it has collected and has here remained until now set free by the piercing of the clay hood above it.

How considerable the deposit of oil may be in this locality of course no one can tell. The agencies depositing the clay and gravel were wide-spread and general in their action, but extremely variable in their local results. An examination of any railway cutting through a gravel bank will illustrate this. Small bowlders, gravel, sand and clay, will be found in many cases to be almost indiscriminately mixed, and no one class of material can be traced for any great distance. We should not, therefore, expect this peculiar structure of a clay-capped sand bed, which seems to be the requisite basis of a paying gravel well, to extend continuously over a very wide area. The whole question may be briefly resolved thus:

Given the clay-sheet without the sand-bed; the sand-bed without the clay-sheet; or the clay and sand in reversed positions, and no oil could be obtained. So also given the clay and sand in good condition and proper position, but in a locality where there is no oil-producing sand beneath, and the same result would follow.

If then the success of a gravel well depends upon the rare and rather accidental conjunction of the several necessary conditions above mentioned, we need not apprehend any danger of an overflowing of the storage tanks, or an overstocking of the oil supply from the products of these drift deposit wells.

§ 681. *Area of the Gravil pit Oil Pool.*

The location and surroundings of the gravel-pits may be seen by reference to Plate XIX. The Drake well is not noted on this map; it should be on the island in Oil creek, at the entrance of the highlands below the intersection of Pine creek.

It will be observed that the productive spot is on the nose of a point projecting down into the old valley; and probably the peculiar position of this head-land in relation to the transporting currents of the glacial period caused the deposit in this place of coarse quicksand, which contains oil, and afterward covered it with the irregular hood-cap of clay; for the two deposits seem to thus lie in conjunction only on this point. The thickest part of the clay is on the point of the hill, and it thins and slopes rapidly towards the flats. The shallowest pit was fifteen feet deep, with only two feet of clay—the deepest fifty-two feet, with fifteen feet of clay. An abrupt rise in the surface accounts for the difference in depth.

A superficies of a little over one acre will cover all the productive territory at this date, (Dec. 1879,) and on this small area about one hundred pits have been sunk—70 on the flat below the plank-road, and 30 above it—those on the lower side having been the most productive, probably owing to the fact that they were first opened. Many other pits were dug outside of this cluster, but no indication of oil was found.

§ 681. *Production and Value of the Gravel pits.*

From the Pioneer well—dug at a cash outlay of *six dollars*, and opened on the 6th day of April, 1877—four hundred and seventy-three barrels of oil were sold up to the 30th of June. At first it only brought light oil prices (about $2 50) notwithstanding its gravity of 32°; but after its true value became known it readily commanded the same price as other heavy oils, and was shipped to the lubricating refineries of Franklin and Rochester, at $4 90 per barrel.

Supposing the oil from this well to have averaged $3 50 per barrel, it is easy to see how enticing the "dug-well oil business" would appear to the many who possessed the necessary capital to engage in it—muscle and a pick and shovel—when they figured up something like the following:

473 barrels of oil, @ $3 50=	$1,655 50
Less ¼ royalty, ...	413 88
Gross receipts, ...	$1,241 62

Cost of well,	$6 00	
Cost of pump, tank, &c., say	50 00	
Cost of pumping 85 days, say	170 00	
		226 00
Net profits for 3 months' work,		$1,015 62

It was this feature of little outlay with quick returns and large profits, that drew so many people to the spot, and created such an unusual excitement. So eager was the crowd to get a foothold within the charmed district that leases twenty feet square were readily taken at $20 bonus and *half the oil*, and larger ones in proportion.

A steam engine was soon brought into requisition, and the pits were so crowded that twenty-five pumps could be operated with it at once. The net-work of vibrating walking-beams, joined together in every conceivable manner by bolts and links, or tied by ropes, formed when in motion one of the most novel sights ever seen in any country. The ludicrous movements of these pumping arrangements, suggested in some one's mind a resemblance to a mass of huge disabled grasshoppers writhing and kicking upon the ground, and thereupon the place was immediately dubbed "Grasshopper City."

