GEOLOGICAL SURVEY OF NEW JERSEY.

ANNUAL REPORT

OF THE

STATE GEOLOGIST,

FOR THE YEAR

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NEW BRUNSWICK, December 12th, 1882.

To His Excellency George C. Ludlow, 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 1882.

With high respect,

Your obedient servant,

GEO. H. COOK,
State Geologist.

REPORT.

The Geological Survey of the State has been continued through the year, and its work has been, as heretofore, to develop and make public the natural products and resources of New Jersey. The amount of work which has been done is here arranged under the following heads:

I. The United States Coast and Geodetic Survey of New Jersey.
II. Topographical Surveys.
III. Geological Work in Progress:
  1. Red Sandstone District.
  2 Eruptive Rocks of Sussex County.
  3. Iron Mines and Mining Industries.
  4. Plastic Clays and their Uses.
  5. Shore Changes.
IV. Seaside Developments.
V. Climatic Peculiarities.
VI. Agricultural Development in Southern New Jersey.
VII. Drainage.
VIII. Water Supply.
IX. Statistics of Ores, Clays and Clay Products, and Lime.
X. Publications.
XI. Expenses.
XII. Persons Employed.
XIII. Work to be Done—Plan for the Coming Year.

I.

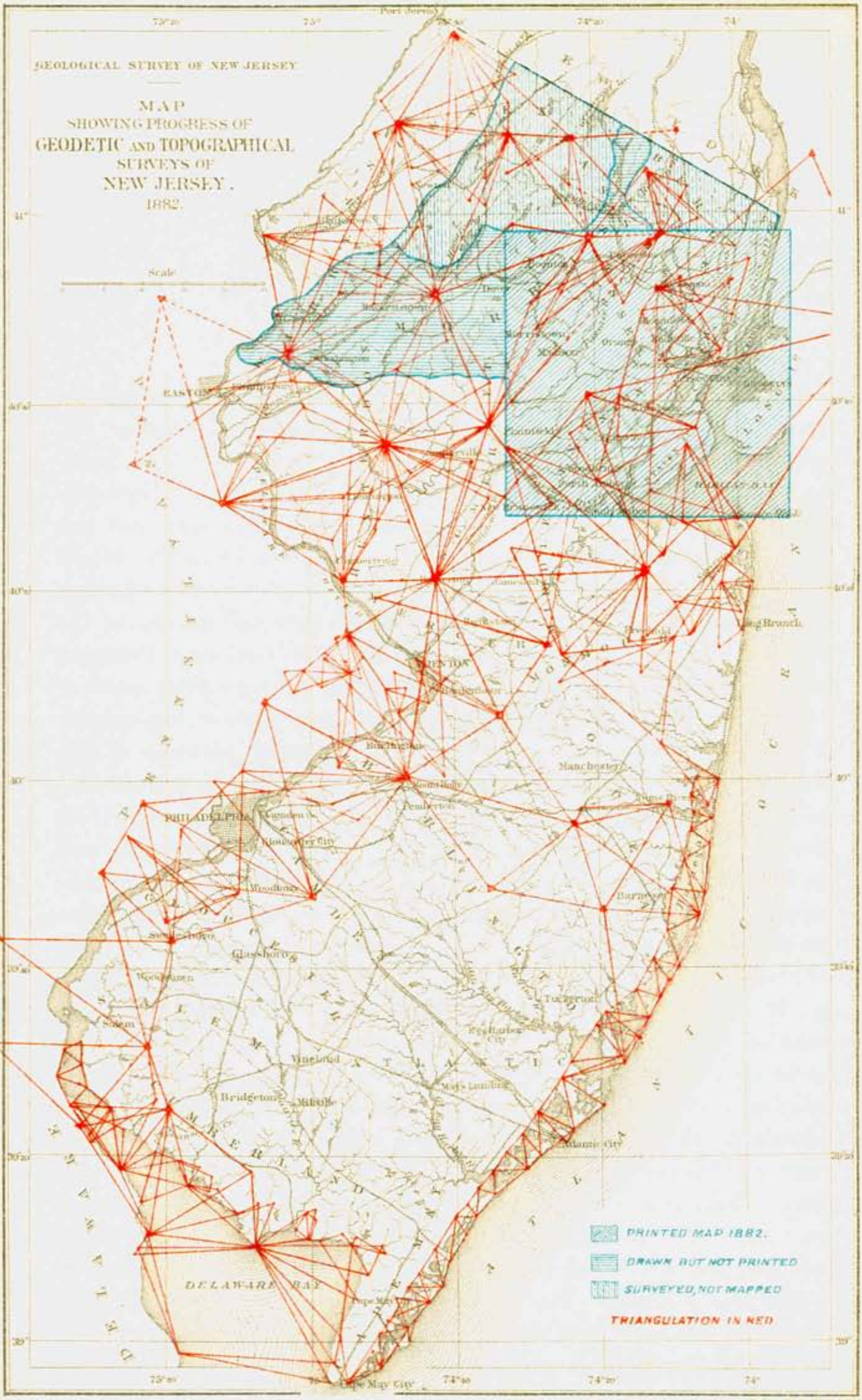
THE UNITED STATES COAST AND GEODETIC SURVEY.

The operations for determining with accuracy the latitudes and longitudes of marked and conspicuous points in the different sections of the State have been continued during the season just closed. The progress made has been very satisfactory. The condition of the atmosphere has been favorable for making accurate observations, and more than an average amount of work has been accomplished during the year. The accompanying map shows the location of the points which have been occupied and observed upon. They are marked in full red lines. Those which are not yet completed are made in dotted red lines. The portions of the State not marked are still unsurveyed. Up to this time there have been occupied :

11 primary stations (new).
15 primary stations (old).
45 tertiary stations (new).

These, when completed, which it is hoped can be done next season, will cover 5,326 square miles, or nearly three-quarters of the area of the State, the whole area being 7,576 square miles.

This work, though done by the United States Coast and Geodetic Survey and at the expense of the general government, is of great value to the State of New Jersey. It furnishes an accurate basis for our maps, and enables us to give a degree of precision to them which we could not otherwise secure. It follows the direction given by our survey and completes its work in those parts of the State where the prosecution of the topographical surveys renders the geodetic points necessary for the correct construction of the maps.



Julius Bien & Co. lith.

