GEOLOGICAL SURVEY OF NEW JERSEY.

ANNUAL REPORT

OF THE

STATE GEOLOGIST,

FOR THE YEAR

1888.

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NEW BRUNSWICK, December 18th, 1888.

To His Excellency Robert S. Green, Governor of the State of New Jersey, and ex-officio President of the Board of Managers of the State Geological Survey:

SIR—I have the honor herewith to submit my annual report, as State Geologist, for the year 1888.

With high respect,

Your obedient servant,

GEO. H. COOK,
State Geologist.

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REPORT.

The work of the State Geological Survey has been steadily prosecuted during the past year. In the annual report for 1887, it was stated that the Topographic and Magnetic Surveys of the State were completed, and that the reports upon these would be prepared and printed as rapidly as possible. This work is done, and the first volume of the final report of the Geological Survey of New Jersey is being distributed. It is an octavo volume of xi. and 439 pages, and contains a report on the Geodetic Survey, by Prof. Edward A. Bowser, on the Topographic and Magnetic Surveys, by C. C. Vermeule, C.E., and on the Climate of the State, by Prof. John C. Smock. It also contains two maps of the State on a scale of five miles to an inch; one showing its civil divisions, and the other its elevations, mountains, ridges, valleys and plains, together with its rivers and its drainage areas.

The work now preparing for publication as the second volume of the final report will contain a full catalogue of the minerals found in the State, with their localities; a catalogue of all the plants growing in the State, with notes of their occurrence and localities; and also catalogues of its vertebrate and invertebrate animals. Appendices to these catalogues will give some practical and economic particulars regarding them. Most of the work of preparing these catalogues is already done.

So much attention has been given in former reports to the study and description of the geological structure of the rocks of the State, that the work still to be done is mainly in combining and systematically arranging the materials which have been collected by various persons who have made New Jersey a study in former years. This is especially the case with the marl and clay formations in the middle of the State, and the limestones, slates and sandstones in the north and northwestern portions. There are some obscure and difficult points of structure in the red sandstone and the gneissic rocks, but it is thought that important progress has been made in clearing up these difficulties, and that the volume on structural geology can be pre-

pared as soon as that above mentioned is out of the way, and that one on the economical geology can then properly complete the series.

The prompt publication and liberal distribution of the results of the State surveys have contined to meet the approval of our citizens, and to supply suggestive and needed information. The expenses of printing, mailing and expressage are large, but the returns in the development and wealth of the State abundantly justify the expenditure. The whole system of artesian well-boring was started at the direct suggestion of the Survey, and it has brought inestimable sanitary and pecuniary benefits to the whole Atlantic coast, and has been of great service throughout the State. The description of the location and structure of our fire and potters' clays, and its publication has caused the development of some of the best clay properties in the country, and has made public our immense stores of the best plastic and refractory materials in the immediate vicinity of the great manufactories and markets of the continent. The preparation and publication of our topographic maps, in advance of those of any other State, have tended to draw attention to the peculiar advantages of New Jersey in its location, its varied surface, its healthful sea-side and mountain resorts, its water-supply, and its unequaled means of travel and communication. The maps are studied by engineers for projected improvements, by citizens seeking homes in the country, by land-owners who desire to improve or open their properties, as well as by intelligent and inquiring citizens of all kinds who are interested in the development and prosperity of the State. The publication of the condition of our mines, our quarries, our lime production, our marls, our drained lands, our water-supplies and other matters of general interest is continually inciting to new enterprises and the investment of capital, and the notes in regard to soils and the means for their improvement, are helping to develop our agriculture and to greatly increase its products.

The annual and other reports have always been distributed without charge to those who receive them, and are sent on application. Several of the reports, notably those of 1873, 1876, 1879, 1881, are out of print, and we can now only supply incomplete sets.

The first edition of the topographic map was all distributed. A second edition has been printed, and by the act of the Legislature of 1888 it was directed to be sold at the cost of paper and printing, to those applying for it. In pursuance of this authorization the following notice was sent to all the newspapers in the State, and was generally published:

GEOLOGICAL SURVEY OF NEW JERSEY,
NEW BRUNSWICK, N. J., July 15th, 1888.

DEAR SIR.—In order to meet the constantly increasing demand for the sheets comprising "The Atlas of New Jersey," the Board of Managers of the Geological Survey have decided to allow them to be sold at the cost of paper and printing for the uniform price of 25 cents per sheet, either singly or in lots. This amount covers all expense of postage, or expressage, as the case may be. Application and payment, invariably in advance, should be made to Mr. Irving S. Upson, New Brunswick, N. J., who will give all orders prompt attention.

The following is a list of the titles of the sheets. Those from 1 to 17 are on the scale of 1 mile to an inch:

No. 1. Kittatinny Valley and Mountain, from Hope to the State line.
No. 2. Southwestern Highlands, with the southwest part of Kittatinny valley.
No. 3. Central Highlands, including all of Morris county west of Boonton, and Sussex south and east of Newton.
No. 4. Northeastern Highlands, including the country lying between Deckertown, Dover, Paterson and Suffern.
No. 5. Vicinity of Flemington, from Somerville and Princeton, westward to the Delaware.
No. 6. The Valley of the Passaic, with the country eastward to Newark and southward to the Raritan river.
No. 7. The Counties of Bergen, Hudson and Essex, with parts of Passaic and Union.
No. 8. Vicinity of Trenton, from New Brunswick to Bordentown.
No. 9. Monmouth Shore, with the interior from Metuchen to Lakewood.
No. 10. Vicinity of Salem, from Swedesboro and Bridgeton, westward to the Delaware.
No. 11. Vicinity of Camden, to Burlington, Winslow, Elmer and Swedesboro.
No. 12. Vicinity of Mount Holly, from Bordentown southward to Winslow and Woodmansie.
No. 13. Vicinity of Barnegat Bay, with the greater part of Ocean county.
No. 14. Vicinity of Bridgeton, from Alloway's town and Vineland, southward to the Delaware bay shore.
No. 15. Southern Interior, the country lying between Atco, Millville and Egg Harbor City.
No. 16. Egg Harbor and Vicinity, including the Atlantic shore from Barnegat to Great Egg Harbor.
No. 17. Cape May, with the country westward to Maurice river.
No. 18. New Jersey State Map. Scale, 5 miles to an inch. Geographic.
No. 19. New Jersey Relief Map. Scale, 5 miles to the inch. Hypsometric.
No. 20. New Jersey Geological Map. Scale, 5 miles to the inch.

The figures on the accompanying map show the location of the several topographical maps, with their numbers.

Yours respectfully,

GEO. H. COOK,
State Geologist.

A large number of maps have been sold upon these terms, and the proceeds are returned to the State Treasury.

The distribution of Vol. I. of the final report has just begun. The expense of sending it out by mail is large, 22 cents postage for each volume; but its usefulness as a book of reference is such as to warrant the expenditure. In perhaps one case in twenty the postage is returned, and it would be only fair for all private parties who receive it to relieve the Survey of this expense.

The reports and maps are all sent to every public library, as far as known, in the State; to several libraries in New York and Philadelphia, and to many other public libraries outside the State, which have applied for them. In this way reference can usually be had to them.

It has been suggested as a proper use to be made of the maps, to have them properly backed and mounted, and furnished through the State Superintendent of Schools to all the school districts of the State. This would tend to a wide distribution of the results of the Survey, and to a thorough knowledge, among our own citizens, of the natural resources of the State, and would be money judiciously expended.

Of the subjects coming within the province of the Geological Survey, notes are presented in this report upon the following:

I. Geological Studies of the Triassic or Red Sandstone and Trap Rocks.

II. Drainage of the Great Meadows in the Pequest Valley; Drainage of the Low Lands on the Passaic, above Little Falls.

III. Water-Supply and Artesian Wells.

IV. Statistics of Iron Ores, Zinc Ores, Fire-Clays, Stoneware-Clays and Bricks.

V. Assistants.

VI. Expenses.

I.

ON THE TRIASSIC OR RED SANDSTONE ROCKS.

The Red Sandstone Region of New Jersey is a plainly-marked and well-known portion of the State. It comprises a broad belt of country which lies between the Hudson river, on the northeast, and the Delaware river, on the southwest. Its boundaries may easily be traced. Beginning on the Hudson river, in latitude 41° N., the boundary follows the Hudson river, New York bay, Kill von Kull and Staten Island sound almost to the mouth of Woodbridge creek. At this point it leaves the sound, and passes just north of the village of Woodbridge, and under a surface covered with heavy deposits of clay and glacial drift, southwest to the Raritan river, at the mouth of Lawrence's brook. It follows this stream up to its head, near Monmouth Junction; and thence underneath the gravel of the divide to the Millstone river, near Kingston; and thence on it follows near the line of the Delaware and Raritan canal, to the vicinity of Baker's basin, about 5 miles northeast of Trenton; and from there onwards, across country, in which the rock is covered by earth, to the Delaware, about a mile northwest of Trenton. It then follows that river up to near Holland station, on the Belvidere Delaware railroad. At the foot of the mountain, near that place, it leaves the river, and follows, in a northeasterly course, entirely across the State, following the southeast foot of the mountain, and passing near Little York, Pattenburgh, Clinton, Lebanon, New Germantown, Pottersville, Peapack, Bernardsville, Morristown, Boonton, Montville, Pompton, and thence along the Ramapo river to the New York boundary, at Suffern's, on the New York, Lake Erie and Western railroad. From that place it follows the State boundary to the place of beginning, on the Hudson river, in latitude 41°.

The area which it covers is about 1,540 square miles, and it is the most thickly-settled and best-known part of the State. Its surface is mostly rolling, and it is traversed by several abrupt and disconnected mountain ridges. The soil which covers the rolling part of this dis-

trict is of a decidedly reddish and characteristic color, in which it resembles the underlying rock; while the soil on the mountain ridges is of a lighter yellow color, without the tinge of red, and is derived from the trap rock which underlies it. The surface of this area, which lies north of an irregular line between the mouth of the Raritan river and Morristown, is in many places covered with a thick deposit of gravel, sand and clay, which frequently rises into large hillocks, and is not unusually disfigured by the presence of erratic boulders. The line mentioned above is the southern margin of the glacial drift, and the gravel, sand, clay and boulders are all derived from the rocky and mountainous regions which lie on the north of this marginal line.

This whole region is usually spoken of as the Red Sandstone, or by some as the New Red Sandstone Region. Geologists are now agreed that it is of the Triassic age, at least its lowest parts, and that its higher or newer portions are of the Jurassic age, and hence some designate it as the Jura-triassic. As a convenient name for the purposes of this report it will be called the Triassic. The rocks of the whole region may all be included in two divisions, viz., sandstones and trap rocks.

The sandstones consist of the well-known brownstone or freestone which is so much used in building—of layers of stone which are so fine grained as to be called shale—and of others in which the pebbles or fragments of stone cemented together and making up the rock are so coarse as to be called a conglomerate; but these have the common character of being composed of the materials worn off and washed down from the higher grounds which bound this region along its northwest and southeast borders. These materials have been deposited in extended and tolerably uniform layers, and in course of time have hardened into stone. They are known as sedimentary rocks. They are remarkable for their color, and for the general lack of beds or strata of limestone, and for containing very few fossilized remains of vegetable or animal life.

The trap rocks which make the mountain ridges are sometimes called *igneous* rocks, implying that they have been under intense heat, and so melted, and in cooling have taken the form in which they now are; at other times they are called *eruptive* rocks, because they have broken through the stratified rocks when in a melted state and come to the surface; others still prefer the name of *intrusive* rocks, because

they have in some cases forced their way in between the layers or strata of the other rocks among which they lie. These rocks, where weathered, are of a dull-grayish or yellowish-rusty color, and when freshly broken are of a more or less bluish-gray color; and they are much harder and tougher than any of the sandstones. They may by the careless observer be confounded with granite, but can easily be distinguished by the absence of quartz grains in them. Besides the name trap rock they are known as basaltic rocks, and among geologists as diorite rocks.

The red sandstone rocks are of sedimentary origin, and the rounded pebbles, and the occasional fossils found in them are sufficient evidence of this fact. But from the layers and beds of the rock composing the mass of the formation, all inclining towards the northwest, instead of being level or nearly so, as sediments are deposited, difficulties have been experienced in the attempts to find an adequate cause for this remarkable position of almost all the rocks of this formation. Prof. Henry D. Rogers, in his report on the Geology of New Jersey, endeavored to explain it, and many other geologists have put forth still other explanations. If looked at as one connected body of sandstone and shale, unbroken by faults, it would, with its breadth of 20 miles, and with an average dip to the northwest of as much as 8°, its thickness must be estimated as not less than 14,000 feet. This is so incredibly great a thickness that many attempts have been made to find some explanation of the occurrence of these rocks in their present position without requiring them to be so thick. That the strata were originally horizontal is apparent from the position of the pebbles in the strata—their longer diameters incline to the same degree as the strata, though such pebbles when deposited always have their longer diameters horizontal. The same remark may be made in regard to the ripple marks, and the tracks which are found in the surface of some of the layers of the rock. The strata must have been nearly level when first deposited, and have afterwards been tilted into the position in which they are now found.

If faults could be found in the rock, which faults extended lengthwise of the formation in a northeast and southwest direction, so as to divide it into narrower strips, each of which could be tilted separately, an explanation of this monoclinal structure could be found, without involving so great a thickness of the formation. The same strata might be brought to the surface at every fault, and in crossing the

formation in a northwest and southeast direction the same strata would be crossed many times.

There has been great difficulty in getting the proof that such faults exist, on account of the uniformity of the rock in composition, structure and color; also, on account of its rapid disintegration, and consequent loss of marked results of former changes. In most other rocks, strata of limestone or of slate are to be found marking the successive deposits, or layers containing peculiar fossils have given character to the different parts of a formation.

In our annual report for 1881, p. 58, and 1882, p. 16, attention was called to an apparent repetition of the same strata in the successive quarries along the Delaware, above Trenton, going north; and faults were described in the report of 1882, as occurring at Arlington, and in that of 1883, as at Haledon.

SECTION BETWEEN WESTWOOD AND HOHOKUS, BERGEN COUNTY.

SECTION ONE MILE NORTHEAST OF SERGEANTSVILLE, HUNTERDON COUNTY.

An extended search was made for faults in 1885 or 1886 by Mr. N. H. Darton, now of the United States Geological Survey, and Prof. W. M. Davis, in a paper read before the American Association for the Advancement of Science in 1886, and also published in the American Journal of Science, Vol. XXXII. (3), p. 342, has given at some length the effects of faults in the trias of Connecticut, which has many characters in common with ours in New Jersey.

The completion of the State topographical maps has enabled us to make a clear exhibit of the ridges, with their steep southeast and gentle northwest slopes, such as would be found by faults as shown in the figure.

A closer study of the rock strata has shown that there are some characteristic differences which can be made plain, and which appear in places remote from each other. The occurrence of some small but

well-characterized fossils in some peculiar strata, which are exposed in several localities distant from each other, also lends support to the same view. (See Mr. Nason's report, farther on.)

All the observations thus far made in New Jersey, support the conclusion that the trap rocks are intrusive, and of later age than the red sandstone of Series I. and II. of Mr. Nason's report.

There are, along the northwest border of the red sandstone, several deposits of conglomerate rock, some of which contain pebbles and fragments of trap rock. These were noticed by Dr. Kitchell in the annual report for 1855, p. 145. The peculiar character of these conglomerates led Prof. Rogers, in 1840 (see his final report, p 135), to consider them as of a different and later age than the rest of the red sandstone formation, though the strata were conformable to it, and no fossils or other characteristic line of division had been found. In the present state of our knowledge, we consider the conclusion of Prof. Rogers the most probable one.

In order to mark out and illustrate these conclusions by proper reference to facts and localities, Mr. Frank L. Nason, Assistant Geologist, has been occupied in visiting and describing important localities, which go to sustain these conclusions; and he has also been successful in finding new and accessible localities of the characteristic fossils and rocks.

THE TRIASSIC ROCKS,

OR

THE RED SANDSTONES OF NEW JERSEY.

Enclosed within the area of the Red Sandstone District, the boundaries of which have been given in the preceding pages, are no foreign rocks save the traps. There are rocks, however, which appear but shortly removed from actual contact, and they are as follows: Gneisses appear at Trenton, and were formerly exposed in Jersey City before improvements hid them. This line forms the southeast border. On the northwest, from Ramapo Mount to Peapack, from Pottersville to Annandale, on the Central Railroad of New Jersey, and from Pattenburgh to Little York, gneiss also appears. The remainder of the boundary line is formed by silurian limestones and slates.