The "city," however, like its namesake, was destined to be short-lived. With the early frosts of October it perished. On the 10th of August the *Oil City Derrick*, after a careful examination of the field, reported 23 wells pumping, with an aggregate production of 170 barrels per day, and 46 pits in different stages of completion. But by the middle of October everything was quiet; a few *old wells* were pumping, but probably the whole output did not then exceed 40 barrels a day.

In 1878, Messrs. Potts & Johnson having secured control of all the desirable territory, managed, by judicious pumping and frequent additions of new wells, to keep up an average production of about eight barrels per day for nearly the whole year; but the following season the new wells were more uncertain and the yield of oil gradually declined to almost nothing.

No accurate account has been kept of the quantity of oil actually drawn from this pool, which may be said to have been practically exhausted by the winter of 1879, but from the best information to be had it appears to have been from ten to twelve thousand barrels.

The largest well in the pool is said to have yielded 30 barrels of oil the first day; but they all ran down rapidly and very few of them paid to pump longer than three months, notwithstanding that they could be kept profitably in motion if they produced only a fraction of a barrel of oil. As the oil came in with an inexhaustible supply of fresh water it was useless to pump longer when the water once became clear.

In digging one of the deep pits a pebble sandstone five feet thick and entirely covering the bottom of the hole, was encountered at a depth of 25 feet from the surface. It had to be drilled and blasted the same as fixed rock, but it was not in place, being evidently a *large block of Church run conglomerate* slipped from the hilltop half a mile away. The edge of the same block was supposed to have been struck in another excavation a rod or more from this one.

In another pit at a depth of 20 feet the workmen passed through a one foot layer of *black peaty material* containing matted masses of small twigs and rootlets. A trace of this was only seen in one other well although there were several that should have shown it if it had been of any considerable extent.

§ 682. *Powers' Corners district in Ohio.*

The Oil sand in this section is about 60′ thick—in layers of varying character. In some wells the oil is found at three points in the rock, at say 5′, 40′, and 55′. The wells are generally short lived, but some exceptional ones have produced lightly for 6 or 7 years. A well pumping 100 barrels during its life is considered an average well. One of the most prolific wells in the district—the Thompson well, near Powers' Corners—is said to have produced from 1800 to 2200 barrels. But this was one of the first wells, and none like it have since been found. The oil brings from $12 to $15 per barrel of 40 gallons, (September, 1878.)

About 1 mile north of Grey well three shafts were dug during the excitement, about the year 1865. A drift was run in the oil rock from No. 1 north to No. 2 about 150′, and also part of the way from No. 2 westerly to No. 3, the interval between No. 2 and No. 3 being about 300′. The design was to expose a large surface of the oil rock, and thus secure a greater flow of oil. But it was a failure financially. The amount of oil is limited—it is heavy and almost free from gas, and can only be obtained by washing the rock as it were with water. Some of the wells furnish all the water a 4″ pump can handle. The oil comes in globules with the water, and collects at the top of the tank while the water is let off at the bottom. When the water comes clear the well is abandoned, as it is an indication that the rock has been washed out within the reach of that well. Then another hole is put down, and the current directed in that direction, and another portion of rock is cleaned, thus the whole territory is gone over, some farms having had as many as 80 wells put down upon them. The old wells are sometimes re-tubed and pumped the second time, producing in some instances quite an amount of oil. The effect of these drill holes so thickly scattered over the tongue of clayey land between Grand river and Mosquito creek, has been to much improve the soil for agricultural purposes. The wells afford a ready exit for the surface water, and a system of drainage has thus unintentionally been established of no little value to the farmers of that section.