II.
TOPOGRAPHICAL SURVEY.

The field work of the Topographical Survey has been continued throughout the season. A party of five, and part of the time six, topographers has been steadily at work, since the first of May, leveling, contouring and surveying the northern portion of the Highlands and the unfinished part of Bergen county. The area surveyed this year is 480 square miles, of which 380 square miles lie on the Highlands and include all the portion of Sussex county east of the Lehigh and Hudson River Railroad south of Hamburgh, and all east of the Wallkill from there northward; also West Milford and Pompton townships, in Passaic county, and the corner of Morris county north of 40° 58′, north latitude. It is the most difficult piece of topography in the State, including, as it does, the irregular plateaus of the Wallkill, Bowling-green, Hamburgh and Wawayanda mountains; the rough, jagged and desolate ridges of conglomerate known as Green Pond, Copperas and Bearfort mountains; the peaked Wanaques and the high ridge of gneiss called the Ramapo mountains. It is sparsely populated, mostly covered with timber, which increases the difficulties. On this account progress has been somewhat slower than the average will be hereafter. It took the same time, for instance, to work up 10 square miles on Bearfort that was required to work up 20 square miles of average Highland country, or 30 square miles of the regular sandstone country of Bergen county, notwithstanding the fact that we substituted the telemeter and trigonometrical leveling for the leveling instrument, the former being peculiarly suited to this country, giving great satisfaction as to accuracy and saving fully two-thirds of the time. Bearfort was found to contain five beautiful little lakes, ranging from 1,100 to 1,400 feet above tide-water, three of which had never been mapped at all, and the remaining two very erroneously both as to size and location. The whole district is interspersed with many fine ponds and lakes, and the scenery is picturesque and beautiful.

The 480 square miles which have been surveyed during the season will be mapped in the course of the winter, and excepting about 150 square miles of the extreme southern part of the Highlands, which remains to be surveyed, the map of the Archaean portion of the State, the district in which all our iron mines are found, will be ready for the engraver.

The whole area covered by the survey up to the present time is 1,740 square miles. Of the work of preceding years, amounting to 1,260 square miles, 847 square miles are included in the map published this year, and 413 square miles are mapped ready for the engraver. The small map accompanying shows the location and comparative extent of these surveys.

As stated in last year's report, the levels previous to that time were referred to mean tide at Newark, as near as we could get to it without a long series of tidal gaugings. During the early part of this season we connected our previous levels with those of the United States Coast and Geodetic Survey from Sandy Hook to Phillipsburg, referred to mean tide at Sandy Hook as determined by a series of observations six years long. The test was made at Phillipsburg after three years of leveling, and the error was found to be nine-tenths of a foot, which is probably not more than the difference between our old datum and theirs. The elevations will henceforth refer to mean sea level at Sandy Hook.

The maps resulting from these surveys, so far as they have been published, are fast commending themselves to the public, and have already proved their usefulness in many ways. They have been studied advantageously in the location and construction of water-works, they furnish readily complete information as to the comparative feasibility of different routes of travel, the practicability of drainage works, the fall of streams for power, etc., and as their utility comes to be better understood they will largely curtail the expenses of preliminary surveys in all engineering works and improvements.

III.

GEOLOGICAL WORK IN PROGRESS.

1. RED SANDSTONE DISTRICT.

There is a renewed interest in the geology of this district, in connection with the issue of the first of our topographical maps of New Jersey. This map is entitled a map of "a part of Northern New Jersey," and nearly all the area which it represents is included in the red sandstone district.

The presentation of more accurate and detailed maps of a country gives the opportunity of calling in the aid of a much larger number of intelligent observers to ascertain the facts and study out its geology. The red sandstone is represented not only in New Jersey, but also in New York, Connecticut, Massachusetts, Pennsylvania, Maryland, Virginia and North Carolina, and it is marked by many characters, which are common to it, in all these States. Its brownish-red color strikes the eye of every stranger who crosses it. And the well-known brownstone, so much used in building, is all obtained from this district.

Its geological age, structure and origin have been the subjects of study by some of the ablest American geologists for nearly fifty years past, and many questions connected with it are still unanswered. Profs. Wm. B. and Henry D. Rogers, in 1839, demonstrated that it was not as old as the coal formation, and Prof. Ed. Hitchcock, in the same year, with W. C. Redfield, presented strong evidence to show that it was older than the lowest member of the Jurassic formation. At a later period some evidence was brought forward by Lyell and others to show that some of the upper portions of the red sandstone were of the Jurassic formation. The extreme scarcity of fossils found in this rock has hindered geologists from reaching settled conclusions in regard to its precise geological position and age. Shells and other invertebrate fossils are not found in it. Fossil fishes have been found in these rocks in numerous places, and the foot-marks of animals have been found plainly impressed upon the rocks. Remains of trees, leaves and other vegetable growth, are found in many places, but usually not distinctly marked. Bones of a few reptiles have been found. The number and character of them, however, has been such as not to fully satisfy the inquirers into the age of the sandstone.

Fossils from this rock, with their localities carefully marked, are much needed, and it is to be hoped that many such may yet be collected, and persons knowing of such fossils or localities are desired to communicate with this survey.

At the present time most geologists designate it the Triassic formation.

The *structure* of the formation is remarkable. Its strata in New Jersey generally dip towards the northwest, as do those in Pennsylvania, and those most westerly in Maryland, Virginia and North Carolina. On the contrary, the red sandstone in Massachusetts, Connecticut, eastern Virginia and North Carolina, all dips towards the southeast. There is very little curvature to the strata, or bending or folding in any way. Thus, in passing across the belt of this rock which lies in New Jersey, the geologist going from the southeast towards the northwest will find generally the strata dipping towards the northwest at angles of from 15° down to 5°, or less, but no strata dipping towards the southeast. Neither has the rock been fractured or much disturbed by any later changes. A very few faults have been found, but they are of only a few feet in extent. Taking these data for a basis of calculation, it would make the formation not less than 25,000 feet in thickness. This peculiar structure and enormous thickness have given rise to much speculation and study as to its origin, or the source whence all this material was derived.

Its origin was attributed, by Prof. Rogers, to a broad stream or water channel extending from higher grounds in North Carolina, and descending in its course across Virginia, Maryland, Pennsylvania, New Jersey and New York to its outlet on the ocean. And this stream, in the course of time, brought down and deposited in its channel or trough the materials in the position in which we now find them. The difficulty in accepting this explanation is, that the strata dip towards the northwest side of the stream, and not up or down it, as we should expect it to do. Various other explanations have been attempted, depending on changes of level due to the enormous weight of a mass of rock five miles thick upon a limited portion of the earth's surface; or to the internal changes effected by the rupture of the earth's crust and the escape of the great masses of eruptive rock which are now piled up in the numerous trap ridges of this district; but none of these fully meet the difficulties of the case.