Yet the rocks comprising the series known as the trias, are by no means homogeneous, either in texture, composition or color. Red, however, is the predominating color. In texture the rocks vary from exceedingly compact, so hard as to ring under the hammer and to break with a conchoidal fracture (this last characteristic being confined to the indurated shale), to rocks made friable by the decomposition of some of the component minerals. Red or gray argillaceous shales are also found, which have, probably, never been compulted into rocks proper. At other times a sandstone, which does not appear to have been acted upon by high temperatures, is changed almost to a quartzite in appearance. Between these extremes of texture are interpolated an almost infinite variety of rocks of varying degrees of compactness. One of the series forms the freestones, so called, which are among the most beautiful and durable of our building-stones.

Passing the shales and sandstones proper, the next in texture come the conglomerates. The most noted example of these are the "Pebble Bluffs" on the Delaware river near Milford, Hunterdon county. This hill or bluff is made up of boulders measuring from one inch to one foot in diameter. All are well rounded. At Stockton, Wil-

burtha and other places along the Delaware, the sandstones have pebbles from the size of peas up to as large as black walnuts, rarely larger. To a limited extent, they are also found on the New Jersey side of the Hudson river.

Shales are also abundant in the red sandstone belt. The more typical ones are designated in this report as the "Raritan," since they are found along the banks of this river more perfect than elsewhere in the State. The shales graduate from typical forms to such as are with difficulty distinguished from slates. In color they range from light gray to bright red. The slates are not slates, properly speaking. They are usually more or less micaceous, and have not a perfect slaty cleavage; some are thin laminated, others are thick. Examples of the former are typically located at Weehawken and Shady Side, on the Hudson; at Rocky Hill, Princeton and Wilburtha.

The sandstones proper often display a tendency towards slaty cleavage. To such an extent is this, at times, developed, that an apparently firm and compact bed is rendered worthless by what is locally known as "reedy" structure. Rather thickly laminated mica slates occur interbedded with the sandstones. The "reedy" structure is confined almost wholly to the red sandstones. The preceding paragraphs give a general notion of the sandstones. The particular description with sections will follow.

As regards the position of the triassic rocks, with respect to the plane of the horizon, they are nowhere parallel, but are tilted at various angles toward every point of the compass. These angles vary from 3° to 5°, minimum, and 70° to 80°, maximum. An average will give 15°. There is a decided preference for the direction as well as of the magnitude of the dip. From two hundred and fifty observations, recorded at random over the entire field, in Rockland county, N. Y., and in New Jersey, one hundred and sixty-three give a N. W. dip. Twenty-four have a S. W. dip; N. E. has twenty-nine, and S. E. sixteen dips. The dips N. and W. are fourteen in number; S. five; E. none. Combining, the N. W. and S. W. quadrants have two hundred and one of the dips; the N. E. and S. E. the remaining fifty-two.

Another fact worthy of notice is that the planes of tilting are monoclinal. Exceptions to this rule are, at present, unknown.

It has been noted that by far the greater number of observations show a N. W. dip. Another point worthy of careful consideration is

this, in a belt extending from Stony Point, N. Y., to Trenton, and of an average width of about twelve miles, no more than six or seven localities will show a deviation from the N. W. dip. These exceptions are located near Martinsville, Washington valley, and near Hopewell. From Trenton across the entire width of the Delaware river boundary, there is no exception to the N. W. dip. In most places along this belt the same dip obtains for several miles back from the river.

When, however, we come to the examination of the distribution of the dips in other than the N. W. quadrants, no such regularity exists; there are no long belts in which a given dip prevails, but the deviations from the N. W. are clustered together in limited areas, and more than one direction is usually present. In Clinton valley, Hunterdon county, is a limestone area of triangular shape. The hypothenuse of the triangle is represented by a sinuous line reaching from Pattenburgh, on the Lehigh Valley railroad, to near Stanton, on the same road. From the latter point, a leg of the triangle extends N. W. till intersected by the other, reaching N. E. from Pattenburgh. About this limestone area the sandstones are much disturbed. This disturbance extends, in observed localities around Round and Pickles mountains. So far as it is possible to observe, the sandstones and shales dip at right angles to the trend of one of the larger axes of the mountain. Around a small trap outburst near Flemington, the dips are again disturbed. Around New Germantown and Peapack, this deviation from N. W. is again recorded. By far the most satisfactory example is the vicinity of Liberty Corner. Taking this place as a center, a radius of six to eight miles will cover an area which shows dips towards nearly every point of the compass. These variations are noted on the crescent-shaped part of Second mountain. Beginning at Bernardsville, and following along Mine brook, the shales dip S. S. E., S. E. changing to nearly E., then N. E. nearly N., and finally, just N. E. of Martinsville, the dip goes N. W., and so continues to the crescent at the northern extremity of the mountain, near Pompton. In each of these places the shales invariably dip under the trap.

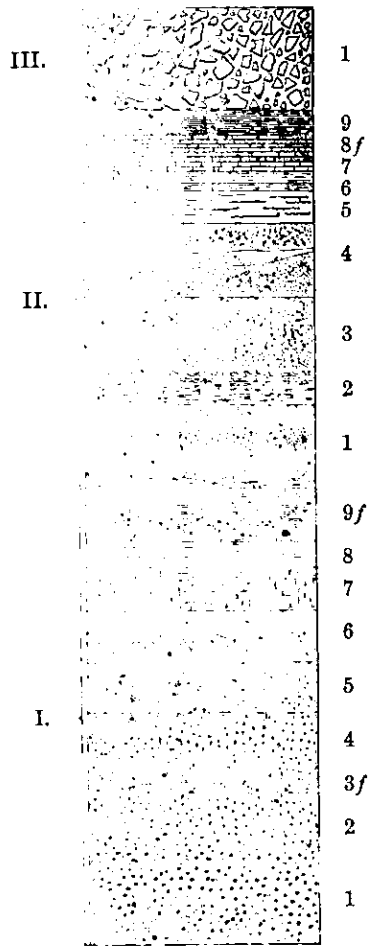
Again starting from Bernardsville, and following the inner curve of the crescent, the dips, as before, follow at right angles to the trend of the mountain at any point. The angles run, at first, S. E., N. E., nearly N., and, near Union village, resume the N. W. dip. This locality, on either side of the mountain, is decidedly the best one for

noting the influence of the trap on the adjacent shales, both on account of the numerous exposures, and also of the crescent-shape of the outburst.

Other localities where variations are less perfectly noted are in the vicinity of Basking Ridge, New Vernon, Montville and Pompton. From the foregoing it will be readily seen that disturbances inharmonious with the general N. W. dip are to be found only in the neighborhood of trap rocks, or where rocks much older indent the borders of the trias. It will also be noted that along the major axes of trap outflows, where the direction N. E. to S. W. is preserved, no deviation from N. W. dip is present. The same is true when the older rocks, as limestones, appear, as, for example, the limestone and Potsdam sandstones, which outcrop at Lime Port, Pa. (on the Delaware river, two miles above Lambertville, N. J.), and thence extend S. W. to within two miles of Neshaminy creek. When, however, either irregular spurs shoot out from the body of the trap, as at Rocky Hill, or when isolated bosses push up through the sandstones, as Round hill, and a small outflow near Flemington, the continuity is broken. Limestones lying at an angle to the general trend of the formation, are also a disturbing factor.

As has been mentioned before, the rocks of the trias are not all of the same texture or color. While in one place an abundance of lime pebbles may be present, in another they will be wholly absent. In one series of quarries the characteristic will be fine, even-grained strata, in another coarse, irregular textures will prevail. In one series trap pebbles or lime, in another foot-prints, and in a third crustaceans and fishes will be present.

A thorough examination of all of the worked quarries has led to the division of the rocks of the trias into three series. These series are marked by no sudden transition, but rather showing an easy gradation of one into the other. In fact, the division is made more for convenience in reference than for any other reason. At the same time the rocks are very easily distinguishable.



SECTION SHOWING THE RELATIVE POSITIONS OF THE TRIASSIC SANDSTONES.
3*f*, I., Lowest Stratum Bearing Estheria Ovata.
9*f*, I., Middle Stratum Bearing Estheria Ovata.
8*f*, II., Limestone Stratum Carrying remains of Cypris or of Estheria.

*SERIES III.

GENERAL CHARACTERISTICS.

The rocks of the first series are characterized by heavy beds of brecciated limestone, with cementing material of fine lime, mud and quartz

*See column above for the relative positions of the sandstones referred to in Series III., II. and I.

sand. Pebbles and boulders of other rocks, well rounded, are also present. The cementing material, as at Ramapo, on the Mahwah river, six miles above Suffern's, N. Y., is frequently red shale mud. That the conglomerates on the N. W. border of the trias, for this is where the limestone is found, depend upon the character of the bordering older rocks for their material, is very evident. This is shown by the limestone conglomerates passing into a conglomerate made up wholly of gneiss pebbles, with mingled quartzite, in the vicinity of Boonton, Whitehall and Pompton. The gneiss conglomerates are very friable and loosely cemented. The pebbles themselves are often in an advanced stage of decomposition. This conglomerate grades easily into a conglomerate made up principally of trap pebbles. The cementing material in this case appears to consist largely of trap sand. It is evident that no traces of either plant or animal life would appear in this series.

The dip and strike are the same as for the rocks of the two lower series. They are confined wholly, so far as is known, to the N. W. border of the formation.

Series II.

GENERAL CHARACTERISTICS.

This series is specially characterized by the abundance of the Raritan red shales. The rocks of the series vary from the fine-grained, red, argillaceous shales to fine, even-grained red or brown and light gray sandstones. The shales are loosely compacted; probably never have been, many of them, a rock proper. The sandstones are compact, "free" working, and are very durable, rather improving than deteriorating on exposure to the weather. In these rocks feldspar is less abundant than in the lowest series, and is never found fresh, but wholly decomposed. Quartz pebbles are rare, and, in reality, should be called coarse gravel, rather than anything else.

The animals and plants appear to be of a higher order. Remains of animals are confined to tracks and fragments of bones. Plants are found in the form of fine impressions. The typical order of rocks is as follows:*

*The order of the series is made somewhat ideal by putting together the results of studies on neighboring quarries, rather than from any one.

9. Raritan red shales, which grade into coarser material in the vicinity of Milford and on the N. W. generally.*

8. Red, thin-bedded, jointed, firm-grained sandstones. Usually hard and very compact. Often somewhat micaceous.

7. A thin, slaty limestone, very pure.† Light gray in color, grading into dark. The stratum thins out to a nodular limestone in shale, towards the N. W. border.

6. Red shales, interstratified with "reedy" sandstones.

5. Rather thick, slaty or shaly bed, on which are tracks of birds and reptiles.

4. Dark red or brown quarry-stone. Occurs in beds from one foot to six feet thick.

3. Gray sandstones, carrying plant remains.

2. Muddy, argillaceous shales, "callous"‡ of the quarrymen. This comes in irregularly.

1. Gray sandstone. Also carries plants, and is rather coarse.§

The quarries in which these observations were made are located in Newark, Belleville and Avondale, on the right bank of the Passaic river. They extend over a line four miles in length, and appear, as one passes from quarry to quarry, to be almost exact repetitions, the one of the other. This appearance is heightened if either hand specimens or chips are carried from one quarry to another for comparison.

This caution, however, is to be observed: The rocks are sandstone, and are but the cemented deposits of what were once incoherent beds of sand. Sand-banks, when opened to-day, do not show a regular succession of strata of a uniform thickness, but rather a thickening or thinning of beds approximating lenticular-shaped masses which may "pinch out" or disappear altogether, from place to place. Again,

*These coarser sandstones and conglomerates, into which the shales graduate, dip *under* the first series (I.), and are wholly distinct from it.

†For analysis, see Geology of New Jersey, 1868, p. 214. The limestone is much purer than this analysis shows. As there stated, the rock was not found *in situ*. It has since been found in three different places, December 29th, 1888. It is found one and one-half miles S. W. of Feltville, one-half mile S., and just back of the cottages, on a steep bluff, W. of Blue brook. The rock is full of a small species of cypris(?).

‡This "callous" is often found in angular masses, enclosed in the gray sandstones, and has thus given rise to the mistake of supposing them to be pebbles of red shale. They are probably only pieces of red mud, washed out into the sands from the shore.

§So far as observed, this is the last stratum of the series. The series probably runs much deeper, and with the same alternations of red, gray and shaly rocks.

one stratum may be wholly or in part replaced by a lenticular mass of a much finer material. These changes may take place very rapidly, and a bed ten feet thick in one bank may be wholly absent from another only two or three hundred feet distant.

The quarries above mentioned are only from fifty to sixty feet above mean tide level. Near Paterson, under First mountain, quarries evidently belonging to this series are worked. They are three hundred feet above mean tide. They differ in many respects from the Belleville quarries, but are higher up in the series. They probably, with the exception of the track stratum and the lime stratum, represent beds from 2 to 6, inclusive.

Another line of quarries begins at Little Falls and extends for a distance of thirty-four miles, through Washington valley, and ending at Dr. Beekman's quarry at Pluckamin. With few exceptions the quarries closely resemble those at Belleville. The exceptions are noted where the quarries are shallow, and only the lower gray sandstones are worked.

While plant remains, in the form of coaly shells filled with sandstone, and thin seams of coal running through the sandstone itself, occur at Belleville, they are, with few exceptions, confined to the quarry bottoms. At Paterson, plant remains are not noted, but at Little Falls, Pleasant Dale, Martinsville and Pluckamin plant remains are again present and abundant.

Attention is called to the parallelism of the lines of the quarries, together with their lithological and structural resemblances.

Series I.

GENERAL CHARACTERISTICS.

The beds of this series are usually very thick. The series has comparatively little red shale. Fossil remains of fishes and crustaceans, together with imperfect remains of plants, for the most part in the form of coal grains.

The rocks are much coarser in texture, the color is generally lighter than the gray stones in the preceding series. Thin layers of glassy quartz pebbles running irregularly through beds of coarse sandstone are common in the lower strata.

The series is generally highly feldspathic, noticeably so, in contrast with the sandstones of Series II. Even where the feldspar is gener-

ally decomposed, fresh pebbles of a bright, fresh, flesh-red color are present, with only slight traces of disintegration.

The rocks of the series* are as follows:

9. Thick beds of dark-gray arenaceous slates and shales, carrying fossils, crustaceans and fishes.

8. Red shale, moderately thick bed.

7. Dark-red sandstone, rather slaty, micaceous, of varying thickness. The laminæ carry circular markings like the ends of tubes. These "tubes" often extend through the entire stratum in a sinuous line.

6. Rather coarse red sandstone; beds from three to five feet or more thick.

5. Pink or tinted-gray sandstone, rather coarse, moderately thick-bedded.

4. Coarse gray sandstone, from ten to fifteen feet thick.

3. Thin stratum, two inches thick, carrying fossil crustaceans and plants.

2. Very coarse gray sandstone, with layers of glassy quartz pebbles, and fresh, reddish feldspar.

1. Disintegrated gray sandstone, only slightly coherent; falls to pieces in handling.

The typical localities for these gray sandstones are at the two series of quarries on the line of the Delaware. The first begins at Wilburtha, the second at Stockton.

Aside from the similarity of the rocks, from a lithological standpoint, the succession of strata in the quarries is essentially the same. The finding of the fossil, estheria ovata, in the quarry at Wilburtha, and the finding of a thin stratum in the Pennsylvania Railroad Company's quarry, above Prallsville, similarly placed, and also carrying the estheria, is a strong plea for the hypothesis of repetition by faulting. The fossil species may not be the same. The texture of the stratum in which they occur is different, but taken in connection with other favorable points, the warrant for the assumption is very strong.

The same apparent repetition of lithologically identical strata in successive quarries is even more marked than in the sandstones of the second series.

*The series is made out, as before, from a number of quarries, rather than from any one.

There is yet further testimony in favor of the hypothesis of longitudinal fractures extending in a northeast-southwest direction, and which also throws light on the question as to the relative age of the trap.

In Hudson and Passaic counties, and also in Rockland county, N. Y., there are three distinct ridges of sandstone, extending in nearly an unbroken line to Hook mountain, in N. Y.

An examination of this mountain from some commanding point, shows a series of peaks, with their gentler slopes extending decidedly to the west. There is no striking difference, only on close observation it will be readily noticed. The steeper slopes face to the east.*

At Rockland lake the fracture extends nearly to the level of the lake. The higher bluff is on the S. E. The roads which cross the mountain are known as the "Long Clove" and the "Short Clove," and they pass through deep notches in the mountain. No difference in slope can be detected here; but the cloves themselves, being so close together, afford unmistakable evidence of a fracture.

To the west of Great Clove is High Torn. Still farther is Little Torn. The slope from the one to the other is very evident, but is not so great as it appears, since the country, as a whole, gradually rises to the west. As a matter of fact, there is but little difference in the altitude of the two peaks. The Ramapo river and the east and west branches of the Hackensack flow in nearly parallel lines, and all take their origin within the hook of the mountain. The streams flow in the valleys between the most prominent ridges.