The oil appears to come into the wells from a band of coarse gray *sandstone*, described by those who have seen it in the shafts and drifts, as "honey-combed." It is not more than from one to three feet thick, and lies between bands of flags and fucoidal sandy shales. The pieces of sandstone thrown out on the surface weather white, with iron specs thickly scattered over their surfaces. On breaking them they are found to be still *saturated with oil* and give out an unmistakable odor of petroleum. The wells show that the rock dips quite strongly to the south, or perhaps a little west of south, and the best wells have been on the higher part of the rock or north end of the district.

Grey Well.

§ 683. On road running south from Powers' Corners, 1 m. N. of its intersection with the road running west from Bacousburg, Trumbull county, Ohio. Authority, Mr. Grey.

Elevation of well mouth above tide, (barometer,)		940
Conductor,	14 to 14	
Blue slate and shale,	33 to 47 =	893
In sand,	4 to 51	

Pumping about 1½ barrels per day. An old well recently re-opened, (September, 1878.)

A deep well was put down on the Cowdry farm about two miles south of Powers' Corners. The following record from memory, by one of the drillers, indicates the character of the formation in this section:

§ 684. *Cowdry farm well, Deep well.*

Elevation of well mouth above tide, about		940
Conductor,	10 to 10 =	
Blue sandy shale,	35 to 45 =	895
Berea grit (oil sand),	110 to 155 =	
Blue shale,	580 to 735 =	
Sandstone,	2 to 737 =	
"Soapstone,"	198 to 935 =	
Sandstone,	3 to 938 =	
"Soapstone,"	176 to 1114 =	

No red rock was found, and the drilling below Berea grit was all of a homogeneous character. No oil below Berea grit.

§ 685. *Truxall Well, ½ mile south of Powers Corners.*

Elevation of well mouth above tide, about		945
Conductor,	10 to 10 =	
Flags, 3 in. to 1 ft. thick,	8 to 18 =	
Bluish shale,	12 to 30 =	915
SS., honeycombed and creviced (not through),	8 to 38 =	

In this neighborhood the drill has been sunk 70′ in the sand without going through it.

Water Wells at Warren, Ohio.

Eagle House Well.

§ 686. Elevation of well mouth above tide, about		890′
Conductor (set in an old water well,)	25 to 25	
Slate with hard shells,	85 to 110	
SS., white, fine, solid, no seams saturated with oil but water fresh and good,	40 to 150	
Shales and slates free from shells,	250 to 400	

No red rock in well. At 313′ heavy flow of gas for three days, then ceased. Some salt water below gas vein. Water now stands within 4′ feet of surface and is excellent for ordinary use. Diameter of drill hole 3″.

Van Gorder Well.

§ 687. Elevation of well mouth above tide, about		890′
Conductor, surface clay and gravel,	20 to 20	
Hard flaggy slates,	20 to 40	
Soapstone,	20 to 60	
Hard slates,	40 to 100	
Slate with some pebbles,	33 to 133	
SS., white, (not through,)	20 to 153	

No red, sandpumpings grayish-blue to white, water stands within 6′ of top. Remarkably soft and pure.

Chase Well, at the National Hotel.

§ 688. Elevation of well mouth above tide, about		890
Conductor, surface clay and gravel,	23 to 23	
Sandy shale,	60 to 83	
"Loadstone,"	1 to 84	
Soapstone,	46 to 130	
SS., white and fine, (not through,)	14 to 144	

Copious supply of soft water, used in preference to rain water for washing and all hotel purposes and standing constantly within 5′ of the well mouth.

CHAPTER XXXVII.

Notes on various building stone quarries in Ohio.

Nelson Ledge.

§ 689. In the northeast corner of Portage county, Ohio, about 1½ miles northeast of Nelson Centre. Elevation of base (by barometer) 955′ above ocean.