Prof. W. C. Kerr, in his "*Geology of North Carolina*," *1875, p. 145*, says: "There is no way of accounting for the present position of these (Triassic) beds with their opposite and considerable dips, but by supposing an up-lift of the intervening tract, such, and so great, that if the movement were now reversed, it would carry this swell of nearly 100 miles breadth, into a depression much below the present level of the troughs in which these remnant fringes lie, so that there has been an erosion not only of 10 to 20,000 feet of the broken arch of Triassic beds over this area, but also of a considerable thickness of the underlying rocks on which they had been deposited."

At the meeting of the American Institute of Mining Engineers, held in Philadelphia, February, 1878, Oswald J. Heinrich, M.E., read a paper on "The Mesozoic Formation in Virginia," in which he took the ground that "the destruction of a connection formerly existing between all the mesozoic depositions along the Atlantic States might therefore be attributed to a slow and unequal rising of the eozoic rocks, after the deposition of the former upon the uneven floor of the latter, noticed in the anticlinals of the latter, and producing an unequal denudation of the mesozoic deposits. The rising of these older rocks upon one side may also have produced subsequent partial depressions of the section along the Atlantic."

A paper "On the Physical History of the Triassic Formation in New Jersey and the Connecticut Valley," was read by Israel C. Russell, before the New York Academy of Sciences, on the 27th of May, 1878, in which he advocated the same view as Mr. Heinrich. He says "that the facts which we have gathered as to the physical history of the Triassic beds of New Jersey and the Connecticut Valley, tend strongly to show that these two areas are the borders of one great estuary deposit, the central portion of which was slowly upheaved and then removed by denudation. * * * That the detached areas of Triassic rocks occurring along the Atlantic border, from New England to North Carolina, seem fragments of one great estuary formation, now broken up and separated through the agency of upheaval and denudation."

Prof. Dana, in the *Am. Jour. Science, Ser. 3, Vol. XVII., pp. 328–30*, presents strongly the difficulties for which the above hypothesis is insufficient.

There are a large number of other articles in geological reports and scientific journals, which have been written upon this formation, but the peculiarities of its origin and structure are still demanding observation and study. And it is brought prominently forward in this report for the purpose of enlisting the aid of the large body of observers in our State, who may, by their varied contributions, supply the material which is needed in order to correctly solve the questions still open.

The hypothesis we are at present disposed to follow is, that the various detached portions of this general formation which are found east of the Apallachians, and extending from Massachusetts to South Carolina, were once, in some way, connected, and perhaps, also, those further northeast in the British Provinces. That after their deposition on a very uneven bottom, the underlying rock has been disturbed by a number of axes of elevation, or else of great faults, which have crossed the formation obliquely but in a direction much nearer north and south than the general trend of the formation. The Hudson river, and the country east of it towards the Connecticut, represent one or more of these. The axis which crosses the Delaware at Lambertville, and in which the magnesian limestone is now exposed in Pennsylvania, and the lower, coarse white sandstone in New Jersey, is another; and the long line of exposure of the Triassic in Virginia, in a nearly north and south line, south of the Potomac, shows the direction and extent of another of these; and numerous smaller ones can be traced out. The elevation of these axes would give a general dip of W. N. W. on one side, and E. S. E. on the other, but not at right angles to the trend of the formation, and it would not require so great a thickness for the whole mass as has been generally computed.

After this process of elevation was well advanced the eruption of the trap-rocks began, and must have been continued for a long period

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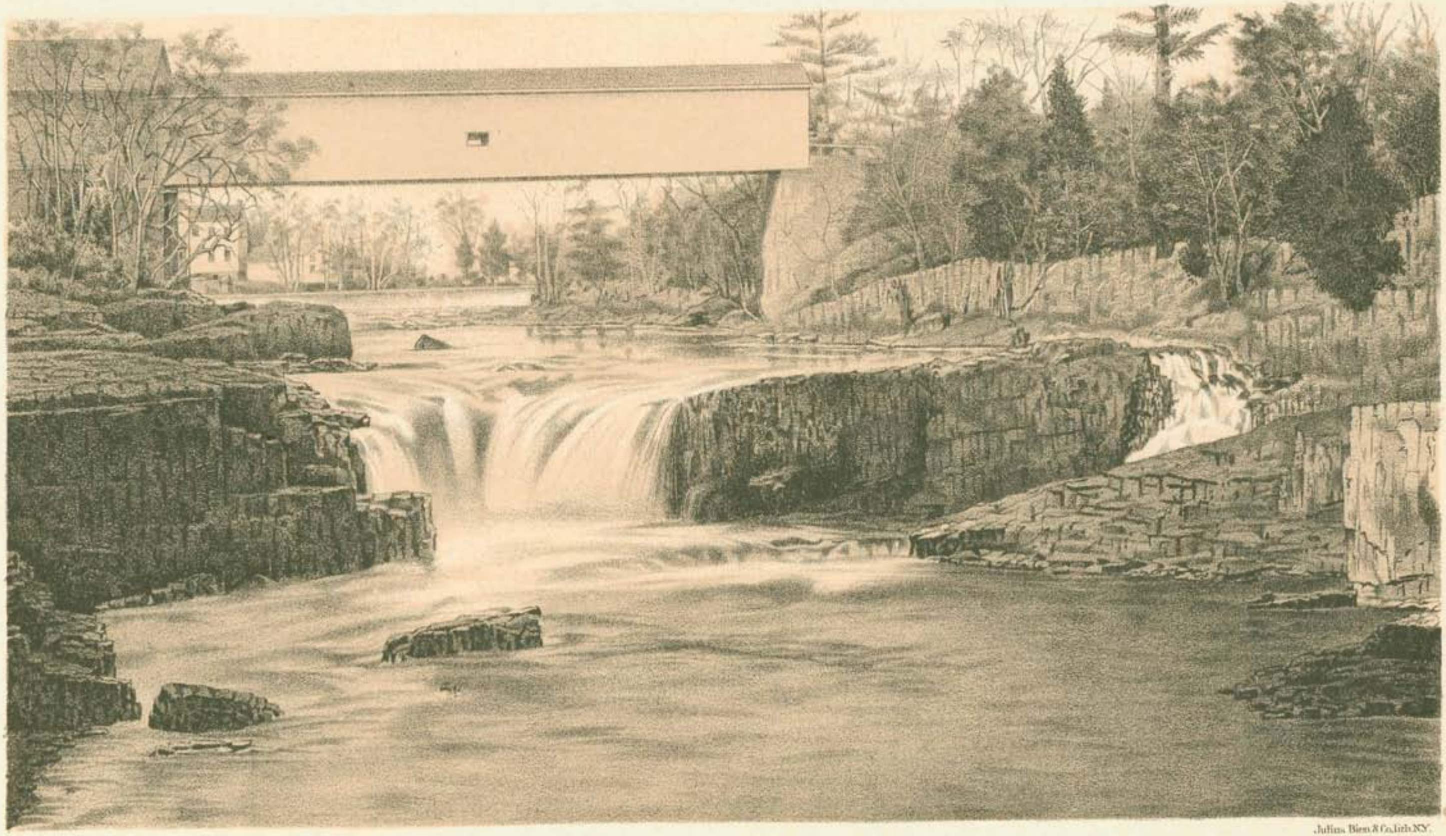
NOTE.—The accompanying view of the country near Plainfield shows the three characteristic features of the denuded red sandstone which are mentioned in the text. The view was taken from the brow of the terminal moraine of the glacial drift, at Avon Park, two miles southeast of Plainfield. 1. The abrupt ending of the moraine of sand and gravel is seen in the foreground. 2. The extended plain from the moraine to Plainfield and the mountains beyond. 3. The ridges or mountains of trap-rock in the background; the second ridge showing through a gap in the first.