There yet remains to be considered the evidences of cross fracture, extending from the southeast to the northwest. In turning the attention to this subject, the most ready suggestion will be the course of the principal streams flowing across the field. The courses of the Delaware, Raritan, Rahway and Passaic rivers, after allowing for all differences, are yet too nearly parallel to be the work of mere chance. The parallelism of the longer axes of the trap ridges is very noticeable, and will be mentioned under the description of the trap. If the attention be now directed to the exceptions to this rule, their singular appearance may be explained.

In the case of the two crescent-shaped trap hills known as Pickles mountain and New Germantown mountain, if two lines be drawn

*This paragraph refers to the Hook proper, trending nearly N. W., S. E. from Rockland lake.

through the longer crests of the mountains, these two lines will be found to cross at nearly right angles, on each mountain, and the homologous sides of the two angles will also be parallel. The lines will be parallel, respectively, to the northeast and northwest lines.

The great bend in Sourland mountain is at right angles to the axis of the wings an either side of it.

The hook on the northern boundary of Rocky Hill has also a northwest by southeast strike. The new map, based on the topographical survey, brings out this fact very clearly. The parallelism between the bends at the northern and southern extremities of First and Second mountains is too evident to need more than casual mention.

The "S" shaped mountain known as Hook mountain may likewise be resolved into lines roughly parallel to each other.

Through First mountain are numerous deep notches through which streams flow. In many of these, as Stony brook notch, at Plainfield, are located trap quarries. Here the rocks are badly broken, and show numerous slickensides, whose direction, normal to the plane of the horizon, shows a vertical displacement. The notches at Little Falls and at Paterson, where the Passaic river breaks through, are marked examples of the point in hand. The Palisades range has many quarries in which vertical striations point to vertical displacement. The Pennsylvania railroad cuts near Jersey City, and the quarries from Weehawken to near Shady Side, are localities where these displacements have been noticed. Perhaps, however, the most striking proof of cross fracture is the following: At Weehawken, southern point near the West Shore railroad's coal pockets, the trap breaks across the heavy beds of black shale. These shales have a gentle dip to the northwest, and finally disappear just above the New York, Lake Erie and Western railroad ferry landing. From this point the gray feldspathic sandstones, more or less disintegrated, crop out on the surface, dipping under the trap, till about one-half of a mile south of Shady Side they disappear and again give place to the black shales.

In these shales, as at Weehawken, are found the estheria ovata and remains of fishes. There is a decided fracture across the trap at this point. If a straight line be drawn parallel to the Palisades, and another at right angles to it at Shady Side, the second line will pass through Great Notch in First mountain, and just a little northeast of the notch at Little Falls, where the Passaic breaks through Second mountain.

The evidences of life, both plant and animal, during the Triassic age in New Jersey, are very meager. Yet such evidence as exists is so positive in its nature as to allow legitimate inference to go far beyond the warrant of facts, and to assume the presence, during this age, of numerous and well-developed genera and species. The traces of plant life are found, not only in the gray decomposed sandstones in the form of thin seams of coal, but often in delicate tracings on the shales and flagging of numerous quarries.

At Trenton, about a mile and a half north from Warren street railroad station, and on the banks of the feeder of the Raritan canal, a seam of coal was found during the summer of 1888. The seam is about one inch thick, and can be traced for a distance of fifteen feet. The seam is in a coarse, gray, friable sandstone. In the quarries, two miles above this place, lenticular, tube-like trunks of various sizes are found, the walls of which are thin layers of coal. So numerous, at times, are these trunks and branches that they ruin a foot or more of the building stone in the stratum in which they occur. No recognized genera or species are found in these rocks. The same may be said for all of the gray sandstone quarries from Trenton up to and including the last quarries at Stockton and Prallsville.

At the flagstone quarries, formerly owned by Smith Clark, at Milford, beautiful plant impressions are very numerous. Many of them may be at once referred either to the cycads or conifers; others are so interlaced and fragmentary as to give no clue to their proper classification. There are, however, in the possession of the Survey, plant impressions from this quarry, of what are evidently conifers. One specimen in particular has a main stem seven inches in length, and several branches four inches long. A fruit, perfectly preserved and resembling a tamarack cone, was found with this last-mentioned specimen. In the quarries near Martinsville stems of plants and trunks of good-sized trees are found with a thin shell of coal preserving the leaf scars. Fan-shaped impressions of leaves of true ferns are occasionally met with.

In the same valley, Washington, two miles further up, a quarry opened by the side of a brook shows the same gray sandstones and with similar plant impressions. Five miles from this point, and in the same direction, is a quarry of gray sandstone, also showing plants. The plants are not as numerous, nor are the stones of the same color, but from certain surroundings the rocks are judged to belong to the

same series as the preceding, but above them, or a little higher in the geological column.

At Little Falls, in the same valley, gray sandstones, with plants, are again found. Other localities are the quarries at Paterson, Bloomfield, Woodside, Belleville and Newark.

In many places along the northwest border of the trias, especially between Bernardsville and Morristown, black, oily-looking shales are found. The bulk of these shales is often an impure coal. So perfectly are coal measures simulated that it has led to the useless expenditure of much money in the search for coal. In the valley near New Providence the same black shales having plant remains are found.

The remains of animals are confined largely to tracks and scattering fragments of bones. Two complete skeletons have been reported discovered in the quarries at Belleville, but none are certainly known to exist. The tracks of reptiles, birds and insects are found in numerous localities.

From the quarries at Milford and Tumble station, on the Delaware, tracks are abundant on the flagging. Reptiles and insects are noted, but the tracks of birds have not been positively identified. The color of the flags is a dark reddish-gray. By far the best locality is the

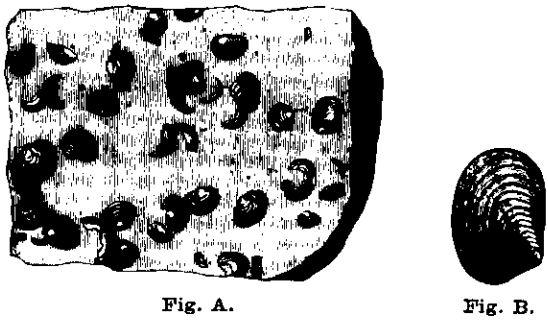


Fig. A. Fig. B.

Fig. A shows the Estheria on the slate as they occur at Weehawken; Fig. B shows an individual, × 3.

one at Whitehall, Morris county. Here slabs have been quarried twenty feet or more in length, and having several consecutive tracks of the same animal. The rock on which these tracks occur is decidedly thick-bedded, and is reddish-brown in color. Fishes have been found at Boonton, on the bank of the Rockaway river. They were very perfect, generally. They have also been found at Pompton Furnace, by a brook which empties into the furnace pond. The locality is on

the land belonging to the Pompton Steel and Iron Company. Imperfect remains have been found at Washington's Crossing (eight miles above Trenton), at Fields' copper mines, in Washington valley (two miles due N. W. from Dunellen, on the Jersey Central railroad), and at Weehawken and Shady Side, on the Hudson river, opposite 42d and 122d streets, New York. Brachiopods or lamellibranches have not certainly been found within the limits of the State. A bivalve shell, which was supposed by the one who found it to be a new species of estheria, was submitted to Prof. C. E. Beecher, of Yale University. Though not well enough preserved to be identified, it was pronounced to be a lamellibranch.*

Previous to this season (1888) the crustaceans found had been restricted to one locality in the State. This locality, at Weehawken, has been known for a good many years. Only one species had been found, the estheria ovata. Nine new localities have been added to the list, one new genus and two species of fossils.

The discovery of the fossils was, in itself, of no great importance, since they added nothing to paleontology, and they are, in general, so poorly preserved as to be recognized with difficulty. As an aid, however, to the identification of synchronous horizons, they are of great importance.

These fossils have been found at the following localities: At Walter's quarry, at Wilburtha, four miles above Trenton, very perfect impressions are found in a thin stratum of argillaceous slate. The stratum is not more than two inches thick, and it carries numerous, but imperfect plant remains. The stratum occurs interbedded between two heavy layers of gray sandstone. At Savage's quarry, one-fourth of a mile above Walter's, the same fossil is found, only not so well preserved. The quarry at this place is confined entirely to black or very dark-gray slates and shales, which weather brick red. No sandstones, proper, are present. The shales are thick bedded, and are interstratified with slates. The shales carry the fossils. Fish scales and spines are found in the same stratum with the estheria, though they are not as abundant nor as perfect as in many other localities.

Washington's Crossing, five miles above Wilburtha, and between the canal feeder and the public road, is the next locality along the Delaware. For nearly two miles only slates and shales crop out at this place. The character of the outcrop is identical with that at

* These fossils were found at Klinesville.

Wilburtha. Fish remains accompany the estheria. The scales are perfect rhombohedrons.

A species of estheria is found at the Pennsylvania Railroad Company's quarry, about one mile above Prallsville. The fossils are here more poorly preserved than at any other locality encountered. While it is probable that the species is not the ovata, there is no doubt of the fossils being estheria. The stratum in which they occur is a micaceous slate, carrying a great deal of fine sand, and is very hard, almost flinty, in texture. The stratum is two inches thick, and occurs between two heavy beds of gray, or reddish-gray sandstone.

No more fossils, save plants and tracks of animals, have been found in the remaining sandstones along the line of the Delaware. The estheria was also found northwest of Flemington, on the Klinesville road, in an abandoned quarry, owned by Robert Thatcher, Esq. The shale carrying the fossil, although differing slightly from that at Savage's quarry, and at Washington's Crossing, is yet essentially the same. No fish remains were found. Associated with the estheria were found a species of cypris, and a lamellibranch, genera and species at present indeterminable.

In Washington valley, near Warrenville, four and one-half miles N. N. W. of Bound Brook, is an old mine known as "Fields' copper mine." In the debris thrown out from the mine are gray slaty shales inclining to black. Remains of fishes are here very abundant and perfect. Several well-preserved specimens of the estheria were found. Nothing could be judged of the stratigraphical relations to the associated rocks, since all were mixed together on the dump. From general appearances, however, it is inferred that the fossiliferous shales belong to the same horizon as those at Wilburtha and at Washington's Crossing.

The estheria and fish-scales were found at Shady Side, December 1st, 1888, on the Hudson river, three and one-half miles north of Weehawken. Evidently the slates are a repetition of those at Weehawken. Two other localities give fossil fishes and crustaceans—near Boonton, on the Rockaway river ("the old fish quarry"), and Pompton furnace. The slates and shales in which they occur, are light gray, and are rather arenaceous. Those at Pompton are much softer and more argillaceous than those at Boonton.

At any of the places mentioned careful search will reveal the fossils referred to, to any one who chooses to look for them. Even under the

most favorable circumstances it is a matter of some difficulty to find the shells. They are so delicate as to be found only in the finest-grained rocks. As the conditions favorable to their preservation do not often occur in a sandstone series, it frequently happens that only a thin stratum is fitted for preserving fossils. In the triassic rocks of New Jersey it invariably happens that only a stratum, no more than two or three inches thick, is the one to be sought for. Bearing this fact in mind, as well as the fact that the shales are often many feet in thickness, it will be readily seen that a careful study of the texture of the shales and slates as a whole, as well as of their individual strata, will be of great assistance to the searcher. These slight differences mean a great deal, rightly interpreted. It would rarely happen that a period of quiescence, except in the case of sheltered bays or coves, would obtain in one part of a limited sea-bottom and not in another; that a fine-grained arenaceous stratum would be forming on one side of an estuary and not on the other, or at least as far as the middle. A limestone formation, however thin or impure, would be apt to extend over the entire area of a given formation. For these reasons, where two strata of rocks, though separated by considerable horizontal distance, yet bear a close resemblance to each other, have similar surroundings, and carry either plant or animal remains, or both, which are practically identical, they are assumed to belong to a synchronous horizon.

It is proposed to arrange the foregoing facts in a system, and to examine them in this light.

Taking the locality at Weehawken as a starting point, and following along the line of the southeastern border of the trias to the Delaware river, a locality is found which agrees in every respect with our starting point. Though the rocks in which the fossils occur on the Hudson are, as a rule, finer grained and more slaty than those on the Delaware, yet the positions of the two are analogous. Each stratum lies in a series of alternating black slates and shales, and each is underlaid by heavy beds of gray sandstone. Both are near the southeastern border of the trias.

Moreover, along this line at Monmouth Junction (on the Pennsylvania railroad), at Rocky Hill and at Princeton are heavy beds of black shaly and slaty rocks which are distinguishable in no way, save by a greater degree of induration and lack of fossils, from those at the localities just mentioned. The fact of these rocks lying in close

contact with the trap at these places, easily explains both the induration and lack of fossils. They also, probably, overlie gray sandstones, since along the banks of the Raritan canal, two miles south of Princeton, are numerous quarries of gray stone.

On the basis of identity of rocks and fossils it will be affirmed that the slates and shales at Washington's Crossing are a repetition of those at Wilburtha. Between this place and Wilburtha there are decided evidences of repeated faulting. In fact, at Savage's quarry there is an indisputable fault. The vertical displacement is thirty or forty feet. Near the middle of the quarry the rocks are badly broken. The crevices are filled with crystals of quartz and calcite. On the floor of the quarry are fine slickensides, both on the slates and on the thin plates of calcite interpolated between the laminæ. The surfaces are finely polished, and the striæ are normal to the line of faulting, just as if the rocks had slipped on their bedding planes. Above Washington's Crossing, no more fossils have been found till Stockton, eleven miles above, is passed. Between Brookville and Stockton, however, the decomposed gray sandstones, too badly disintegrated to be used, crop out prominently in a high bluff facing the river. From Stockton to Prallsville, and so on one mile above to Sillery's and Corcoran's quarry, the sandstone, though coarse and very feldspathic, is yet excellent for certain purposes. It is gray, has crystals of fresh flesh-colored feldspar, together with the same pebbly layers as those at Wilburtha.

In addition to the similarity of texture and lithological characters, the occurrence of a thin, fossiliferous stratum of micaceous shale, between two beds of gray sandstone, lends additional probability to hypotheses of the repetition of the Wilburtha series of gray sandstones by deep faulting. Above Sillery's no sandstone appears on the surface till the station of Raven Rock is passed. At this place a small quarry of reddish or pink sandstone, similar to the layers on top of the quarries at Prallsville and Wilburtha is found. At Byram is a quarry of what is locally termed "bluestone." It is quarried broken and used as road metal. This bluestone is nothing more nor less than a heavy bed of shales, which have been baked into fine jaspery rock. The position of this series of slates and shales, with respect to the gray sandstones, is identical with the black slates and shales at Wilburtha. That is, the distance from the outcrop of the gray sandstones above Trenton to the shales at Wilburtha, is equal to the distance of the outcrop of the gray sandstones at Stock-

ton to the "bluestones" at Byram. Fossils would, no doubt, have been found at this latter place, had not the intense metamorphism destroyed all traces of them.

Moreover, the contour of the country about Byram is very noticeable. Going in a straight northeast line from Byram station to a point of the Lehigh Valley railroad above Flemington Junction, a high range of hills, with an average altitude of five hundred and fifty feet, will be on the northwest. The steepest slope faces southeast. At the northeast extremity of this range lie the slates and shales at Klinesville, in which the fossils are found. Aside from these very striking facts, there are others, which lend additional plausibility to the hypothesis that this range of black slates has been thrown up by faulting. The trap outflow at Byram, though limited in extent, yet follows northeast along, or just above, the bed of a stream for a considerable distance. Trap appears in the vicinity of Flemington, gray sandstones appear at Klinesville, and just across the South Branch of the Raritan, another series of trap rock appears to indicate a profound fracture with consequent disturbances of superficial strata.

Though out of the province of the State Survey, the country was explored for a distance of twelve miles to Neshaminy creek, Bucks county, Pennsylvania. This was done for the purpose of tracing the line of apparent fracture and elevation, extending from near Stanton, on the Lehigh Valley railroad, and striking the Delaware between Lambertville and Stockton.

As has been already mentioned, the gray sandstone (Series I.) appear overlying the silurian limestones at Lime Port, Pennsylvania.

Following the limestone valley from near Center Hill, Pennsylvania, and on the eastern boundary, is a very conspicuous hill of quartzite of undoubted Potsdam age. Still east of this, appear the sandstones which belong to the second series.

Just before reaching Neshaminy creek, near Bushington, the elevation disappeared, and the sandstones of the second series appeared.

The course of the stream at this point is parallel to the Delaware river.

From these facts it will be seen that a cross section (running N. W. by S. E.) would be identical with a cross section through Klinesville, and running also N. W. by S. E.