A reproduction of a Pennsylvania or New York "Rock City," with the exception that the exposure lies but a few feet above the level of the plain below it, and not conspicuously on a ridge or hilltop, as is the case in Penna. and N. York. From 50′ to 60′ of rock exposed at the ledge, conglomeritic in places from top to bottom. Pebbles pea to hazelnut, ovoidal, and of same aspect as those of Garland, Olean, &c. Many of the pebbles are crushed and fractured as if the mass had been subjected to heavy pressure, and the weaker material had yielded to the stronger. The interspaces between the pebbles are but partially filled with sand and clay. This fact no doubt accounts in part for the crushing of the least resistant quartz—one pebble ground directly upon another, the cementing material being too scanty to fill the interstices and assist in equalizing the pressure. It also accounts for the rapid disintegration of the rock when exposed to the action of moisture and frost.

So porous a conglomerate as this is seldom seen.

Other sandrocks, sometimes conglomeritic, are seen in different exposures, extending up 100′ or more above the top of the ledge. These are massive, frequently obliquely bedded, and precisely similar in character to rocks of the same horizon in Penna. The conglomerate may be said then, to be about 150′ in thickness in this locality, but it is probably in two or three bands with thin local partings of shale. A constant and copious rain during my visit to the ledge prevented as full an examination of these points as was desired.

§ 690. *Quarry in Fowler township, O.*
(*About 1½ m. S. E. of Baconsburg.*)

A massive coarse firm sandstone, excellent for architecural and engineering purposes, in courses from 2′ to 6′ thick. Some of them olive gray, others yellow and iron stained. About 20′ seen. Elevation of top 1130′. No fossils noted. Escarpment faces the west. Top oxydized and sharply glaciated. Direction of striae S. S. E. Large granitic bowlders along the face of the escarpment.

§ 691. *Burghill Conglomerate.*

On farm of Mr. Hayes half a mile south of depot. Elevation of top about 1125′, bottom 1100′. A fine exposure covering a large area. Pebbles ovoidal from the size of a grain of wheat to a hazelnut. About 25′ of cliff exposed, but probably more below. The rock is broken in large masses and scattered to the north and west below the face of escarpment. On the southeast slope of the hill the rock is bare in many places and always plainly glaciated, the grooves running with the trend of the slope, about S. S. E.

A similar exposure may be seen about 2 miles E. of Burghill on the farm of Mr. Turnkey. It caps the ridge east of the Pymatuning and forms perpendicular cliffs 20′ to 25′ in height. Elevation of top about 1200′. From the topography below this ledge one would infer that another sandrock lies a short distance below it.

§ 692. *Foulke's quarry.*
(*One mile south of Mossmantown, Mercer Co., Pa.*)

Top 1290′; 12′ to 15′ thick.

Coarse yellowish soft sandstone in massive layers from 4′ to 5′ thick. Of irregular fracture; iron stained on top and in the seams; containing scattered pebbles, small and ovoidal, with clay balls and iron concretious. Some impressions of carboniferous plants. Glacial scratches on top. Escarpment faces the west and extends south a mile or more, bordering the level drift-filled plain below. Large granitic bowlders lie scattered over this ridge, but principally along the escarpment, and intermixed with well rounded bowlders of this local sandstone.

§ 693. *Austin Flag quarry.*

(*3 miles N. of Warren, Ohio.*)

Elevation of top above tide, (aneroid,)		915
Drift clay overlying the quarry, =	8′	
Flags, blue and gray, rather irregularly bedded,	2′ 6″	
Olive shales, friable,	2′ 6″	
Flags, blue and gray, 1″ to 8″ thick,	2′ —	
Black shale, containing *Lingula melia*, seen,	2′ —	

This quarry is the most remarkable one of the kind I have ever seen. The upper band furnishes some good flagging, but it also works up nicely into blocks for street pavements, for which it is largely used. This stratum alone would make a valuable quarry.

But it is the lower stratum which has given the quarry its wide-spread reputation.