Julius Bien & Co. lith. N.Y.

SANDSTONE PLAIN, PLAINFIELD
WITH TRAP-ROCK RIDGES IN BACK GROUND AND TERMINAL MORAINE IN FRONT.



Julius Bien & Co. lith. N.Y.

LITTLE FALLS ON THE PASSAIC.
SHOWING THE RETROCESSION OF THE FALLS.

of time. The peculiar curved form of the trap ridges would necessarily occur where the upward force of the eruptive rock was applied against the inclined surface and pressure of the stratified rocks. The denudation of the surface, to the extent of from 100 feet to 600 feet or more, took place after this, but mainly before the Cretaceous period. By denudation the softer sandstones and shales have been removed to so great an extent as to leave some portion of the Archaic and Silurian rocks entirely uncovered, to leave the red sandstones and shales in the deeper troughs between the axes of elevation, and to leave the hard eruptive rocks, which were but little above the other rocks, now standing out above the plain surface of the denuded sandstones and shales in the long, rocky and rough ridges which are so prominent a feature of our Triassic formation.

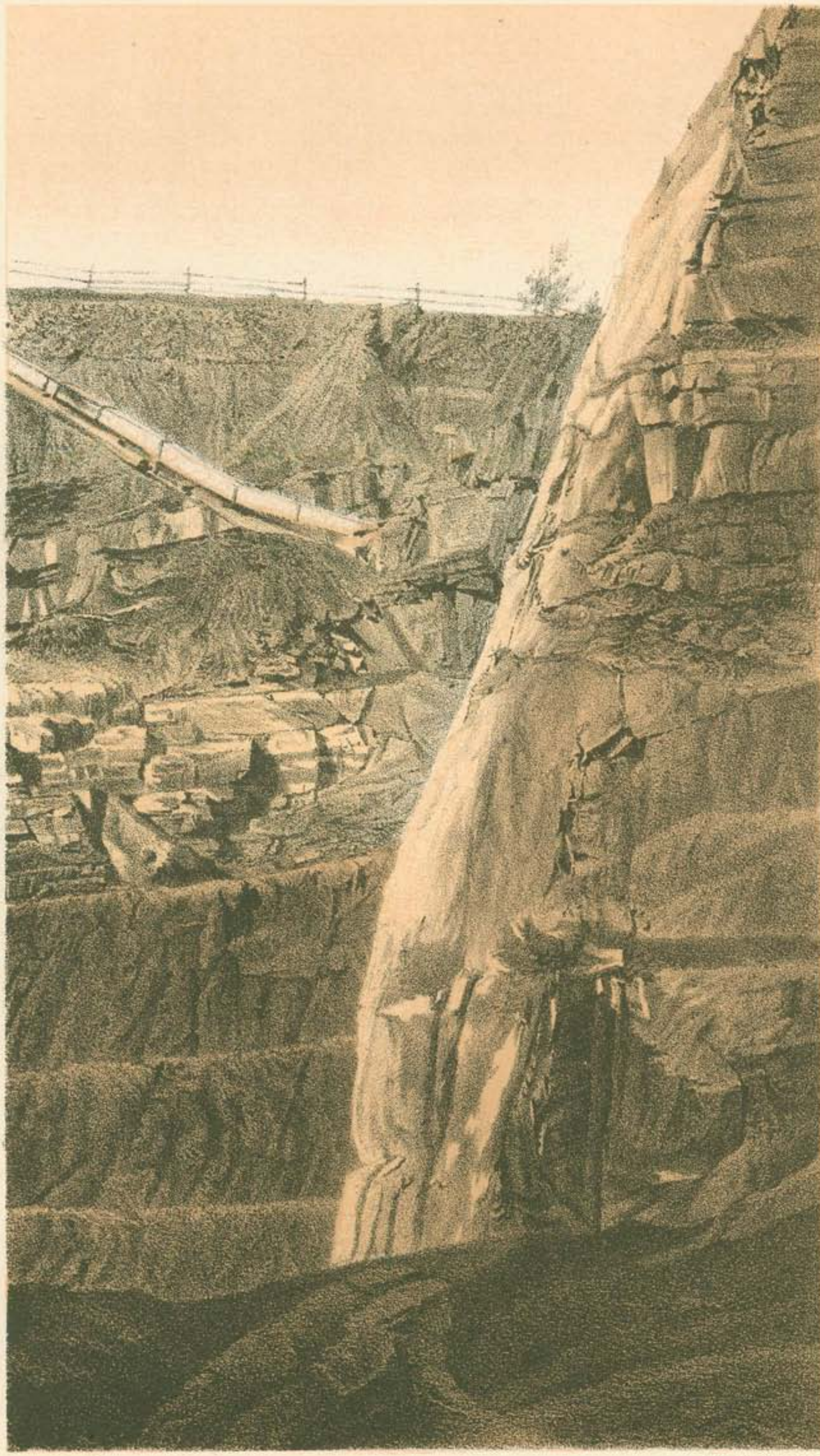
More facts can be consistently arranged upon this hypothesis than upon any other which has been suggested, and we propose to try it still further in the prosecution of our work.