The trap rocks, which are so characteristic of the trias, are abundantly developed in New Jersey. Since there is such a remarkable

division of the traps of the sandstone area by the valley of the Raritan, they are here referred to as the northwest and southwest traps. The northwest series includes the Watchung and Palisades mountains; the southwest, Pickles mountain, Sourland mountain and Rocky hill. Beginning with the great trap ridge on the Hudson river known as the Palisades, they will be described in order, going northwest.

The northeast terminal of the Palisade range is in Rockland county, New York, near Ladentown. This point is two miles N., 50° W. of Nyack-on-the-Hudson. From here the range runs northeast about three miles, when it turns southeast for a distance of about eight miles, when it meets the Hudson river at Haverstraw. Here the trend of the range again changes to northeast-southwest. With the exception of a trend to the west, which the range makes at Nyack-on-the-Hudson, it continues in a straight line, nearly, following the course of the Hudson to Weehawken, New Jersey. Here the trap narrows, and permits the gneisses to appear between it and the river at Jersey City. The same trap appears on Staten Island, where it ends at the Staten Island sound, just north of the point where the Fresh Kill joins it.

West of the Palisade range, are the Watchung mountains. The first is known as First mountain. It begins near Darlington, a point four and a half miles northeast of Oakland, a station on the New York, Susquehanna and Western railroad. From Darlington, the direction is southwest to a point about one mile southwest of Oakland. Here the direction changes to the southeast for four miles. Directly west of Midland (railroad station, New York, Susquehanna and Western railroad), the direction again is southwest. This direction is followed in nearly a straight line for thirty-six miles to Bound Brook, on the Lehigh Valley railroad, seven miles northwest of New Brunswick. At this point the ridge changes abruptly to a northwest trend for six miles, and ends one mile directly south of Pluckemin.

The Second mountain of the Watchung range begins near Pompton Furnace. It runs southeast for seven miles, or to near Paterson, about one and a half miles west of the city. It follows, from this point, a direction parallel to the First mountain, for a distance of about thirty miles. At a point a little north of west of Bound Brook it turns to the northwest, still parallel to the First mountain, to one mile north of Pluckemin. Here the direction changes to northeast, runs a distance of seven miles, and ends near Bernardsville, Somerset county.

The third range of trap (the Third mountain of the Watchung) is not continuous, at least it does not show continuously on the surface. Different parts of the range are known as Hook mountain, Riker's hill and Long hill, respectively. Hook mountain begins at a point about one mile directly east of Pompton, or one mile east of Pompton station, on the New York and Greenwood Lake railroad. It is an "S" shaped mountain, with its northern concavity opening to the northwest, and with its southern concavity opening to the southeast. Riker's hill, which appears to be closely related to the Hook mountain, begins at a distance of three miles from the southern terminus of the Hook mountain, and runs parallel to Second mountain, for a distance of three miles. After an interval of four miles is passed, the northeastern extremity of Long hill appears. This hill extends W. S. W. for a distance of eleven miles, and terminates about two miles northeast of Liberty Corner.

The longer axes of the trap ranges just mentioned are not straight lines, but are long, easy curves, with their convexities facing the southeast. It may not be amiss to anticipate a little. Not only is it true of these ridges, but it is also true of the traps confined to the southwestern field of the trias. It is true, even to the smaller isolated masses of trap, which push through irregularly, and with no visible connection with other outbursts.

The next long ridge of trap lies in the southwestern division of the trias. It begins at a point on Lawrence's brook, six miles south of New Brunswick. The larger axis of this ridge, while it trends northeast by southwest, makes only a small angle with the east and west line. Its length is about eighteen miles. Its southwestern terminus is near Hopewell station, on the Delaware and Bound Brook railroad. Along a southwest prolongation of the major axis of Rocky hill, two minor outcrops of trap appear on the New Jersey side of the Delaware, and one just across the river in Pennsylvania. Though there is no apparent connection between these outflows, there can be but little doubt of their being located on the same fracture.

Near Neshanic, a station on the Lehigh Valley railroad, the last of the long trap ridges begins. It is known as Sourland mountain at its northeastern extremity, and as Goat hill, on the Delaware, near Lambertville. It extends in nearly a straight line, for a distance of sixteen miles in New Jersey, and it reaches across the Delaware into Pennsylvania. It has been explored for only a few miles, outside of the State limits, by this Survey.

This is the last of the long ranges of trap. Besides these ridges there are fifteen isolated trap outflows of varying areas. One of these is located on the Delaware, four miles south of Lambertville, and in close proximity to the terminus of the Rocky hill axis. The next is located three miles above Lambertville. It is but little larger than the last-mentioned place, reaching back from the river only about a mile. The next outflow of trap is too small to be placed on the maps. It is known as the Point Pleasant trap, in the previous reports of the Survey. It is about four miles above Stockton. It is very evident, in spite of its limited outcrop, that it is by no means an unimportant one. Its effect on the shales which overlie it has already been noticed. Reference has been made to the fact that it is also in a northeast line which passes through Round and Pickles mountains. The trap boss at Flemington is but little removed from this line. Both Round mountain and the Flemington trap are too limited in extent to require more than a passing notice. Pickles mountain, however, is of a little more importance. It is the only trap in New Jersey, both of whose extremities lie outside of the trias. From Stanton, on the Lehigh Valley railroad, it extends due northeast to White House, on the Central Railroad of New Jersey, three miles away. At this point the mountain turns at right angles, and terminates one mile above Lebanon (Central Railroad of New Jersey), four miles from White House.

Six miles from Pickles mountain another crescent-shaped hill appears and is known as New Germantown mountain. From the linear arrangement of these last-mentioned trap areas, and also from the parallelism of this line to the general trend of the formation, it is assumed that these are also located on one and the same line of fracture.

A small outcrop of trap is noted near Blackwell's mills, on the Millstone river. Another small hill lies between Ten Mile run, on the Trenton turnpike, and Griggstown, on the Millstone river. About one mile southwest of New Brunswick the Pennsylvania railroad cuts through a small outcrop of trap. On the Raritan river, at Martin's dock, two miles from New Brunswick, trap rock appears intruded between some of the strata of the red shales and breaking across others.

Near the point where the New York and Greenwood Lake railroad crosses the Hackensack river, two hills of trap appear on the

left bank. These are known respectively as Snake hill and Little Snake hill.

The next isolated trap area is located on the northwestern border near Whitehall. It is flat, low-lying, being only a few feet above the level of the surrounding country. It rests on the Archæan rocks. Southwest of Morristown, about two miles, are two slightly-curved trap hills, with their larger axes lying at right angles. They have no visible connection.

The last isolated trap lies about two miles northeast of Bernardsville. It rests on the Archæan.

In composition the rocks present a wearisome monotony. They are diorites with no mica and little quartz. They usually have more or less angite, and would thus be called angite diorites. The "Point Pleasant" trap (Byram's station, Belvidere division, Pennsylvania railroad) at first sight appears to be of a different nature. The only difference, however, is that the hornblende is of a much lighter color. The weathered rock forms a brick-red soil, as usual.

In texture, the rock varies greatly in the same eruptive mass. Lambertville will furnish a good typical locality. The outcrop here is known as Goat hill. Its width on the Delaware is about one mile. On the upper (Lambertville) side, the trap appears only shortly removed from its contact with the sandstone through which it breaks. At this point it is a dense, hard, dark oil-green rock, which rings under the hammer, and breaks with a sub-conchoidal fracture. It is aphanitic. Approaching the center, porphyritic crystals of feldspar and hornblende appear microscopically, and at length the whole crystalline structure becomes apparent to the naked eye. Cavities, into which project well-defined crystals of feldspar and fibrous tufts of hornblende, are numerous. The rock, broken, shows long-bladed crystals of hornblende two, or even three, inches in length.

The proportions between hornblende and feldspar vary. Patches occur in which hornblende is nearly or quite replaced by the feldspar, and *vice versa*. The rock everywhere decomposes to a brick-red, tenacious, clayey soil. In Long hill, First and Second mountains, the rock is very amygdaloidal. The cavities are sometimes very large. The cavities would average in size that of a large pea. Long cylindrical tubes, of a diameter of one-eighth to one-fourth of an inch, and from three to six inches in length, are observed frequently. These cavities are usually filled with zeolitic minerals. As only surface rocks have been examined, the species of mineral cannot be

determined. At Long hill, however, and on First mountain, at Paterson, the amygdaloids approach grapes in size, and are then often filled with crystalline quartz, usually amethyst, and the "chalcedonic" (Dana) varieties, such as agates, chalcedony, onyx, &c.

Beautiful zeolite minerals are found in great abundance lining the walls of fractures, and large steam pores, in the Palisade range. Some of the finest specimens known have been taken from the various tunnels which pierce the Palisade range near New York. The State Museum has fine specimens from this locality. Fine specimens are also on exhibition at the New York State Museum, at Albany, N. Y.

The cavities containing the minerals, whether caused by fracture or by gas, are not confined to the upper surface of the rocks. At O'Rourke's quarry, in Orange, and at other quarries, cavities are found on the *under* surface of the trap which is in contact with the sandstone.

The effects of the intruded trap are very noticeable in many places. In the vicinity of Byram, Princeton, Rocky Hill and Monmouth Junction the fine-grained slates and shales have been so thoroughly indurated as to have the appearance of basanite. At Weehawken and at Shady Side, the slates are not baked as hard. The rock, thus changed, rings under the hammer and breaks with a conchoidal or sub-conchoidal fracture. Numerous other localities might be cited where there has been evident alteration to a greater or less degree. The numerous traces of copper ores, together with the frequent occurrence of native copper itself, accompanied with more or less change of texture, bears ample testimony to the close proximity of trap rock, even when it is not visible.

New Brunswick is a good example in point. Large masses and sheets of copper have frequently been found in excavating through some of the streets. These are found in the shales, and the shales themselves are often thickly coated by, or impregnated with, the green and blue carbonates. The oxides and sulphides are present, but in smaller quantities. Few mines have ever been worked, though openings are very numerous where search for ore has been made.

The intrusive nature of the trap is still further shown by its effect on the overlying sandstones. At Lambertville, the sandstones which overlie the trap, in addition to being baked very hard, are filled with good-sized, well-crystallized black tourmaline crystals. In a quarry from which foundation-stones are taken, large nodules of epidote are very numerous.

Epidote and tourmaline have been observed in the sandstones at Rocky Hill. On the rise of the land to the west of Ten Mile run, the fine-grained sandstones have a peculiar mottled appearance. These spherical nodules are often found to be composed of some radiated micaceous minerals, probably a decomposition product. It is well to note that in many cases where the shales are modified by heat, no superficial disturbance, beyond the usual dip, can be observed.

Reference has already been made to a series of conglomerates on the northwest border of the trias. These differ very essentially in many respects from the other triassic rocks. They are composed of lime and quartzite pebbles, in varying proportions.

After passing the high vertical bluffs on the Delaware, above Milford, known as "Pebble Bluffs," the country, though rolling, is far more even and gentle in its contour. The red shale here begins again, and holds its own till within one mile and a half of the road to Spring Mills.

At this point begins a rock locally termed "Honeycomb," on account of the great number of angular cavities which it contains. One surmises at once that this peculiar appearance is due to the dissolving out of limestone pebbles. Breaking a large, fresh-looking rock confirms this idea.

Though a continuous outcrop was not to be found, yet, from occasional glimpses, the nature of the rock appeared to be undergoing a gradual transition to the pure lime conglomerate found on the border. This conglomerate, including the honeycomb, has a frontage of about one and a half miles, and it reaches along the Archæan border to a school-house just west of Spring Mills. The dip of this rock is conformable to the trias generally.

No pebbles of Potsdam sandstone were found. Fresh pebbles of a flesh-colored feldspar were found in the honeycomb rock.

No other locality of this conglomerate appears till the New Germantown quarries are reached. These are situated between Lebanon, on the Central Railroad of New Jersey, and New Germantown. Several quarries are opened about one mile northeast of Lowe's hotel. These quarries are operated to supply lime for the neighboring farms. This belt extends along the road towards Pottersville, and north of New Germantown. This rock is in no way distinguishable from that of the first locality. It cannot be traced beyond New Germantown,

with the exception of a locality at Pompton. A third locality lies in New York State, along the Mahwah river, four or five miles above Suffern's, a station on the New York, Lake Erie and Western railroad. It lies on the Haverstraw road. This quarry is made up largely of boulders, very angular, and from one foot to four or five feet in diameter. The cementing material is lime, though red shale mud is very abundant.

From this point on to Haverstraw, numerous outcrops of conglomerate appear, carrying more or less limestone. It is usually very coarse. It continues to the Hudson river, at Stony Point, where the New York, Buffalo and West Shore railroad cuts through the formation. A high bluff or precipice, on the banks of a stream south of Stony Point, is also a lime conglomerate, principally.

The conglomerates at Pompton Furnace, and at Paterson, also have lime pebbles, but not enough to especially characterize the rock in which they occur. By far the most interesting conglomerates, from a geological standpoint, are those which lie between Boonton and a point two and a half miles west of Pequannock (a station on the Greenwood Lake railroad).

The two planes on the Morris canal, between Boonton and Montville, are located on a gneiss conglomerate. No trap pebbles were found at either of these planes. The rock is composed chiefly of gneiss pebbles, more or less decomposed. The mass is very loosely cemented. In fact, no trouble is experienced in loosening any pebble from its matrix with an ordinary hammer. One-fourth of a mile northeast of where a branch of the Rockaway river is crossed by the public road at Montville proper, a road turns to the east and crosses the canal. One-eighth of a mile from this corner, on the south side of the road, a bluff of conglomerate appears.

At first sight this rock is in no way distinguishable from the rock at the planes. A closer inspection, however, reveals pebbles with the peculiar appearance of decomposing diorite. A blow from a hammer shows them to be such. The trap bears a considerable proportion of the entire rock mass, and it is, probably, much greater than it appears, for a goodly part of the interstitial matter is trap sand. The bulk of the remaining pebbles is gneiss or some micaceous rock and occasional quartzite pebbles. This conglomerate can be traced continually to within about one mile of its northeast boundary. At this point is an outburst of trap which is only slightly above the level of the sur-

rounding country. The point where the next conglomerate appears is about one mile northeast from the trap first mentioned. It is hardly distinguishable from a trap dyke, on account of its meager exposure, and largely owing to the fact that even this exposure is almost hidden by the grass growing between the pebbles, rooted in the decomposing rock which fills the interstices. The rock, however, is a real conglomerate, and is made up almost entirely of trap pebbles and boulders. They are sub-angular, not rounded. Only the gneisses and quartzites have this appearance.

The dip is the same as that of the lime conglomerate, and also of the trias. There are numerous pebbles which are in the possession of the Survey, both of trap and gneiss, which were taken from the rock. An examination of these specimens will remove all doubt as to the nature and composition of the rock. The localities themselves are very easily accessible.

There is one peculiar feature of these conglomerates which makes them readily noticeable. While the majority of the sandstones of the trias have their higher crests arranged in axial relations, one to another, and a decided pitch to the northeast, these hills are more like rounded knolls or bosses. The slope is about even on either side. If there is a longer axis to the hills it is at right angles rather than parallel to the main trend of the trias. This gives to them more the appearance of foot-hills to the Archæan. This feature of their topography is very noticeable, especially looking west from Pompton Plains. Further to the southwest this feature becomes less prominent, on account of the general rise of the whole country to a higher plane. It is also unnoticeable at the conglomerate locality at Suffern's, N. Y.

No reference has, thus far, been made to the age of these conglomerates, relative to the lower series, though, from the fact that trap pebbles are present, it would be inferred that these rocks, at least, are younger than the trap. The traps are certainly younger than the sandstones, and from this it would follow that these conglomerates are somewhat younger than the rest of the trias. Yet, as has already been stated, no distinction in the dip, either in direction or magnitude, can be detected. This would seem to indicate that the sandstones and conglomerates were conformable, and that the disturbances which threw the sandstones into monoclines affected the conglomerates in like manner. From facts collected it is evident that the sandstones had, to some extent at least, been forced into their present position before the erup-

tion of trap took place. It is just as evident that this disturbing force did not cease its activity with this eruption, since the traps are broken in a northeast-southwest direction, and along a line at right angles to this. The cloves, High Torn and Little Torn, on Hook mountain, near Haverstraw, N. Y., are the evidences of the one; the breaks across First and Second mountain by Stony brook, and by the Passaic river, of the other.

If, now, the lime conglomerates are of the same age as the trap and gneiss conglomerates, and there is no reason to doubt it, the period of time covered in the building up of this upper series must have been very limited. This is inferred from the fact that the thickness of the series does not exceed, if it equals, five hundred feet; and from the fact that the lime pebbles are only sub-angular, or, in some cases, are a real breccia. The same it true of the pebbles and boulders of trap.