The stone is reached by stripping. The surface clay, upper flags and shales, have been removed, and several acres of the lower band lie open to daylight. A stone floor stretches out over the whole area more smooth and uniform than the best laid pavement in a city. One could hardly believe that any sediment could be laid down over large spaces in so complete a plane. Here are 2′ of perfect flags, lying in from 6 to 10 courses, and separated from each other by invisible parallel planes of division; and these lines of separation are so complete that the quarrying of the stone becomes a mere matter of cutting out the squares into the dimensions required.

Large areas a rod wide, perhaps, and four or five rods long, are sometimes cut loose from the main body by wedges inserted at short intervals along a line and driven simultaneously; and when the connection is thus broken the mass moves as readily on the bed-plate as the top plank in a pile would move upon the one under it.

There is little or no waste in this lower stratum, every layer being perfect. They vary in thickness in different portions of the quarry from one inch to eight inches.

The top of the upper stratum is smoothed and polished in some places as nicely as any stone worker could do it by rubbing two plane surfaces together; in others sharply cut striæ run in parallel lines across the polished surface as nearly as could be ascertained in a S. S. E. direction.

There is a uniform dip to the south, making the drainage very easy. In opening the drain 2′ of black shale is disclosed.

This shale is very hard, requiring nearly as much labor in its excavation as if it were ordinary sandstone; but on exposure to air and moisture soon crumbles into a blue-black clay. Some layers of this shale contain immense numbers of *Lingula melia*, principally in broken fragments.

The flags themselves are said to be remarkably void of fossils. Occasionally a single shell has been found, and several small beds of apparently drifted coal plants have been noticed, but they are not of usual occurrence. The only fossil seen at the quarry was a small fragment of *lepidodendron?* about six inches in length, water-worn, and imperfect.

About two miles S. E. of Warren, on the Howland road, at an elevation of 915±, a band of flags shows itself in the roadway apparently from 5 to 10 feet thick. This would appear to be a higher band than the Austin quarry, and affords another proof of the variable character of the Cuyahoga shales in this section.

§ 694. *Section at Oil City, Venango county, Pa.**

S. S., massive, in hill top; crops out in cliffs; elevation not accurately ascertained, but the top of the hill is about 1515′; and the base of the rock is between 1350′ and 1400′ above ocean.

? Unseen, between	100′ and 150′	to 1241
SS., beds 2′ to 4′ thick, parted by shale and slate,	20′	35 to 1206
SS., massive and hard,	15′	

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* By H. M. Chance.

Slate,		5	to	1201
SS , massive and hard,		6	to	1195
Shale, slaty or shaly slate, with some sandy layers,		21	to	1174
SS., hard and fine-grained beds, 3'' to 2' thick,		11	to	1163
Shale; sandy, greenish-gray,		19	to	1144
? Unexposed,		96	to	1048
SS., fine-grained beds 1' to 3 thick, 10' exposed,		10	to	1038
Shales, sandy, thin-bedded and fine-grained,		8	to	1030
SS., thin-bedded and fine-grained, with shale, (forms roof of L. S. & M. S. RR. tunnel,)	6'	23	to	1007
SS., thin-bedded and fine-grained, to RR. level,	17'			
? Unexposed to river level (low-water),		22	to	985

§ 695. *Section at Franklin, Venango county, Pa.*[*]

Coal 2 miles east of river, at elevation of			1479
? Unexposed 65'-40' dip,=	25	to	1414
SS., massive and coarse-grained, (about)	30	to	1384
? Unexposed,	104	to	1280
SS., flaggy, 5 feet exposed,	5	to	1275
? Unexposed,	167	to	1108
SS., Bell's quarry,	28	to	1080
L. S. & M. S. R. R. depot,	—	to	1014
A. V. R. R. depot,	—	to	988

The top of the SS. in the quarry south of the Galloway farm is at an elevation of 1109'. The rock is here a grayish drab colored flaggy SS., rather fine-grained, and splitting into plates from 1'' to 6'' in thickness.