The location and extent of the formation in New Jersey, both its sandstone and trap-rocks, are laid down with reasonable accuracy on the accompanying State map.

The view of Little Falls on the Passaic, four miles above Paterson, is intended to show the extent of erosion or wearing back of the falls since the river began to run over this outcrop of trap-rock. It is not possible now to indicate where the drainage lines in the sandstone ran previous to the outbursts of the trap. But since the close of the eruptive period, when the general surface configuration had assumed somewhat its present shape, the drainage of the Upper Passaic valley has found an outlet over the Second mountain range through the depression at Little Falls. The ledges on both banks of the river below the falls, and quite down to the edge of the trap, have many pot-holes in them, indicating that the stream once ran there. The general level of the trap-rock, on either side of the falls, is 170 to 180 feet. The eastern line of the wall or escarpment of this rock crosses the river in a south-southwest course, from the old quarry on the left bank, near the west end of an alluvial island and striking the right bank of the stream below the aqueduct and opposite the M. E. Chapel. The top of the ledges or line connecting the existing levels is about 50 feet above the stream. From this line the gorge is worn back its full depth to the aqueduct, which is about 400 feet. Thence to the falls the depth is less, and the distance is near 300 feet. The average breadth of the gorge may be 300 feet, varying a little in its different parts. The original falls were apparently over the mural front where the line of trap-rock crosses the stream near the quarry and the west end of the island. The breadth was then not less than 300 feet and the height 50 feet. The whole distance worn back amounts, therefore, to near 700 feet. The head of the main fall is now 654 feet from the head of gates in the Beatty dam, and the depth of the channel slopes down to 11 feet below the top of ledge at the dam. The total length of the wear has been about 1,400 feet. The falls are shown in the Plate No. 2. This view is taken from a ledge on the right bank of the river near the Morris canal aqueduct. The trap-rock walls on the sides of the river are seen with their prismatic structure and planes of bedding.

FAULTS in the red sandstone have been observed at a few localities only. On account of the great uniformity in the color and composition of the shales and sandstones, it is difficult to prove the existence of any great displacements in the strata, and the faults proved to exist are only very slight ones. But a few such have been seen. They have been observed in the bluff northwest of Milford along the Delaware, in the rock cuttings on the line of the Lehigh Valley Railroad, near Sidney Church, and in the Central Railroad cuts, near White House, in Hunterdon county. At Arlington, on the line of the New York and Greenwood Lake Railroad, there is a very plainly marked fault. But the amount of the offset in these faults is not certain. The most conspicuous and clearly marked one is that in the sandstone of the quarries at North Belleville. The view of this fault, as seen in Robison's quarry, is shown in Plate No. 3. The displacement here amounts to about five feet. The plane of the fault dips 65° or 70° to the west, or, more accurately, N. 87° W. (magnetic bearing). The beds on the west have slid down, while those to the east have been upraised. No doubt other faults can be found. And the existence of long lines of faults may help to explain the apparent great thickness of the formation. Slickensides also occur, but they give no clew to the extent of movements in the rock.

There are no evidences of folds on a large scale, unless the repetition of certain orderly series of strata, as along the Delaware, near Greensburg, may be interpreted as the corresponding parts of closely folded synclinals and anticlinals, whose axes all dip towards the northwest at a low angle. Or, the ridge and valley structure of Bergen county, may be due to similar close folds. At present these explanations are



Julius Bien & Co. lith. N.Y.

RED SANDSTONE QUARRY, NORTH BELLEVILLE

SHOWING LINES OF BEDDING AND FAULT

hypothetical. Folds, on a small scale, have been observed along the Lehigh Valley Railroad, near Sidney Church and Pattenburg. A succession of cuts in the sandstone and conglomerate exhibit a gentle synclinal near the former place, and smaller folds with slight faulting and some contortions, to the northwest and nearer Pattenburg. At one point the strata are crumpled as if they had suffered under a lateral pressure. The rocks in this vicinity appear to have been much disturbed, and make a marked exception to the wonderful uniformity so strongly characteristic of the formation generally. The discovery of additional localities exhibiting phenomena of faulting, folding, &c., is greatly to be desired. Thus far, a very general examination has failed to find any other than those referred to above.

DESCRIPTION OF THE RED SANDSTONE FORMATION IN NEW JERSEY.

The red sandstone formation in New Jersey is a part of the long and comparatively narrow belt which stretches continuously from the Hudson river in a general southwesterly course into Virginia. Its length, from the Rockland county line on the northeast to the Delaware river, is about 70 miles. Its breadth varies from 15 miles at the State line to 30 miles on the Delaware. The area of the formation, as measured on the State geological map, is 1,507 square miles. Its boundaries are shown in detail upon the geological map which accompanies this report. On the north and northwest it abuts against the older blue limestone and the gneissic and granitic rocks of the Highlands. Topographically viewed, it is a plain shut in on the north and northwest by the Highlands and open to the south and southeast. The blue magnesian limestones are in coves, as it were, to the west of southwards projecting tongues of the Highlands. The map shows such areas at Peapack and north of Clinton. The Pottersville and Little York outcrops are smaller and narrow and lying at the margin of the Highlands. For the sinuosities in the northwest boundary the reader is referred to the map. The tidal waters of the Hudson river and New York bay make the eastern limit as far as Bergen Point. Southwest of Staten Island Sound the southern border of this formation is overlapped by the newer deposits of Cretaceous clays and sands nearly all the way across the State. But near Trenton, the older gneissic rocks appear, separating the sandstone and the clay beds. This wedge-shaped outcrop of older and crystalline rock crosses the river at Trenton and constitutes the south boundary of the belt in Pennsylvania. Practically the crystalline rocks on the east of the Hudson and the outcrops of gneiss in Jersey City make its eastern margin. The Trenton gneiss belongs to the same belt, and it is no doubt continuous under the beds of clays and sands throughout the whole extent of this border of the sandstone. The absence of the coarser-grained sandstones in the outcrops in Middlesex county and the incurving boundary line, are proofs that the border is here covered by more recent deposits. The isolated hill, known as Inslee's Hill, south of Woodbridge, and the prolonged lines of the Palisade mountain and Ten-mile-run ranges of trap-rock indicate the true border as being from one to three miles south of the present outcrop. Beyond the State line to the north, this belt of sandstone terminates at Haverstraw bay and near Stony Point. Its maximum breadth appears to be where it is crossed by the Delaware river. It narrows in Pennsylvania and does not widen much until the Susquehanna is crossed near Harrisburg. The general trend of the belt bears more to the west at the Delaware, and it constitutes the arc of a large circle whose convexity is turned to the southeast. It corresponds to the great Appalachian system by which its features were determined.