It is certain, therefore, that these conglomerates must have been formed between the periods of time subsequent to the eruption of the trap and that marked by the cessation of the force which gave the whole trias its dip and pitch, and lifted it above water-level. The fact of the presence of trap pebbles requires that the conglomerates must be considered as the youngest rocks of the formation, while the conformability indicated by similar relations to a horizontal plane makes them, by the laws of conformability, a member of the Triassic group. There is no evidence of a long period of time separating them, but rather that the one passed into the other by an easy gradation.

Finally, in seeking for a confirmation of our hypothesis from other than internal evidence, the attention is directed towards the Archæan "Highlands" of the State. It is assumed that from this, the oldest formation, we can at least learn something to aid us.

Though the final work on the geology of this section has only been begun, yet the work of previous years, and embodied in former reports, is exhaustive enough for the purpose in hand. Even were this not so, the completion of the topography of the State and the excellent physical description accompanying it,* furnish us a key to its stratigraphy. In the plate opposite this page, accompanying this report, the course of all the principal drainage streams, including that of the Delaware, is given, unincumbered by other topographical features. A glance will show a strikingly simple system of classifica-

*See the Report of the Topographer of the State, C. C. Vermeule, C.E. Final Report Geology of New Jersey, 1888, Vol. I.

tion. With scarcely an exception, all of the streams in the northern section of the State, including the trias, can be arranged parallel to one of two straight lines at right angles to each other. The direction of these lines is from the northwest to the southeast, and from the northeast to the southwest, respectively.

The topography of the country is just what one would expect from its lines of drainage. The larger streams represent valleys, and flanking these valleys are ranges of hills or mountain crests, arranged in the same linear direction. The Delaware, from the Water Gap to Port Jervis, N. Y., Paulins Kill, the Wallkill river, Beaver and Pequest, Lopatcong creek and the Musconetcong river, all have easy slopes reaching down to their banks. Leaving the Archæan and looking at the trias, its larger streams, many of them, have a similar course. For instance, through a part of their courses, at least, the Raritan, the Passaic, the Ramapo, Pompton and Hackensack rivers all run parallel to this northeast trend of the Archæan.

Reference has already been made to the trend of the sandstone ridges, but special attention is asked to the trend of the eruptive rocks which is given on the same plate with the rivers. Irregular as they may appear, there is yet a conformability to the facts thus far classified that is worthy of more than a passing comment.

Eruptive rocks always come to the surface through great fissures in the earth's crust. That these great fractures exist in the Highlands of New Jersey can be shown to any one who cares to see. So well known is this fact it is superfluous to state it. Is it, then, too much to assume that the same fractures exist in the Archæan floor of the trias and that these trap ridges are but the manifestations of an otherwise hidden fact?

Further, there remain to be accounted for the strange crescentic forms that accompany many of the trap outbursts. Again recourse must be had to the Archæan for final confirmation of our hypothesis.

From the Water Gap to Bordentown the Delaware changes its direction from southwest to the southeast. In this change it is not alone. Wholly or in part the South Branch of the Raritan, the Raritan proper, the Passaic, the Rahway, the Rockaway and the Pompton rivers all follow this same direction. But this difference is to be noted: These rivers represent no valleys flanked by ranges of gently-sloping hills, but, instead, deep, narrow gorges, for the most part, in the Archæan, and with but narrow valleys in the trias.

Noting the special topographical features which accompany these phenomena, we find that the trend of these ranges of hills is not one unbroken line, but that this line is divided by a series of crests or high points. These mountain crests have a gentle slope and a steep slope. The steeper invariably faces the southwest, while the gentler falls away to the northeast, at an easy angle of about 20°. An examination of these steeper faces, often precipitous, shows that the rock has been fractured profoundly, and that from this division plane the whole series has been pitched from a horizontal line. The consequence is, that the drainage area of these fractures is limited, the streams are smaller, and their courses are dark gorges, rather than broad, sunny valleys. This obvious difference between streams flowing in these directions, at right angles, has led to the adoption of some term expressing the idea. And so the engineers engaged in the State Survey referred to the valley of the Musconetcong or the Wallkill and to the "Clove" of the Delaware (below the Water Gap) or of the Rockaway. Again, placing side by side the known facts of the Archæan with the known facts of the trias, they fall into line, the one with the other.

The major axes of these crescents are parallel to the course of many of the streams of the trias, and these streams, as we have seen, are directed by the evident fractures in the Archæan. Again, is it not warrantable to assume that these fractures extend across the Archæan floor of the trias, thus forming lines of weakness through which these eruptions have taken place?

In the Archæan, the question is argued from known causes to known effects. In the trias there are known effects or facts which in many respects are similar to the facts forming the premises in the Archæan. There can be, therefore, little hesitation in assuming a similarity of causes.

Thus arranging the salient features of the trias, no violence is done to any recorded fact, but by so doing, a system is formed into which more facts can be harmoniously arranged than by other systems thus far suggested.

Moreover, in this way a step is taken towards geological unity in thus making the one and the other mutually supporting. And two formations so distinct in time, in individual appearance, and in the possession and evidences of life, are shown to be closely related through the force which lifted each from the depths of the ocean and thrust it up into mountain, and valley, and plain.

II.
DRAINAGE.

PEQUEST DRAINAGE.

The drainage of the Great Meadows, on the Pequest, in Warren county, continues to show the great agricultural and sanitary benefits which were expected when the plan of the improvement was prepared under the direction of this Board. The extent of cleared ground is increasing every year, and the crops grown upon it are enormously large. These include Indian corn, rye, oats, timothy hay, potatoes, onions, celery and other garden crops, and all of them are produced without manure, and in quality and quantity quite as good as those grown upon the richest and most highly-manured garden soil. From 70,000 to 80,000 bushels of onions have been grown upon the meadows this year, and the fertility and value of the drained land is all that its most sanguine friends anticipated.

The season has been a very wet one. Nearly fourteen inches above the ordinary rainfall has fallen this year, the whole amount being fifty-eight inches, while the average for many years is forty-four.

During most of the heavy rains the channel of the Pequest has proved large enough to carry off the water as fast as it fell. There were a few days in which this was not the case—the stream overflowed its banks, and a portion of the lowest part of the meadows was covered with water, and many thousand bushels of onions were spoiled.

The overflow of the banks, even in this extreme case, was confined to the southwest end of the meadows, and nearest to the village of Danville. The outlet from the meadows in the present choked condition of the channel, is insufficient to carry off the water as fast as it accumulates in the stream as it flows through the flat and drained lands of the former swamp and marsh. The original plan of drainage required the channel of the Pequest to be made thirty feet wide on the bottom, and the sloping banks to widen out on each side one

and a half feet for every foot above the bottom; and it required the bed of the stream, as it passed through the hard ground near Bulgin's bridge, to be deepened about five feet. This would make the breadth of the stream five feet above the bottom, to be forty-five feet wide. The grade or fall of the channel was to be one foot per mile, which was calculated to give the stream a velocity of ninety feet per minute, and when cleared out, to be sufficient to carry off the water from the heaviest rains without overflowing its banks. And when first done it did all that was promised for it. It flowed with an even current, and a velocity of 100 feet per second, and there was no overflow for several years.

The occurrence of an overflow the past autumn, led to an examination of the present condition of the stream and its banks.

This examination was begun on the 19th and 20th of December, when from a heavy rainstorm the banks were entirely full.

The examination began just above the Lehigh and Hudson railroad bridge across the Pequest, a short distance northeast of Great Meadows station. The stream was only thirty-two feet wide. The railroad crosses the stream obliquely on a pile bridge. It has seven bents of four piles each, and these bents, not being in the direction of the current, together act as an obstruction to the free flow of the stream. A little below the railroad bridge the stream at the surface was only thirty-five feet wide, and bushes growing down the banks on both sides leave only twenty feet of clear water space between them. There is a bend in the stream here, and a sand-bar in forming has caused this narrowing of the channel. The road bridge near Mr. Bulgin's house is only thirty-two feet between the abutments, which is seven or eight feet less than it ought to be. The water, on the 20th, was flowing thirty feet per minute faster below this bridge than it was above it.

At a short bend to the right in the river, just below Bulgin's bridge, the channel is only twenty-five feet wide, and much obstructed by bushes and trees above the bend. Perhaps a quarter of a mile further down a stone dam was built by Simon Cummins, which extended obliquely out from the right bank nearly to the middle of the stream, for the purpose of preventing the bank from being cut away by the current. This has been mostly taken out, but there is enough left to make a decided obstruction to the flow of the water. From this point on down, the only noted obstructions are from the narrowing of the stream by the growth of bushes and trees in the slopes of the banks,

and the accumulation of earth behind them, until a point is reached which is about 150 yards above the road bridge at Vienna; and the velocity of the stream was uniform and 165 feet per second. At the point just mentioned a V-shaped wall has been built across the stream to form a fish-weir. This makes a serious obstruction to the flow of the water, backing it up and making a very plainly marked fall over it.

At the Vienna bridge the velocity of the stream was 160 feet per minute above, and 175 feet per minute below the bridge. The space between the bridge abutments is forty feet wide.

About a third of a mile below Vienna bridge the velocity of the stream was 195 feet per second, and the channel is much obstructed by trees and a sand-bar.

At the bridge next below that at Vienna, the water was seven inches higher above the road than it was below, and the velocity of the stream above the road bridge was only 140 feet per second.

An examination of the stream between the Long bridge and Bulgin's bridge was made on the 28th of December, when the water was much lower. At Long bridge the opening between the abutments is thirty-three feet, and the velocity of the water was 144 feet per minute.

About three-quarters of a mile to a mile below Long bridge the stream is much choked by fallen logs, extending wholly or partly across the channel, in four different places. And a short distance further down, a log is wedged between the banks so as to form a slight dam.

At a private bridge just below the junction of Bear creek, the velocity of the stream was 138 feet per minute, and the stream was here thirty-two feet wide. The general width from Long bridge to this point was thirty-five feet.

Just above Post's island there is a bad obstruction, caused by a fallen tree with drift-wood lodged against it. At a private bridge just below Post's island, the velocity of the stream was taken, and was found to be 156 feet per minute.

The water in the stream had fallen very much between the two days of the examination. The fall at Bulgin's bridge was 2.39 feet, and at Vienna bridge it was 1.55 feet.

The obstructions found are quite enough to account for all the damage done. And they show, too, the need for a constant and systematic oversight of the channel, and regular arrangements for the

prompt removal of all hindrances to the flow of water. If the channel was cleared out to its proper depth and width, from above the Lehigh and Hudson railroad bridge down through the bridge below Vienna, there would be very little danger of an overflow in times of freshet. The law to enable the owners of swamp or meadow ground to drain the same, passed November 24th, 1792, with its supplements, and the act of March 23d, 1888, entitled "A further supplement to an act entitled 'An act to provide for the drainage of lands,' approved March 8th, 1871," also provides the proper means for clearing out of streams, and the large interests involved require that these laws should be put in operation.

PASSAIC DRAINAGE.

The plan for the drainage of the lowlands on the Passaic river and its branches, immediately above Little Falls, which was prepared in 1872, and has been delayed, for financial reasons, until the present time, is now ready to be carried through. The Beattie Manufacturing Company, who are the owners of the water-power at Little Falls, have come to an amicable agreement with the commissioners, by which the mill-dam is to be lowered, and large waste-gates put in it, which are to be opened when a rise in the stream shows it to be needful. The channel through the gorge, below the dam, is to be deepened, the rock-reefs above the dam, and the earth-bar at Two Bridges, are to be taken out, and a new cut across the neck of a great bend at Pine Brook is to be opened. With these improvements made, it is expected that the freshets, which have damaged so much property, and been so injurious to public health, will no longer occur. The legislation in regard to drainage, and the plan to be carried out, will be found further on in this report.

LAWS RELATING TO DRAINAGE.

An Act to provide for the drainage of lands.

1. BE IT ENACTED *by the Senate and General Assembly of the State of New Jersey*, That the board of managers of the geological survey, on the application of at least five owners of separate lots of land included in any tract of land in this state which is subject to overflow from freshets, or which is usually in a low, marshy, boggy or wet condition, shall be and hereby are authorized and empowered to examine such tract, and if they shall deem it for the interest of the public and of the land-owners to be affected thereby, they are further authorized from time to time to make surveys of any such tract or tracts of land, and to decide upon and adopt a system of drainage for draining the same, and to cause maps of the same, together with the plans of drainage by them adopted, to be made; and for this purpose they shall be authorized to call in the assistance of the state geologist and such other persons as they may deem expedient, and when they shall have completed their said surveys, maps and plans, they shall make a written or printed report of the same to the supreme court of this state; and thereupon it shall be the duty of the said court at the same or next stated term thereof, or as soon as can conveniently be done upon reasonable notice given to that effect and published in a newspaper circulating in the county where such tract of low lands is situate, to appoint three commissioners (not interested in the lands to be drained) to superintend and carry out the drainage of any particular tract or tracts aforesaid, whose duty it shall be to carry out and execute the system of drainage which may thus have been adopted and reported by the said board of managers in reference to said particular tract or tracts; *provided*, that if, at the time fixed for such appointment of commissioners, it shall appear to the court by the written remonstrance of the owners of a majority of the said low and wet lands, duly authenticated by affidavit, that they are opposed to the drainage thereof at the common expense, then the said court shall not appoint such commissioners as is directed in this section.

2. *And be it enacted*, That the said commissioners, before entering upon their duties, shall take an oath before the chancellor or a justice of the supreme court, faithfully to perform the duties of their office,

and shall cause the same to be filed in the clerk's office of the supreme court, and shall thereupon have full power to cause the said tract of land, for the drainage of which they shall have been appointed commissioners, to be drained in accordance with the general plan of the said board of managers; and for that purpose the said commissioners, and all contractors or other persons employed by them or under their authority, shall have power to enter upon any lands for the purpose of executing the requisite work or procuring materials therefor; and after the completion of said work, the expense thereof and of all materials used therefor, including the compensation of said commissioners (estimated at the rate of five dollars per day for every day actually employed), and also the expenses of the said board of managers, shall be made up by said commissioners and returned to the said supreme court in a report to be made by them, together with a general outline, description or delineation of the lands and territory which, in their judgment, ought to contribute to the said expense; notice of which shall be given in some newspaper or newspapers circulating in the vicinity of said lands, for the space of four weeks, at least once in each week, in order that any persons interested may examine said report and, if they see fit, file objections to the same; if any such objections, duly verified on oath, be filed within said period of four weeks, the supreme court shall determine upon the same in a summary manner and with as little delay as possible, and shall thereupon, without further notice, make a rule or order directing the said commissioners to distribute and assess the amount of said expense and interest upon the lands contained within the territory reported by them originally, or as corrected by the supreme court, in proportion, as near as they can judge, to the benefit derived from said drainage by the several parcels of land to be assessed, and in making said assessment the several parcels of land assessed may be designated by the name of the owner or occupier, or in such other manner as may be most convenient in each case, and the assessment may be made either upon each separate parcel in gross, or at a rate per acre, and the assessment made upon each parcel of land, with lawful interest thereon, shall be a lien upon the said parcel of land without regard to whom the owner or owners of said land may be; and when the said assessment shall be completed, the same shall be deposited in some convenient place for inspection by the parties interested; and notice of the completion of said assessment

and of the place where the same shall be so deposited, shall be given in at least two newspapers circulating in the vicinity of said lands and published at least once a week, for six weeks, which notice shall designate a time and place when and where the said commissioners will meet to hear objections to said assessment; and the commissioners having heard and decided upon such objections as shall be made to them, they shall proceed to complete their assessment and shall file the same in the clerk's office of the supreme court, and a copy thereof, or of so much of the same as shall be made on lands in any one county shall be filed in the clerk's office of said county, and notice of the filing thereof shall be given in at least two newspapers, circulating as before mentioned, once a week for at least four weeks, after which, if no objections be made to the assessment, the same shall be confirmed and made absolute by the supreme court; if objection to said assessment be filed in the said period of four weeks, the supreme court shall hear and determine said objections in a summary manner and with as little delay as possible, but they shall not reverse said assessment, or any part thereof, except for some error in law or in the principles of assessment made or committed by said commissioners; if for any such cause the said assessment, or any part thereof, shall be reversed, it shall be again referred to the said commissioners to be corrected in accordance with the decision of the court in that behalf, and when corrected and filed as before, four weeks' notice as aforesaid shall be given thereof, after which, if no objections be made, the said assessment, as corrected, shall be confirmed; but if any further objections be made, the same shall, from time to time, be considered and determined as before, until the court shall finally confirm the assessment as duly modified and corrected; and when said assessment be finally confirmed, the said commissioners shall give public notice in two newspapers circulating as aforesaid, once in each week for four weeks, requiring the several owners or other parties interested in the lands assessed, to pay the assessment thereon at such time and place in the vicinity of said lands as shall be designated by the commissioners, at which time and place the said commissioners, or one of them, or some person or persons by them appointed, shall attend to receive the said assessments.