SS., thin-bedded, spliting into flags ½'' to 2'' thick,	10'
SS., flaggy, splitting into flags 1'' to 6'' thick,	15'
SS., more massive than above (in floor of quarry).	

§ 696. *Section compiled near Cranberry Coal Bank.*[†]

Ferriferous Limestone on the farm of Jacob Fox, 8' exposed.
Elevation of base of *F. L.* above tide=1587'.
Exposure of *F. L.*, 8 feet.
Height of *F. L.* above coal bank, at least 74'.

Slate, blue,	2'
Coal (*Clarion*),	1' to 2'
Interval at least,	8' to 10'
Sandstone yellowish, whitish and reddish brown, loose and coarse (in air shaft),	56' 0''
Slate (in air shaft),	6' 0''

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[*] By H. M. Chance.
[†] By H. M. Chance.

Coal; Cranberry Bank. (A. T.=1531′),	2′
Fireclay, varying from,	2′ to 10′
Sandstone thin bedded, hard and full of roots,	2′ to 3′
Shale soft olive,	11′
Ball iron ore,	0′ 4″
Shale,	1′
Bituminous slaty shale,	0′ 3″
Fireclay, Interval concealed,	12′
Coal, reported 4′ thick, but with a thick parting slate,	4′
Fireclay (at least),	3′
Sandstone hard (at least 2′ and possibly),	10′
Sandstone thin bedded,	2′
Shale soft, about,	25′
Sandstone white shaly,	4′
Fireclay and shale,	5′
Sandstone fine grained, 6′ to 10′ exposed.	

The place of the *Ferriferous Limestone* at the coal bank would be at or near the level at which the air shaft was started. In this shaft the coal was struck 82′ below the surface. The section reported is—

Surface clay,	20′
Sandstone,	56′
Slate,	6′
Coal,	2′

The *Ferriferous limestone* was not found here; but the blossom of a coal is reported as having been found a short distance off. This is evidently the *Clarion coal* which underlies the limestone at the limestone workings.

Between the coal bank and the limestone quarry a ridge intervenes which rises to 1631′. This should contain the limestone; but the residents in the vicinity state that none has ever been seen, although much sought after.

§ 697. *Note on Pre-glacial erosion.*

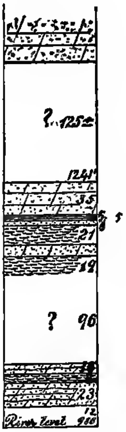
At the meeting of the British Association in 1880, Mr. De France described the pre- and post-glacial surfaces of northwestern England, between the Welch mountains and the Cumberland lakes. To the west of the Pennine chain of carboniferous hills spread the plains of Lancashire and Cheshire, covered with Drift, deep enough at one point (near Ormskirk) to measure 230 feet.

The valley gorges of Cumberland were excavated before the Ice age.

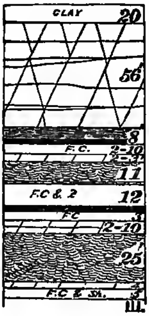
Windermere and the other lakes were excavated during the ice age ; Windermere to a depth of 230 feet, *i. e.* 100 feet beneath present sea level.

The *marine Drift* covers so thickly an extensive area in Lancashire, Cheshire and Flintshire that vales 200 feet deep (like the Ribble and the Irwell) have been post-glacial excavated in it ; the lowest places in the vales being below present tide level, showing that the land has more recently subsided (or the ocean risen.) In the Cumberland mountain valleys the marine Drift no longer exists (if it ever did,) having been subsequently re-excavated and swept out.

"A terrace of post-glacial deposits fringes the glacial area at, and often below (in one place 70′) the sea level, consisting of peat, with a forest at the base, resting on a marine post-glacial deposit." (Report in Nature, Sept. 9.)



Oil City



Cranberry

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