The rocks of this red sandstone formation (using this term in its widest significance) are shales, sandstones, siliceous conglomerates, calcareous conglomerates, limestones and the trap-rocks. The predominance of the red shales and sandstones have given character to the surface and a name to the whole district. They crop out over wide areas and make up the greater part of the drift which conceals the strata over other large tracts. It should be said in this connection that very nearly half of the belt is north of the terminal moraine, and the rocks are, to a great extent, concealed by glacial drift and by alluvial beds deposited in basins formed by glacial moraines. The drift-covered area lies north and northeast of the moraine, in Hudson, Bergen, Passaic, Essex and Union counties, and the northern part of Morris and the eastern part of Middlesex. In Somerset, Hunterdon and Mercer counties, the outcrops are much more numerous and the soil is more largely made up of the shales and sandstones. The conglomerates are confined mainly to the northwest border. Their outcrops are too small for representation upon the map. Conglomerates are seen in the central portion of the belt, in Bergen county, at Paterson, and near Stockton, Hunterdon county. Occurring in beds a few feet thick only, they soon disappear, dipping beneath the overlying shales and sandstones.

The trap-rocks have resisted erosion on account of their greater hardness, and hence stand out above the softer shales and sandstones, and are more prominent features in the topography. Their actual outcrop is comparatively small and amounts to 190 square miles, or about one-seventh of that of the other rocks. The map exhibits the trap-rock areas by greenish belts in the brown sandstone. The details of the boundaries are not given, since they are substantially as printed in 1868, in the "*Geology of New Jersey*."* The general course of these trap-rock outcrops is parallel to that of the belt itself—from northeast to southwest. Palisade mountain, the Watchung mountains and Sourland mountain, are long ranges in this direction. The exceptions to this course are mostly where they turn to the west and northwest, giving to the outcrops crescent-shaped terminations. The general parallelism of two or more close lying ranges is also noticeable. The First and Second Watchung mountains are striking examples of closely parallel and crescent-shaped ranges. The interior Hook mountain, Riker's Hill and Long Hill, make a third line in the series. The trap-rocks cannot be said to be confined to any particular portion of the belt. They are irregularly distributed throughout, although there is a marked absence of this rock in the outcrops along a section crossing from southeast to northwest, in the valley of the Raritan. Nowhere else, excepting near the New York line, is the whole breadth free from trap-rock. The semi-circular outcrops near New Vernon, in Morris county, and of Round Valley mountain, in Hunterdon county, are also peculiar features.

SHALES.—The shales of this belt are of all degrees of hardness, from scarcely compacted clay to what may be termed argillaceous sandstone. While the softer varieties can be split apart readily along the planes of bedding or lamination, or on irregular planes nearly parallel to the bedding, they cannot be crushed by the hand. They are in this way distinguishable from clays and marls which can be broken by the pressure of the hand in any direction, and which show no signs of lamination. In the more indurated or altered shales the degree of hardness is above that of clay slate and approaches that of quartz in form of jasper or chert. The prevailing shades of color are red. In

*See pages 176–194.

many places the shale is of a bright pinkish shade and gives a warm and lively color to the soil. Yellowish shades also are common. The harder, altered varieties are generally of some dark color, purple to black, and cherty-like in appearance. The composition is like that of sandy clays, very much modified by the presence of bituminous or calcareous matters, so that we have bituminous shales, impure limestones or calcareous shales, besides the various grades of arenaceous or sandy shales. There is no definite composition and scarcely any which could be given as a type.* The softer varieties soon fall to pieces on exposure to the air, and make reddish clayey soils, or when wet, tenacious red mud. The dark-colored, indurated shales do not crumble readily, but resist the weather for a long time. They make a light-colored, clayey, cold and tight soil.

SANDSTONE.—As in the shales, there is a great variation in the sandstones also. In color, hardness, endurance, solidity, and in composition there is a wide range. Red is the prevailing color, but much of the beautiful and well-known building stone of our many quarries in this rock, is light-colored. A typical rock is the argillaceous sandstone, which can be broken easily by the hammer, and which soon falls to pieces on exposure to the frosts and other atmospheric agencies. Next to the shale, this is the more common rock; and much of the shale, when followed down, becomes a shaly sandstone. This variety has no value for building purposes. It occurs in beds usually from a few inches to two feet thick, and is traversed by joints, as the more solid strata. This variety is in many places interstratified with the thicker and more solid building stone. The sandstone varies greatly in the fineness of grain, from a fine conglomerate to a dense mass in which no grains are apparent to the unaided eye. Much of the stone at the foot of the Palisades, for example, consists of a cemented mixture of quartz and feldspar, in slightly rounded or even angular fragments. At the Trenton, or Greensburg quarries, on the Delaware, a similar rock is quarried. Nearer Trenton the rock is of quartz and feldspar so slightly compacted that it crumbles in the hand. Mica is also a common constituent, but in very thinly scattered flakes. There is scarcely any sandstone in the formation which can be said to be micaceous. Quartz is, however, the predominant constituent. Feldspar and mica are quite subordinate. Compounds of copper, coal and

* Analyses. See "Geology of New Jersey," pp. 384–385.

other minerals are less common or accidental constituents. Analyses indicate from 88 per cent. upwards of silica. The cementing material may be siliceous, calcareous or ferruginous. The disintegration of sandstone produces a more open and more sandy soil than that derived from shale. On account of the beautiful color, the ease with which it is dressed, and the durability of the sandstone in many localities, quarries are numerous in it; and in them the variations from bed to bed, and the irregular alternations of shale and sandstone, with forms of bedding, joints, faults, and other features in the structure, are well exposed. In consequence of the frequent alternations in bedding the outcrops of any particular type of rock are narrow, and hence are not traceable on the surface. Certain horizons, however, are marked by characteristic layers or beds and by certain grades of stone which extend lengthwise the belt for long distances. The mapping of these areas has not thus far been practicable.