3. *And be it enacted*, That if the assessment on any parcel or parcels of land be not paid at or before the time mentioned in the said notice for paying the same, the commissioners are hereby authorized and

empowered to employ and authorize an agent or agents to demand and receive the assessments which may be so unpaid, together with the interest thereon, and two per centum commissions for collecting the same; which agent or agents shall proceed to demand of all persons whose lands shall be assessed, and whose assessments shall be placed in their hands for collection, so far as such persons may be known, and may reside in the county in which such lands shall be situate, and not incapacitated to transact business; but if the owner of any such lands shall not be known, or shall not reside in said county, or cannot be found by said agent or agents, or shall be under age, insane or otherwise incompetent to transact business, or if, on being found, and such demand being made, he or she shall neglect or refuse to pay such assessments, with interest and costs, the said commissioners shall be and they are hereby authorized and empowered to sell said parcel of land for the least number of years that any person will take the same, and pay the assessment thereon, with interest thereon; and the cost and expenses of such sale shall be the same as allowed to sheriffs in like cases, which term shall be ascertained by a public bidding and outcry, of which two months' notice shall be given in a newspaper circulating in the vicinity of said land; and when such sale shall be made, the said commissioners, on receiving from the purchaser the amount of the assessment, with interest, costs and expenses of sale, shall give him or her a deed for the land for the period or term for which the same was bid off; and thereupon the said purchaser shall be entitled to immediate possession of said land, and to take the rents, issues and profits thereof, for the period or term aforesaid; and if possession be denied or resisted by any person or persons, the supreme court, on application thereto, and the fact of such sale being shown by affidavit and a copy of the commissioners' deed, shall make an order directing the sheriff of the county in which said lands lie to put the said purchaser in possession.

4. *And be it enacted*, That if the system of drainage which may be adopted in any case herein provided for shall require the obstruction or injury of any water-course, or the alteration or lowering of any mill-dam, or the permanent occupation of any land, whereby the owner or occupier thereof shall be injured, or shall sustain damage to his legal rights, such damage shall be estimated and appraised by the said commissioners, and shall form part of the expenses of such drainage to be raised by assessment as herein directed; *provided*, that any person

whose damage may be so assessed shall and may appeal from the award of said commissioners, so far as it relates to the amount of said damage, to the then or next circuit court of the county in which such damage shall occur, which court shall cause a jury to be impaneled to try the said appeal without further pleadings and without other notice of trial than the service of a copy of said appeal upon the said commissioners, or one of them, designating the time of trial at least ten days prior thereto, and the verdict of such jury shall be conclusive as to the amount of said damage, unless set aside for some illegality or misdirection of the court, but such appeal shall not have the effect of delaying or interrupting the proceedings of said commissioners, who shall be authorized to assume the amount of said damage to be so assessed by them until the same shall be varied by such verdict of a jury, and on paying or tendering the amount so assessed by them, the said commissioners, to the party injured, or in case he be a non-resident of this state, or cannot be found, or is under any incapacity to receive the same, upon paying said amount so assessed by them into the said supreme court, the said commissioners may take possession of the property in question and proceed to execute the work necessary to effect said drainage in accordance with the plan adopted as aforesaid; if the verdict of the jury be the same as, or shall be less than the award of the commissioners, the party appealing shall pay the costs of the appeal, otherwise no costs shall be recovered on either side; if the verdict shall be greater than the award of the commissioners the excess shall be added to the expenses to be assessed for such drainage, at any time before the actual collection thereof, and shall be distributed to the various parcels of land to be assessed therefor in the same proportion as the other expenses shall be assessed upon the same; if such excess be not ascertained until after the general assessment has been made, and the collection thereof commenced, a new assessment of such excess shall be made in the same proportion as the general assessment, and shall be collected in the same manner.

5. *And be it enacted*, That to enable the said commissioners to raise the necessary moneys to carry on the work of draining said lands, they are hereby authorized to borrow such sums from time to time as may be necessary for that purpose at the legal rate of interest, and to give their bonds as such commissioners therefor, and to pledge for the repayment thereof, the assessment to be made as aforesaid; *provided*, that the said commissioners shall not be person-

ally bound to pay the said bonds or any interest thereon; *and provided further*, that if the said interest on said bonds (which shall not be made payable at shorter intervals than once in every six months) shall not be paid, as the same may become due, it shall bear lawful interest until paid.

6. *And be it enacted*, That any vacancy happening among the commissioners so to be appointed by the supreme court shall be filled by the said court at the first stated term after such vacancy may occur, but until such vacancy is filled, the other two commissioners shall have full power to proceed with the duties of the commissioners, and in all cases the action or decision of any two of the commissioners shall be valid and sufficient; and the compensation of the commissioners, and also of the board of managers of the geological survey, when engaged on any tract, or in reference to the drainage thereof, shall be five dollars per day, and the expenses of said board of managers for their own time and services, and for compensation paid to any other persons in examining, surveying and reporting, in reference to any tract of land which they shall report as necessary or proper to be drained, shall be added by the commissioners to the expenses to be assessed for the drainage of said tract.

7. *And be it enacted*, That if at any time after any tract of land has been drained under this act, the ditches or other works of drainage shall require alterations or repairs, the supreme court, on the application of any person interested in such drainage, may appoint three commissioners to make said repairs, who shall qualify and proceed in the same manner as the original commissioners, and the expense, when footed up, shall be assessed upon the same lands which were assessed for the expense of the original drainage; and in precisely the same proportion, and the same remedy shall be had for the collection thereof.

8. *And be it enacted*, That this act shall not extend to any salt marshes or lands flowed by tide-water.

9. *And be it enacted*, That this act shall take effect immediately.

Approved March 8th, 1871.

A Supplement to the act entitled "An act to provide for the drainage of lands," approved March eighth, eighteen hundred and seventy-one.

1. BE IT ENACTED *by the Senate and General Assembly of the State of New Jersey*, That when the assessment made by the commissioners appointed to carry out and execute the drainage of any tract of land by virtue of the act to which this act is a supplement, shall have been approved and confirmed by the supreme court, the said commissioners may either collect the whole amount of the same immediately, according to the provisions of said act, or at their discretion, from time to time, and at different times collect such proportionate parts of the same as may then be required for the current expenses of said drainage and the interest on any money raised by said commissioners by the issue of bonds in pursuance of said act, and for a sinking fund for the redemption of such bonds.

2. *And be it enacted*, That if the said commissioners, after having commenced the drainage of such tract, and proceeded therewith, shall, before the drainage of the same shall be completed, be compelled to suspend the completion thereof, from any inability at that time to raise the money required therefor, they shall proceed to ascertain the tracts of land benefited or intended to be benefited by said drainage, and the relative proportions in which the said respective tracts have been or will be benefited thereby, and also the expenses already incurred in said drainage, and as near as may be the additional expenses required for the completion thereof, which expenses they shall assess on the respective tracts of land in the proportions aforesaid, and make report of said assessment and their proceedings in the premises to the supreme court, who shall hear and determine any objection thereto in the manner prescribed in the act to which this act is a supplement, and after said assessment shall have been approved and confirmed by said court the said commissioners shall collect the same in the manner prescribed by said act, either at one time or at different times, in such installments as may be required for the payment of said expenses, and apply the moneys so collected to the payment thereof.

3. *And be it enacted*, That any lands conveyed for the purpose of effecting said drainage, shall be conveyed to the said commissioners in trust, for the use and benefit of all the owners of said lands proposed

to be drained, but said owners shall have no power to incumber their respective interests in the same.

4. *And be it enacted*, That the appeal given by the fourth section of the act to which this act is a supplement, to the owner or occupier of any lands who shall be injured or sustain damage in his legal rights by said damage, from the award of the assessment of said damages by the commissioners, shall be made to the supreme court instead of the circuit court of the county in which the lands lie, as provided by said act, and the supreme court shall order said appeal to be heard before the circuit court of such county as the supreme court shall deem proper, and such court shall cause a jury to be impaneled to try said appeal, and shall try the same in the same manner as is directed in the fourth section of said act.

5. *And be it enacted*, That this act shall take effect immediately.

Approved March 19th, 1874.

A Supplement to an act entitled "An act to provide for the drainage of lands," approved March eighth, eighteen hundred and seventy-one.

1. BE IT ENACTED *by the Senate and General Assembly of the State of New Jersey*, That when any portion of the assessment made by the commissioners appointed to carry out and execute the drainage of any tract of land, by virtue of the act to which this is a supplement, or of the supplement to said act, approved March nineteenth, eighteen hundred and seventy-four, shall be called for and collected, the said commissioners shall apply the amount thus received to the redemption and cancellation of bonds, for the payment of which the said assessment was pledged, in pursuance of the act to which this is a supplement, or as the case may be, they may decrease or withold from issuing bonds to the same amount; *provided*, that if it becomes necessary to sell the bonds authorized to be issued by section five of the act to which this is a supplement at less than par, they shall not be sold at a discount of more than ten per centum.

2. *And be it enacted*, That this act shall take effect immediately.

Approved March 31st, 1875.

A Further Supplement to an act entitled "An Act to provide for the drainage of lands," approved March eighth, eighteen hundred and seventy-one.

1. BE IT ENACTED *by the Senate and General Assembly of the State of New Jersey,* That the board of managers of the geological survey may, and it shall be lawful for said board, at any time, to add to, alter or amend any system or plan of drainage for any tract of land which is subject to overflow from freshets, or which is usually in a low, marshy, boggy or wet condition, which said board has heretofore adopted and filed in the office of the clerk of the supreme court, or which said board shall hereafter adopt and file in the office of the clerk of the supreme court; and every such addition, alteration or amendment, after being adopted by said board and certified by the president of said board and the secretary thereof, shall be filed in the office of the clerk of the supreme court, and thereupon such addition, alteration or amendment shall become and be a part of the system or plan of drainage to which such addition, alteration or amendment relates, and shall be executed by the commissioners appointed by the supreme court as if such addition, alteration or amendment had been incorporated into and formed a part of the original system or plan.

2. *And be it enacted,* That this act shall take effect immediately.

Approved March 8th, 1877.

Supplement to an act entitled "An act to provide for the drainage of lands," approved March eighth, one thousand eight hundred and seventy-one.

1. BE IT ENACTED *by the Senate and General Assembly of the State of New Jersey,* That section eight of the act entitled "An act to provide for the drainage of lands," approved March eighth, one thousand eight hundred and seventy-one, which reads as follows:

"8. *And be it enacted,* That this act shall not extend to any salt marshes or lands flowed by tide-water," be and the same is hereby repealed.

2. *And be it enacted,* That all the provisions of the act to which this is a supplement shall be and the same are extended to any salt marshes or lands flowed by tide-water in this state.

3. *And be it enacted,* That this act shall take effect immediately.

Approved May 11th, 1886.

A Further Supplement to an act entitled "An act to provide for the drainage of lands," approved March eighth, in the year of our Lord one thousand eight hundred and seventy-one.

1. BE IT ENACTED *by the Senate and General Assembly of the State of New Jersey*, That section one of an act entitled "A further supplement to an act entitled 'An act to provide for the drainage of lands,' approved March eighth, one thousand eight hundred and seventy-one," which supplement was approved March eighth, one thousand eight hundred and seventy-seven, be and the same is hereby amended so as to read as follows:

1. BE IT ENACTED *by the Senate and General Assembly of the State of New Jersey*, That the board of managers of the geological survey may, and it shall be lawful for said board, at any time to add to, alter or amend any system or plan of drainage for any tract of land which is subject to overflow from freshets, or which is usually in a low, marshy, boggy or wet condition, which said board has heretofore adopted and filed in the office of the clerk of the supreme court, or which said board shall hereafter adopt and file in the office of the clerk of the supreme court; but such addition, alteration or amendment shall first be submitted by said board to the supreme court of this state, and approved by it upon such reasonable notice to the persons interested, by publication in the newspapers or otherwise, as said court shall direct; every such addition, alteration or amendment, after being adopted by said board and approved by said court, shall be filed in the office of the clerk of the supreme court, and thereupon such addition, alteration or amendment shall become and be a part of the system or plan of drainage to which such addition, alteration or amendment relates, and shall be executed by the commissioners appointed by the supreme court, as if such addition, alteration or amendment has been incorporated into and formed a part of the original system or plan.

2. *And be it enacted*, That any owner of land assessed for drainage under the act to which this is a supplement, who may be injured by reason of any drift of wood or accumulation of gravel or other substance or obstruction casually produced upon the lands of another in the channel of any ditch, stream or water-course for the construction or improvement of which his land shall have been assessed, after three days' notice previously given to the owner or occupants of such

lands if they are occupied, and if not occupied, then without such notice, may enter thereon with such assistance as may be necessary, and then and there remove such drifts, gravel, or other obstruction; but any person so entering shall remain liable as at common law for any injury done to the rights of the owner or occupant of such land which might be avoided in the removal of such obstruction, and shall remove off the land upon which such drift or obstruction may be situate, any of the substances composing such drift or other obstruction.

3. *And be it enacted*, That the chosen freeholders of any county are authorized to cause to be removed from any river or water-course within their county which has been improved under the provisions of the act to which this is a supplement, any drift, timber, gravel-bed, or other obstruction (except mill-dams or water-works) that may impair the efficiency of any such improvement, whenever in their opinion such removal shall be conducive to the public health, or shall be advisable for the better protection of any county road or bridge, and the expense of such removal shall be a county charge.

4. *And be it enacted*, That whenever any improvement under the provisions of the act to which this is a supplement requires to be repaired, or when any water-course or river which has been improved under the provisions of this act shall have become obstructed, any five owners of lands which have been assessed under the provisions of said act, and which shall be injured by such want of repair or obstruction, may apply by petition to the board of geological survey, setting forth a description of the work necessary and desired, with an estimate of the cost to be incurred, whereupon, if the work shall seem to the said board to be of sufficient importance, they shall investigate the application, and in case they shall approve the same shall report to the next term of the supreme court, setting forth what repairs are needed and what obstructions require to be removed, with a survey and plan of the necessary work and with an estimate of the cost thereof, which report shall be considered by said court on such reasonable notice to the persons interested, by publication in the newspapers or otherwise, as said court shall direct; if such plan shall be approved by the court, the said court shall proceed to appoint three commissioners to execute the same, who shall proceed to carry it out and to raise money by the issuing of bonds if necessary, and to assess the cost upon the lands benefited by the improvement in proportion to the benefits received, and they shall proceed, in making such im-

provement and assessment and in the raising money therefor, in the same manner as the commissioners appointed under this act to make the original improvement, and shall possess all the powers of the commissioners so appointed for the carrying out of said plan.

5. *And be it enacted*, That it shall be lawful for the commissioners appointed under this act, or under the act to which this is a supplement, with the approval of the board of geological survey, to contract with the owner of any mill-dam or water-works for the construction and maintenance by such owner of flood-gates, and for the use of the same to carry away the water in times of flood or freshet, and any contract so made shall be filed in the office of the clerk of the supreme court, and shall be enforced from time to time, as may be necessary, by the attorney-general, at the request and in the name of the board of geological survey, by bill in equity, or such other remedy as may be appropriate.

6. *And be it enacted*, That this act shall take effect immediately.

Approved March 23d, 1888.

AGREEMENT

BETWEEN GEORGE W. HOWELL, CALEB M. HARRISON AND JACOB H. BLAUVELT, OF THE FIRST PART, AND THE BEATTIE MANUFACTURING COMPANY, OF THE SECOND PART.