CONGLOMERATES.—When the stony matrix holds imbedded pebbles or fragments of other rocks, it is known as conglomerate, or breccia, according as the imbedded pieces are rounded or angular. And the composition may be siliceous, or calcareous, as the quartz, or calcareous materials predominate. There are two prevailing types of conglomerates. The calcareous variety is best known from its use in making lime. It occurs on the northern border of the formation, near Pompton Furnace, in Passaic county; between Pottersville and Lebanon, in Hunterdon, and again near Clinton. In this stone the blue limestone pebbles abound. They are more or less rounded, and range in size from those half an inch in diameter, to some three or four inches across. The matrix is red, shaly, but quite hard. The rock-mass has a variegated appearance. The siliceous, or quartzose conglomerates, are to be seen at Montville, near Peapack, and near Milford, on the northern border, besides other localities, both on this side and also in the central part of the belt. The matrix is red, and apparently siliceous; the pebbles are mostly quartz, but occasionally there are those of older rocks, as gneiss or granite, sandstone, slate, blue limestone, chert, &c. And red shale and red sandstone are also quite common, indicating the wear of older beds of the formation in making these higher beds. The variations are somewhat local; thus, at Montville, there are large and slightly rounded gneiss pebbles with the sandstone and quartz. Above Milford, on the Delaware, the included pebbles are very large, up to cobblestone size, and are nearly all of a red sandstone or quartzite. At Greensburg, and also at Prallsville, the conglomerate holds many white sandstone (Potsdam) pebbles. Some of the more solid of the strata at the latter locality are quarried for building purposes.

LIMESTONE.—This rock is of so limited extent that it can scarcely be regarded as one of its types. It occurs in a thin stratum at Feltville, between the First and Second mountains, and the patches outcropping near Sidney Church, and one on the Bonnell farm, west of Clinton, are also supposed to be of the same age. At all of the localities it is a dark-blue, thin-bedded stone. It is not dolomitic.

TRAP-ROCKS.—Under the head of trap-rock we include all the varieties of igneous rocks found in the belt. The examinations which have been made of such rocks from Bergen Hill, by the late Dr. Geo. W. Hawes, of the National Museum, show that dolerite is the prevailing variety. It makes up the mass of the several trap ranges.

A remarkable feature of the red sandstone formation is the very general dip of its strata towards the northwest and west. The amount of dip or inclination of the beds is nearly everywhere at low angles, from 5° to 20°. A steeper dip is rarely to be observed in the rocks, excepting near the northwest border and near some of the trap-rock ranges. In Bergen county the prevalent direction is west and a few degrees north of west. In Hudson and Essex the direction is more nearly northwest. Throughout Union, Middlesex, Mercer and Hunterdon counties the variation is between north and west. The largest area of exceptional direction, or of altered strike is found in Somerset and the northeast part of Hunterdon counties, where the dip is toward the northeast. This tract extends from the Raritan and Millstone north through Bridgewater, Hillsborough, Branchburg, Readington, Bedminster and Bernard townships. It covers 200 square miles. The dip is at low angles. The other exceptional dips are to the southeast in a narrow belt along the Highlands, in Bernard township, and near the northwest ends of the Second and of the Towakhow mountain ranges, in the vicinity of Pompton, where the direction is to the southwest. The curvatures of the trap-rock ranges show the changes in strike and dip, since, with very few exceptions, the trap-rock is seen lying upon the sandstone and not cutting across its strata. The following table of dips arranged geographically gives the inclination of the strata at a large number of selected localites.

The arrangement of the dips as they are technically termed, is shown in a tabular statement. The localities of the observed dips, or stations, are arranged in a geographical order. Beginning at the northeast they follow one another, through Bergen, Hudson and the parts of Passaic, Essex and Union counties which are east and southeast of the First and Second mountain ranges; thence across Middlesex, the southern portion of Somerset and Mercer counties to the Delaware river. About one-half of the formation is covered by this part of the table. And it is the southeastern or lower part of the formation. The order then follows the valley of the Delaware through the western part of Hunterdon county to the gneissic rocks on the northwest border. A few localities on the Pennsylvania side of the river are included in the list. It is notable that with the exception of five observations between Hopewell and Marshall's Corner, in Mercer county, the direction is in a general northwesterly direction, or in the quadrant between north and west. The second part of the table begins near Flemington, and the localities in the eastern and northeastern parts of Hunterdon follow; then, those near the Highlands on the northwest border, as far as Peapack, in Somerset county. The northeast dips of Raritan and North Branch valleys are grouped together, followed by the southeast dips near Lesser Cross Roads, Peapack and Bernardsville. The localities in the Upper Passaic valley, from Millington northeast to Pompton Furnace, and a few southwest dips north of Paterson close the list. The latter part of the table contains the varying directions, although the northeastern and southwestern directions predominate. There are comparatively few northwest directions.

In this table the first column gives the kind of rock, the second names the locality; the third states the direction (magnetic bearings, which are on the average 8° west of the true meridional line); in the last column the amount in degrees is given, or the angle which the strata make with the horizon.*

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*The term *gentle* is used to indicate dips not exceeding 15°, but which were not measured.

TABLE OF DIPS.