This agreement, made this second day of July, in the year of our Lord one thousand eight hundred and eighty-eight, between

George W. Howell, Caleb M. Harrison and Jacob H. Blauvelt, Commissioners heretofore appointed by the Supreme Court of the State of New Jersey, to drain the low, wet lands lying along the Passaic river and its tributaries, between Lower Chatham and Little Falls, in the counties of Morris, Essex and Passaic, of the first part, and

The Beattie Manufacturing Company, a corporation of the State of New Jersey, of the second part, witnesseth:

WHEREAS, In the year 1871, Zenas C. Crane and twenty-eight other owners of more than five separate lots or tracts of land lying along the Passaic river and its tributaries, between Lower Chatham and Little Falls, in the counties of Morris, Essex and Passaic, in the State of New Jersey, which are subject to overflow from freshets, did apply to the Board of Managers of the Geological Survey of the State of New Jersey, to adopt a system for the drainage of said lands, pursuant to an act of the Legislature of the State of New Jersey, entitled "An act to provide for the drainage of lands," approved March 8th, 1871;

AND WHEREAS, Said Board of Managers, in response to said application, did examine the said lands and cause the same to be surveyed, and finding them subject to overflow from freshets, and usually in a low, marshy, boggy or wet condition, and deeming it for the interest of the public and the land-owners to be affected thereby, did adopt a plan or system of drainage for draining said lands, and did report the same to the Supreme Court of this State;

AND WHEREAS, The said Supreme Court, upon due consideration of said plan, and upon notice to all parties interested, did appoint Aaron Robertson, John H. Anderson and the said George W. Howell, Commissioners, to carry out the said plan of drainage, and said John H. Anderson having died, and Aaron Robertson having resigned, did

afterwards appoint the said Caleb M. Harrison and Jacob H. Blauvelt as their successors in said Commission;

And Whereas, The said plan of drainage provided, among other things, for reducing the height of the stone dam of the said Beattie Manufacturing Company, which extends across the Passaic river at Little Falls, to the extent of seven feet below its present elevation, and the said Beattie Manufacturing Company claimed damages from said Commissioners, on account of said proposed reduction, and such proceedings were had upon said claim, that on the seventeenth day of December, A. D. eighteen hundred and eighty-six, the said Commissioners awarded to the said Beattie Manufacturing Company the sum of fifty-five thousand dollars, as compensation for such reduction, from which award the said company thereafter appealed to the Circuit Court of the county of Passaic;

And Whereas, In order to compose their differences, and to put an end to litigation, the said Commissioners and the said Beattie Manufacturing Company, after said appeal, conferred together, and by themselves, their counsel and engineers, agreed to recommend to the said Board of Managers of the Geological Survey to alter and amend the said plan or system of drainage as follows:

1. The said stone dam of the Beattie Manufacturing Company to be reduced in height twenty inches along its entire length instead of seven feet, as provided in said original plan, and to be provided with an opening and gates, which, when open, will afford a free water-way twenty-five feet in width and sixteen feet in depth below the crest of the dam when so reduced, or the hydraulic equivalent thereof. The expense of so reducing the dam and building suitable gates to be borne by the said Beattie Manufacturing Company. The said gates to be opened for the free flow of freshet-water to an extent sufficient to keep the surface of the water in the river above the dam in ordinary high water down to the height of the top of the dam. The said Beattie Manufacturing Company to enter into contract with the Commissioners to open said gates at their own expense, and to keep them open when necessary, so as to keep the water down as specified.

2. The channel through the dam of the width of twenty-five feet, and the depth of sixteen feet at the dam, to extend up the stream, through the lower rock reef, to deep water above the same, on a grade of about one foot in ten feet, and below the gates to drop about five feet, and to extend down the stream to a point opposite, or nearly so,

to the upper corner of the main stone mill; the bottom of said channel there to coincide with the present bed of the river and to conform throughout to a grade line then adopted and now shown on a profile of the said amendments and alterations on file in the office of the Clerk of the Supreme Court.

3. For the free delivery of the water from the lower end of the twenty-five-feet channel, the river-bed to be excavated to the width of eighty feet, the excavation to extend to the main fall, and the bottom of the same to conform to the grade line aforesaid.

4. A free channel to be provided through both the lower and upper reefs to the width of not less than two hundred feet or more than two hundred and fifty feet, and to a depth of not less than five feet or more than six and one-third feet below the level of the crest of the dam when reduced.

5. The bar in the bed of the river at Two Bridges to be excavated to a width of not less than two hundred feet, or more than two hundred and fifty feet, and to a depth of not less than four feet, or more than five and one-third feet below the level of the crest of the dam when so reduced, the excavation at that width and depth to extend from deep water below the said bar to a point above the junction of the Pequannock river with the Passaic river, and thence to the same depth and to the width of one hundred feet, to deep water, above said bar.

6. Such other obstructions in the river between the dam at Little Falls and the reef at Two Bridges, to be removed as may be necessary to insure a clear water-way of two hundred and fifty feet wide and a depth defined by a grade line, which at the dam is to be not less than five feet or more than six and one-third feet, and at Two Bridges not less than four feet or more than five and one-third feet below the level of the crest of the dam when reduced.

7. A cut-off channel to be excavated at Pine brook, to pass through the Slank bridge on the Morris county side of the river, to be seventy-five feet wide, and five feet deep, and such other improvements to be made and obstructions removed as the Commissioners shall from time to time deem necessary.

And the said Beattie Manufacturing Company further agreed that in case the said alterations and amendments should be adopted and approved, they would, at their own expense, reduce the said dam to the extent of twenty inches below its present height, along the whole

length thereof, and would put flood-gates in the opening in said dam above provided for, and operate the same, as contemplated in said plan. And the said Commissioners agreed to carry out all the other provisions of said plan, at the expense of the owners of said overflowed lands, under the provisions of said act.

And Whereas, The said Commissioners have recommended the said Board of Managers of the Geological Survey to alter and amend the said original plan of drainage, according to said agreement, and the said Board of Managers have made such alterations and amendments, and submitted the same to the Supreme Court for its approval, and the matter of approving the same is now pending in said court:

Now, therefore, to evidence the said agreement and formulate the same, it is, in consideration of the premises, and of one dollar by each of the parties hereto to the other in hand paid, covenanted, understood and agreed by and between the said parties as follows:

First. That the parties of the first part, as Commissioners aforesaid, will, as soon as practicable after the approval of said amendments and alterations, if the same shall be approved, and within three years from that time, excavate the bed of the Passaic river, from the main fall in said river, at Little Falls, to the width of eighty feet, up to the northwest corner of the main stone mill of the Beattie Manufacturing Company, and from that point, to the width of twenty-five feet, up between the stone buttress of the dam and rocks opposite thereto to the crib-work forming the north end of the dam, to the depth of the grade line agreed upon as aforesaid, as shown on the plan of said amendments and alterations now on file in the office of the Clerk of the Supreme Court, a copy of which is hereto annexed.

Second. That the Beattie Manufacturing Company, its successors or assigns, as soon as the excavation last above mentioned is completed, will construct flood-gates in said channel of such character that they may be easily worked and opened at times of flood, and of such width and depth that when open they will leave a clear water-way at least twenty-five feet wide and sixteen feet deep, or the hydraulic equivalent thereof, and will remove the present crib-work dam. If it shall appear that the excavation through the rocks at the site of said gates must be more than twenty-five feet wide, in order to enable the said Beattie Manufacturing Company to place therein gates which, when open, will give the required water-way, the said Commissioners shall

make such increased excavation. The covenants in this section to be performed by the Beattie Manufacturing Company shall be taken and held to run, with the land affected thereby, for the period of five years from the date of this agreement, and shall bind the successors of said company.

Third. That as soon as the said crib-work is removed the said party of the first part, as Commissioners aforesaid, will continue the said opening at the full width of twenty-five feet up the said river, on a grade of one foot in ten feet, through the lower rock reef near to said dam, and the company will aid them, in a reasonable manner, by keeping down the water, but not to such an extent as to deprive their mills of the power necessary for their operation. The party of the first part will also cut a free channel through the two reefs above said dam, known as the upper and lower rock reefs, from the dam to deep water above the upper rock reef, not less than two hundred feet in width or five feet in depth below the level of the crest of the said dam, when reduced as hereinafter provided. The party of the first part will also cut a channel through the bar in said river, at the place called Two Bridges, not less than four feet in depth below the crest of the said dam when reduced, and not less than two hundred feet in width from the lower side of said bar up to the point of junction between the Passaic and Pequannock rivers, and from thence to the same depth and not less than one hundred feet in width to deep water above said bar.

The said party of the first part will also remove such other obstructions in the Passaic river, between said dam and the said reef at Two Bridges, as shall be necessary to insure a clear water-way of a width not less than two hundred feet and a depth conformable to a grade line which, at the said dam, shall not be less than five feet, and at Two Bridges not less than four feet, below the level of the crest of the said dam when reduced.

Fourth. Upon the completion of the said work by the Commissioners the company agrees that it, its successors or assigns, will, with reasonable despatch, reduce its present dam along the whole length thereof, so that the new crest shall be at a level of twenty inches below the present level, which new crest is agreed upon as the height at which the dam may be hereafter maintained, and above which it shall not be raised; except that flash-boards, not to exceed six inches in height, may be used in times of low water, when the normal flow over the dam does not exceed six inches in depth; but said flash-

boards shall in no case be used to raise the water more than twelve inches above the said dam, nor during any portion of the year, except between July first and November first, and they shall be removed in times of freshet, if the operation of the gates prove insufficient to keep the water down to the level of the dam, as hereinafter provided. The company also agrees that it, its successors or assigns, will not erect upon its land lying below the dam (and above the head of the main fall), any other dam whatever, except one in place and substitution for the present dam, as hereinafter provided, nor any dam below the main fall, the crest of which shall be higher than sixteen feet below the crest of the present dam, as reduced, being the level of the bottom of the flood-gates to be constructed in the dam, which is fixed as the level to which the crest of any dam to be erected at a lower point on the river may be built; *provided, however,* that if the present dam shall be carried away, removed or abandoned, a new dam may be substituted for it, from time to time, as occasion may require, either on the same site or at any point on the river below, the crest of which substituted dam may be raised to the same level as that of the present dam, when reduced, and shall afford the same facilities for the flow of water over it, and any such substituted dam shall be provided with flood-gates of the same depth and capacity as those herein required to be placed in the present dam, and all the provisions of this agreement, as to the maintenance and operation of flood-gates, shall apply to said gates in such substituted dam.

Fifth. The flood-gates above provided for shall be maintained in good workable condition, rebuilt when necessary, and operated by the said Beattie Manufacturing Company, its successors and assigns, in the legal or equitable ownership or occupation of the land whereon said dam is erected, and also of the land whereon are erected the gates and machinery used for operating the gates, which is immediately appurtenant to them, and of the lands now owned by the said company, in the bed of the said river, for one hundred feet above and three hundred feet below said dam, so long as the said dam or any dam substituted therefor, shall exist and the said gates be maintained; and the said Beattie Manufacturing Company, its successors and assigns, legal or equitable owners and occupants of said dam and lands last aforesaid, shall open said gates in times of flood or ordinary freshets, when the water is rising and has reached the height of twelve inches above the level of the crest of said dam, and shall keep

the same open to such width or height, and for such length of time, as may be necessary, as far as practicable, to keep said water down to the level of said dam, when so reduced.

In order to correctly ascertain the said height, an iron or stone monument shall be set in the ground, at a convenient point, in the margin of said river, in proximity to and above said dam, and at a place where all persons interested may have access thereto, and there forever maintained, and the level of said dam, and also the said point twelve inches above the same, shall be plainly and durably marked thereon. The gates need not be opened when logs or heavy ice are passing down, and are likely to destroy the gates, if opened.

Sixth. The covenants in the fourth and fifth clauses of this agreement shall be considered and held as continuing and perpetual covenants, and shall run with the said land and bind the same, that is to say, the covenants, provisions and restrictions contained in the fourth clause shall apply to, run with and bind all the land now owned by the said Beattie Manufacturing Company in the bed of the said river above, below and including the present dam across the same; and the covenants and provisions contained in the fifth clause shall apply to, run with and bind the land in the fifth clause mentioned, viz., the land whereon the dam is erected, and the land whereon are erected the said gates, and the machinery used in operating the gates, which is immediately appurtenant to them, and the land in the bed of the river one hundred feet above and three hundred feet below the dam, into the hands of the successors and assigns of the Beattie Manufacturing Company, and of all persons interested in said land, either in law or equity, or as mortgagees or otherwise, and each and all of them, and shall be held and taken to create an easement in the said lands of the party of the second part, for the benefit and advantage of all the owners and occupants of the lands to be drained as aforesaid, and of each and every owner and occupant of land which shall be assessed for the expense of carrying out said plan of drainage, and of his and their heirs, executors or assigns, owners and occupants, either singly or jointly with one or more of the other such owners or occupants, his or their heirs, executors or assigns, shall have the right, at any and all times hereafter, to bring and maintain in the courts of equitable jurisdiction, an action in his or their own name or names against the said Beattie Manufacturing Company, its said successors and assigns, legal or equitable owners and occupants of the lands hereinbefore

mentioned, now owned by it, to enforce the performance and observance of said covenants, provisions and restrictions, or any of them; and said Beattie Manufacturing Company, its said successors and assigns, owners and occupants of the said lands last above mentioned, shall also be liable in an action or actions at law to any and every such owner or occupant of said assessed lands for damages at any time hereafter occasioned by any willful and continued failure or neglect to maintain in workable condition or to operate said gates so to be placed and maintained in said dam; but the said party of the second part, its said successors or assigns, shall not be liable to any action at law to any such owners or occupants for damages occasioned by failure or neglect to operate said gates, unless such failure or neglect be willful and continued. If the gates shall be carried away or damaged, or shall become decayed so that they require reconstruction or repair, it shall be lawful for the Beattie Manufacturing Company, its successors and assigns, to put in a temporary dam above the gates to hold the water back until the gates can with reasonable diligence be rebuilt or repaired; and the company, its successors or assigns, shall not be liable for any damages caused by neglect or failure to operate said gates during the time necessarily taken in such rebuilding or repairing.

If, at any time, any of the owners of land which has been assessed against them or the former owners, for the expense of carrying out the scheme of drainage herein provided for, to the extent in amount of five hundred acres, shall be dissatisfied with the operation of said gates, they may, in addition to such other remedies as they may have, apply to the Chancellor of the State, or to such court of equity as may succeed to his powers, for the appointment of some fit person or persons to operate said gates, and the Chancellor or court of equity shall, upon being satisfied of the reasonableness of said application, appoint such person or persons for such period of time as to said Chancellor or court shall seem proper, which person or persons so appointed shall have full power to operate said gates, according to this contract, under the supervision of said Chancellor or court, and shall receive such just compensation as the Chancellor or court may determine, to be paid by applicants, or by the owner of the dam, or by both, in such proportions and on such terms as the court shall direct, the payment decreed to be made by the owner of the dam to be a charge upon the dam and the land whereon the dam stands, and the land in the bed of the stream, for one hundred feet above and three

hundred feet below the dam. In case of such appointment, the obligations of the owner of the dam shall be suspended only so far as may be needful to permit such person or persons so appointed to operate the gates, and in case he or they shall cease to act, the duty of the owner of the dam shall remain in full force. The land-owners shall have the right to renew such application as often as they may think proper, and to have as many successive appointments as to the Chancellor shall seem fit.

Seventh. And the said party of the second part agrees to permit the parties of the first part, their agents and contractors, to deposit temporarily the broken rock taken from the said two rock reefs, and the materials taken from the other obstructions in the river above the said dam, at places to be designated by its President upon its land, where it owns adjoining the river and opposite said reefs, and other obstructions so to be removed, and to use said land, so far as necessary and convenient, for the purpose of the work of reducing said reefs and removing said obstructions; and also to deposit the broken rock to be taken out below the said dam in the pools and deep places in the river, and permanently place the broken rock taken from the upper rock reef at places on its land in the vicinity to be designated by its President.

Eighth. And whereas a part of the consideration for this agreement to the said company is the enlargement of their pondage, and for that purpose an excavation in said upper rock reef, and in the gravel reef at Two Bridges, to the full width, is not essential; therefore it is further agreed that if the party of the first part shall excavate the upper rock reef to the width of not less than one hundred feet instead of two hundred feet, making such channel south of the present deep channel, and to the depth of not less than five feet throughout said channel of one hundred feet, and shall excavate the gravel reef to a width of not less than one hundred feet instead of two hundred feet, and to the depth of four feet or more throughout said channel of one hundred feet, they shall be considered as having performed their agreement in regard to excavation on said two reefs.

And it is further agreed that after said excavation is made, and said gates made and placed in position ready for use, and so long as said party of the first part are prosecuting in good faith the completion of said scheme of drainage, the said party of the second part will, so far as practicable, without reducing the dam, so operate said gates as to

keep the water in the river down to the level contemplated to be effected by the proposed improvement.

Ninth. This agreement shall not take effect until the said alterations and amendments are approved by the Supreme Court, and it shall then be filed with the Clerk of said Supreme Court, there to remain forever, for the benefit of all persons having an interest in it.

In witness whereof, the said parties of the first part have hereunto set their hands and seals, and the said party of the second part has caused its official seal to be affixed and the same to be attested by its President, the day and year first above written.

GEORGE W. HOWELL, [L. S.]
CALEB M. HARRISON, [L. S.]
JACOB H. BLAUVELT, [L. S.]
Commissioners.

BEATTIE MANUFACTURING CO.,
ROBT. BEATTIE, [L. S.]
President.

Signed, sealed and delivered in the presence,
CHARLES L. CORBIN.

STATE OF NEW JERSEY, County of Hudson, } *ss.*

Be it remembered, that on the second day of July, A. D. eighteen hundred and eighty-eight, personally appeared before me, a Master in Chancery of New Jersey, Charles L. Corbin, of full age, who being duly sworn according to law, on his oath saith that he subscribed his name to the within agreement as subscribing witness on the day that the same bears date; that he saw the said George W. Howell, Caleb M. Harrison and Jacob H. Blauvelt sign, seal and deliver the same as their voluntary act and deed, the contents thereof having been first made known to them; that he knows the common seal of the Beattie Manufacturing Company; that the seal affixed to said agreement is the common seal of said company, and that Robert Beattie, who is President of said company, did, by its order, sign, seal and deliver the said agreement as the voluntary act and deed of said company, in the presence of deponent, the contents of said agreement having been first made known to said Robert Beattie and to said company.

R. V. LINDABURY,
M. C. C. of N. J.

III.

WATER-SUPPLY AND ARTESIAN WELLS.

WATER-SUPPLY.

The public supply of pure and wholesome water to the people of our cities, towns and villages is of growing importance. And it needs to be kept before those who should reap the benefits of it. That there are abundant supplies of the best of water to be found in New Jersey, has been pointed out in several of our annual reports. Perhaps that of 1876 contained the most of detail. And a bare repetition of some of the points may help to give a more definite idea of the magnitude and importance of the supply, as well as to keep the subject prominently in view.

From many years' observations it was shown that the annual rainfall varied in different years from about 30 inches in the dryest years to about 60 inches in the wettest years, and that the average rainfall in all northern New Jersey was $44\frac{5}{10}$ inches per year. Observations upon the amount of water to be collected from the Croton water-shed, show that 60 per cent. of the rainfall runs off in the streams. For purposes of safe calculation, however, it was assumed that only 40 per cent. of the minimum rainfall should be depended upon—40 per cent. of 30 inches is 12 inches.

From a square foot of surface, then, a cubic foot of water can be saved every year, or $7\frac{1}{2}$ gallons.

From an acre, 326,700 gallons can be collected per year, or nearly 900 gallons per day.

From a square mile there can be collected 209,088,000 gallons per year, or daily 572,844 gallons.

The water-shed of the Passaic river above Little Falls is 750 square miles, being made up of the drainage areas of the following-named streams:

	SQUARE MILES.
Ramapo river	148
Wanoque river	108
Pequanac river	82
Rockaway river	165
Whippany river	59
Passaic river	188
Total area of the Passaic and its branches	750

Greenwood lake, with a drainage area of 32 square miles, is included in the Wanoque area.

Lake Hopatcong, with a drainage area of 27 square miles, naturally found an outlet by the Musconetcong river into the Delaware—but by the dam across its outlet, its surface has been raised so as to find an outlet by the Morris canal into the watershed of the Passaic..... 27

Total area square miles to be drawn from..... 777

This area can be depended upon to supply 500,000,000 gallons of water daily.

At Little Falls, all this water is in one stream, at an elevation of 158 feet above mean tide, and it is only 16 miles from the center of Newark, and 22 miles from the center of Jersey City—or only about half the distance from which the Croton water is carried to New York.

By going a few miles farther up the streams most of the water could be collected at an elevation of 250 feet, or high enough to supply all of those cities by gravity.

The quality of this water is unquestionable in purity. It is mostly gathered from a country which is mountainous, mostly in forest and likely to remain so for a long time to come. As a substitute for the filthy water supplied to almost half the people of the State it is of incalculable value, and there should be no delay in securing its health-giving benefits.

ARTESIAN WELLS.

The artesian wells bored at various points on the Atlantic coast between Sandy Hook and Cape May, continue to yield a supply of good and wholesome water, and some very satisfactory ones have been sunk along the Delaware.

The following may be mentioned as some of the advances of the year:

At the Atlantic Highlands it is reported that a well has been driven on the shore, and a flow of good water has been obtained.

At Seabright, Mr. Paul reports that he has 9 artesian wells, of which 6 are down 125 feet, and yield, on pumping, 35 gallons each per minute, the water rising 10 or 12 inches above the surface. All of them three-inch pipes, except one, which is six-inch, but yields no more water than the others. At a later time three more were sunk to a depth of 258 feet, and stopped in fine white sand, bearing fresh water of good quality. From each of these they get about 40 gallons a minute, at 5½ feet above the surface. Mr. Paul thinks that, by pumping, each would yield 100 gallons per minute.

These wells are sunk much lower than those at Asbury Park, and the water is drawn from strata which, in most other places, have been found quite free from water-bearing layers. In boring, the strata passed through were—

18 feet of sand,
5–6 feet of yellow clay,
35–40 feet of marl (lower marl-bed),
35–40 feet of black clay or mud, sand—black and muddy.
At 258 feet there was a thick bed of fine white sand and water.

At Atlantic City a well has been bored to the depth of 1,150 feet, and a good flow of water obtained. The following notes of the materials passed through in boring are from Mr. J. H. Moore, who superintended the work:

		Total depth.
Beach sand	30 feet.	30 feet.
Blue sand and shells	5 "	35 "
Brownish sand	5 "	40 "
Bluish sand	15 "	55 "
Gravel, with large stones	17 "	72 "
Clay and small clear gravel	3 "	75 "
Gravel (same), no clay	15 "	90 "
Seam of white clay	4 inches.	90 "
Brown sand, coarse	5 feet.	95 "
White gravel, milky water	5 "	100 "
White sand, milky water	5 "	105 "
White sand and gravel	7 "	112 "
Conglomerate, earth and oxide of iron pebbles	3 "	115 "
Clay, oxide of iron, wood, inky water	8 "	123 "
Yellowish-brown sand	10 "	133 "
Light brown sand	7 "	140 "

		Total depth.
Fine white sand	9 feet.	149 feet.
White and yellow clay and gravel	1 "	150 "
Medium brown sand	15 "	165 "
Very loose brown sand	12 "	177 "
Rather coarse gravel	3 "	180 "
Gravel, sand and white clay	3 "	183 "
Seam of white clay		
Light-colored sand	10 "	193 "
Fine gravel	7 "	200 "
Light-colored sand	8 "	208 "
Sandy clays	4 "	212 "
Light-colored sand (very packy)	8 "	220 "
Light-colored sand, coarse	20 "	240 "
Gravel, limey and irony substance	6 "	246 "
Very brown sand	10 "	256 "
Light brown sand (packy)	9 "	265 "
Seam of clay		
Light brown sand	10 "	275 "
Dark clay and sand, gravel, wood, very hard and dry	25 "	300 "
Sandy clay	24 "	324 "
Seam of gravel and oxide of iron		
Black slushy sand (inky)	18 "	342 "
Quicksand (blackish)	64 "	406 "
Sandy clay	2 "	408 "
Bluish clay (tough)	8 "	416 "
Dark slushy sand	1 "	417 "
Hard dark clay (brittle)	3 "	420 "
Greenish dark clay (decayed shells)	18 "	438 "
Light greenish clay, with many seams of hard clay from 1 to 7 feet thick	128 "	566 "
Dirty blackish sand, very fine	20 "	586 "
Brown sand	1 "	587 "
Chocolate-colored clay	19 "	606 "
First seams of sand		
Fine black sand	1 "	607 "
Light-colored clay	9 "	616 "
Hard dark clay	2 "	618 "
Shell and clay formation	7 "	625 "
Hard sandy substance	3 "	628 "
Dirty mixture, gravel, sand and shells	18 "	646 "
Sandy clay	2 "	648 "
Blackish sand and gravel	8 "	656 "
Coarse dark loose sand	8 "	664 "
Sandy clay	2 "	666 "
Fine black sand	19 "	685 "
Dark hard clay	5 "	690 "
Clear white fine sand (glassy)	10 "	700 "

		Total depth.
Reddish sand (glassy)	35 feet.	735 feet.
Coarse dark sand	8 "	743 "
Very fine dark quicksand	27 "	770 "
Tough chocolate clay	2 "	772 "
Dark clay, or marl	95 "	867 "
Hard dark substance	6 "	873 "
White clay	5 "	878 "
Green marl	25 "	903 "
Dark clay	4 "	907 "
Green marl	36 "	943 "
Light green marl	5 "	948 "
Sandy marl, or marl silt	17 "	965 "
Yellow sandy loam	6 "	971 "
Yellow sand	1 "	972 "
Yellow loam	1 "	973 "
Dark medium sand	1 "	974 "
Slushy fine marl	2 "	976 "
Coarse sand and shells, mixed	5 "	981 "
Green sand (seams of barnacles)	90 "	1071 "
Sandy clay (green)	16 "	1087 "
Hard substance, like sandstone	8 "	1095 "
Crusty marl substance	2 "	1097 "
White sand	2 "	1099 "
Green crusty marl	1 "	1100 "
Green sand	1 "	1101 "
Green marl	4 "	1105 "
Green sand	2 "	1107 "
Sandy clay	1 "	1108 "
Dark tough clay down to		1150 "

The analysis of the water, made by Messrs. Austen and Wilber, March 14th, 1888, is as follows:

	Grains per gallon.*	
Total solids, at 212° F.		64.336
Silica	0.236	
Sesquioxide of iron and alumina	0.105	
Lime	1.079	
Magnesia	1.020	
Potash	1.493	
Soda	31.240	
Sulphuric acid (503) in sulphates	2.636	
Chlorine in chlorides	19.303	
Total solids determined	57.112	
Volatile constituents	7.224	
		64.336

* Gallon equals 58.318 grains.

Temporary hardness, equivalent to calcium carbonate	3.809
Permanent hardness, equivalent to calcium carbonate	0.326
Oxygen required to oxidize organic matter	0.003
Color	Colorless.
Taste	None.
Smell	None.
Reaction	Faintly alkaline.
General appearance	Exceedingly clear and attractive.

The bases are probably combined as follows:

	Grains per gallon.
Sodium chloride	31.807
Potassium sulphate	2.764
Calcium sulphate	2.321
Sodium carbonate	24.575
Calcium bi-carbonate	0.636
Magnesium	3.709
	65.812

Or by direct evaporation:

Sodium chloride	31.807
Potassium sulphate	2.764
Calcium sulphate	2.321
Sodium carbonate	24.575
Calcium carbonate	0.391
Magnesium carbonate	2.134
Total salts	63.992
Found	64.336

A well at Sea Isle City has been bored to the depth of 380 feet, and furnishes a moderate supply of water through a four-inch pipe. Notes are furnished by Mr. C. K. Landis, who reports that the water rises to within 11 feet of the surface, and yields 30 gallons to the minute, or 1,800 gallons per hour. The following are his notes of the strata passed through:

	Strata.	Total depth.
Sand	16 feet.	16 feet.
Black mud	9 "	25 "
Sand	10 "	35 "
Mud	10 "	45 "
Sand	8 "	53 "
Coarse gravel and shells	10 "	63 "
Clay	35 "	98 "

	Strata.	Total depth.
Coarse sand and gravel, in layers	27 feet.	125 feet.
Clay	12 "	137 "
Coarse sand and gravel	13 "	150 "
Fine sand	23 "	173 "
Coarse sand	27 "	200 "
Fine dark sand	17 "	217 "
Clay	15 "	232 "
Coarse sand	76 "	308 "
Fine dark sand and water	72 "	380 "

A bored well at the house of Mr. Joseph Evans, a mile and a half south of Marlton, has been sunk to the depth of 155 feet, and yields 20 gallons of water a minute, which rises to within 40 feet of the surface. The water is of good quality, and from the fossils found it is judged to come from the sand-bed underlying the lower marl-bed. The well was first sunk to the depth of 380 feet without getting water, as it was driven through this sand layer, without proper testing, and into the beds of clay marl which have usually failed to yield any supply of good water.

The well at Sayreville, mentioned in last year's report as having been sunk 70 feet through the clay and sand, and then into gneiss rock, was afterwards sunk to the depth of 976 feet, but no water was obtained. A small amount was passed at a depth of from 300 to 350 feet, say about 7 gallons a minute.

Another well has been sunk at Communipaw Coal Company's dock in Jersey City, near the ferry. The materials passed are as follows:

Water	12 feet.
Mud	40 "
Hard gravel	3 "
Mud down to rock	17 "
Soft micaceous rock	20 "
Harder rock, with crevices and soft fissures, to	450 "

The water met in the crevices was brackish and the well was abandoned.

IV.
STATISTICS OF IRON AND ZINC ORES ETC.

IRON ORE.

The output of the iron mines of the State for the year 1888, as shown by the shipments of iron ore from stations in the State and the amounts used at furnaces which do not come in the tonnage of the railroad lines, aggregated 447,738 tons—a falling off of 100,051 tons as compared with the production of 1887. For the convenience of reference the statistics of iron ore mined in the State for the years 1870–1888, inclusive, are here inserted in a tabular form. Estimates and U. S. census figures at intervals back to 1790 are also given at the head of the column:

1790.....	10,000 tons.....	Morse's estimate.	
1830	20,000 tons.....	Gordon's Gazetteer.	
1855.....	100,000 tons	Dr. Kitchell's estimate.	
1860.....	164,900 tons.....	U. S. census.	
1864.....	226,000 tons.....	Annual Report State Geologist.	
1867.....	275,067 tons.....	"	"
1870.....	362,636 tons	U. S. census.	
1871	450,000 tons.....	Annual Report State Geologist.	
1872	600,000 tons.....	"	"
1873	665,000 tons	"	"
1874.....	525,000 tons.....	"	"
1875	390,000 tons	"	"
1876	285,000 tons*..		
1877	315,000 tons*..		
1878	409,674 tons.....	"	"
1879.....	488,028 tons.....	"	"
1880.....	745,000 tons	"	"
1881.....	737,052 tons	"	"
1882	932,762 tons.....	"	"
1883	521,416 tons	"	"
1884.....	393,710 tons	"	"
1885	330,000 tons.....	"	"
1886.....	500,501 tons.....	"	"
1887.....	547,889 tons.....	"	"
1888.....	447,738 tons.....	"	"

*From statistics collected later.

This tabular statement shows that from 1870 to 1874 there was a gradual and steady increase in the annual production. The financial depression in the latter part of 1873 marked a turn in the rate of production, and the lowest output for the decade was reached in 1876. The product for 1877 was slightly in excess of that of 1876, and from that year onward there was a gradual rise to the boom of 1879, which showed itself in the large increase in 1880. The maximum was attained in 1882.

ZINC ORE.

The product of the zinc mines for the year 1888, as shown by the shipments over the transporting lines, was 46,377 tons.

The following tabular statement shows the production of the zinc mines of New Jersey for a number of years:

	Estimated tons.			
1868	25,000	Annual Report State Geologist.		
1869				
1870				
1871	22,000	"	"	"
1872				
1873	17,500	"	"	"
1874	13,500	"	"	"
1875				
1876				
1877				
1878	14,467	"	"	"
1879	21,937	"	"	"
1880	28,311	"	"	"
1881	49,178	"	"	"
1882	40,138	"	"	"
1883	56,085	"	"	"
1884	40,094	"	"	"
1885	38,526	"	"	"
1886	43,877	"	"	"
1887	50,220	"	"	"
1888	46,377	"	"	"

NOTES ON THE CLAY, BRICK AND POTTERY INDUSTRIES FOR THE YEAR 1888.

The total amount of fire and potters' clays sent into market from the clay districts on the Raritan and the Delaware during the year is 254,500 tons, valued at about $463,000.

The fire-sand sent from the same district amounts to 80,000 tons, with an estimated value of $60,000.

These two industries employ about 800 men.

The fire-brick made from these clays numbered 14,550,000.

The Perth Amboy Terra-Cotta Works consumed 15,000 tons of clay; and the value of the products was $400,000.

The common brick made on the Raritan, at Keyport, on the Hackensack, at Trenton, Kinkora and Fish House, aggregate 160,000,000.

V.

PERSONS EMPLOYED.

C. CLARKSON VERMEULE, C.E., has continued in the Topographic Survey of the State until its completion. Though in the employment of the United States Geological Survey, in doing the last half of this work, he continued to give that careful and intelligent attention to the interests of the State which has characterized his services from the beginning. He left the State June 7th, 1888.

FRANK VAN BRAKLE, M.S., who has been an assistant in the Topographic Survey, continued his services in office work until November 1st, 1888.

ASHER ATKINSON, C.E., an assistant in the Topographic Survey, has been employed a portion of the time in office and field work quite up to the present time.

FRANK L. NASON, A.M., has been engaged as assistant in the Geological Survey, passing most of his time in field work, since May.

UNO SEBENIUS, E.M., has been occupied in making magnetic surveys of mines, and in tracing lines of magnetic attraction, during most of the season. He began work in January, and is still engaged.

WM. H. SCRANTON, E.M., has rendered valuable service to the Survey, in the careful and skillful examination of several iron ore properties, at different times.

Professors AUSTEN and WILBER have made the analyses, and done other chemical work of the Survey.

IRVING S. UPSON has been engaged during the year, and has rendered faithful and efficient service in the clerical work of the Survey, and in its large and growing publication department.

VI.
EXPENSES.

The expenses of the Survey have been kept strictly within the annual appropriation of $8,000, and its bills are all paid.

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