ROCK.	LOCALITY.	DIRECTION.	AMOUNT.
Sandstone	Bank of Hudson river, Rockland Lake, N. Y	W.	14°
"	Bank of Hudson river, Sneden's Landing, N. Y.	W. N. W.	Gentle.
"	Bank of Hudson river, north of Closter Landing.	N. 75° W.	Gentle.
"	Bank of Hudson river, 1½ miles north of Ft. Lee.	N. 60° W.	Gentle.
"	Bank of Hudson river, Fort Lee	N. 60° W.	8°
"	Bulls Ferry	N. 80° W.	15°
"	Weehawken	N. 60° W.	20°
Indurated shale	East entrance tunnel, N. Y. W. S. & B. R. R., Weehawken	W. N. W.	Gentle.
Sandstone	Hoboken, West Hoboken boulevard	W. N. W.	Gentle.
"	Bayonne City, 44th street	N. W.	Gentle.
Indurated shale	Palisade mountain, west slope, near Alpine	N. W.	Gentle.
Sandstone	Fairview, N. Y. W. S. & B. R. R. cut	N. W.	Gentle.
"	N. Y. W. S. & B. R. R. cut, entrance to Weehawken tunnel	N. W.	Gentle.
"	Sufferns, N. Y., Piermont R. R. cut	N. 40° W.	20°
"	Pascack	N. W.	Gentle.
"	Saddle river, near Luth. Ch	N. W.	Gentle.
"	Hohokus, N. L. E. & W. R. R. cut	W.	Gentle.
"	Paterson, Hartley's quarry	W. N. W.	7°-10°
"	Paterson, Water Power Co.'s quarry	N. 70° W.	7°-10°
"	North Belleville, Philips' quarry	N. 45° W.	10°
"	North Belleville, Robison's quarry	N. 45° W.	11°
"	Arlington, Westlake's quarry	N. W.	Gentle.
"	Secaucus, north of Snake Hill	N. 60° W.	Gentle.
"	Snake Hill near county alms house	N. 20° W.	15°
"	Newark, Newark Quarry Company's quarry	N. 65° W.	5°
"	Newark, Patterson's quarry	N. 60° W.	8°
"	Llewellyn Park, quarry	N. 50° W.	7°-10°
"	Orange, Jas. Bell's quarry	W. N. W.	15°
"	Orange mountain, near Mountain road	N. 70° W.	Gentle.
"	Orange mountain, southeast of last station	N. 60° W.	Gentle.
"	Little Falls, old quarry, north of village	N. W.	10°
"	Little Falls, Beatty's quarry	N. W.	5°-10°
"	Pleasant Valley, Shrump's quarry	N. 70° W.	10°
"	Feltville	N. W.	15°
"	Valley near Feltville	N. 30° W.	Gentle.
"	Washington valley, quarry	N. 30° W.	10°-15°
"	Washington valley, ¾ mile southwest of quarry	N. 20° W.	Gentle.
hale	Copper mine (Field's	N. N. W.	15°

TABLE OF DIPS—*Continued.*

ROCK.	LOCALITY.	DIRECTION.	AMOUNT.
Shale	Near Edonia	N. 30° W.	8°
"	Dock Watch Hollow	N.	Gentle.
"	Plainfield, in Green valley copper mine	N. 15° W.	10°–15°
"	Plainfield, in New Jersey copper mine	N. 20° W.	Gentle.
"	Samptown	N. 30° W.	15°
"	Inslee's hill, south of Woodbridge	N. W.	Gentle.
"	Indian brook, near the Raritan	N. W.	10°
Sandstone	Martin's dock	N. 40° W.	10°
"	Raritan river bank, opposite Martin's dock	N. 30° W.	13°
"	Raritan river, below New Brunswick	N. 45° W.	10°
Shale	Lawrence brook, near Raritan river	N. W.	15°
Shale and sandstone	New Brunswick to Raritan Landing	N. 15°–40° W.	5°–12°
" "	New Brunswick, One Mile run	N. 40° W.	7°
" "	Raritan river, quarry at 5-mile lock	N. 40° W.	10°
Shale	Bound Brook, west	N. 20° W.	5°
"	Bound Brook, west of last station	N. 10° W.	5°
"	West of Middle brook, along canal	N. 10° W.	5°
"	One mile west of Bound Brook	N. 15° W.	5°
"	Milltown, near Lawrence brook	N. 60° W.	30°
"	North of Lawrence brook	N. 70° W.	25°
Sandstone	Ten Mile Run, old quarry	N. 60° W.	Gentle.
"	Old Provost quarry	N. N. W.	13°
"	Griggs' quarry, southeast of Kingston	N. 60° W.	10°
"	Trenton turnpike, near Kingston	N. W.	10°
"	Princeton, quarries near canal	N. N. W.	10°–13°
"	North of Kingston, quarry on canal bank	N. 10° W.	15°
"	North of Rocky Hill, quarry on canal bank	N. W.	15°
"	North of last station, quarry on canal bank	N. 30° W.	18°–20°
"	Near Griggstown, canal bank	N. 15° W.	20°–30°
Shale	Blackwell's mills, canal bank	N. 30° W.	Gentle.
"	Millstone	N. 15° W.	Gentle.
"	Millstone, Plainville road	W. N. W.	5°
"	West of Millstone river and south of Rocky Hill	N. 30° W.	Gentle.
"	West of Millstone, near last station	N. W.	20°
"	Along Beeden's brook, west of Rocky Hill	W. N. W.	Gentle.
"	Near and north of Blawenburgh	N. N. W.	15°
"	Rock brook, northwest of Skillman station	N. 30° W.	20°
"	East of Mt. Rose	N. 30° W.	25°

TABLE OF DIPS—*Continued.*

ROCK.	LOCALITY.	DIRECTION.	AMOUNT.
Shale	Between Mt. Rose and Hopewell	N. 30° W.	25°
"	Hopewell	N. W.	40°
Sandstone	Del & Bound Brook R. R. cut, west of Hopewell	S. W. (?)	Gentle.
Shale	R. R. cut, Moore's station	N. 15° E.	35°
"	R. R. cut, ½ mile northeast of Moore's station	N. E.	Steep.
"	Moore's mill	S. 35° W.	30°
"	South of and near Marshall's Corner	S. 60° W.	....
Flagstone	Woodville, Burroughs' quarry	N. 40° W.	20°
"	Woodville, old quarry, east of Burroughs'	N. 35° W.	20°
Indurated shale	East of Snydertown, Rocky brook	N. 45° W.	13°
" "	Snydertown, Sourland mountain	N. 40° W.	15°-20°
" "	Rocktown (east of and near), Sourland mountain	N. 40° W.	25°
" "	Rock mill, Sourland mountain	N. W.	15°
" "	Sourland mountain, road to Ringoes	N. 35° W.	25°
Red shale	Ringoes	N. 35° W.	25°
"	Near and southeast of Neshanic	N. 50° W.	15°
"	Near South Branch and northwest of Neshanic	N. 50° W.	20°
"	Clover Hill	N. W.	....
Shale	Near and south of Copper Hill station	W.	Steep.
"	Mount Airy	N. W.	10°-15°
"	West of Ewingville, and near Scotch road	N. 20° W.	10°
Sandstone	Trenton, near Cadwallader place	N. 60° W.	25°-27°
"	Trenton, old quarry, near canal	N. N. W.	15°
"	Greensburg, Keeler & Co.'s quarry	N. N. W.	10°
"	Greensburg, Granite and Freestone Co.'s quarry	N. 10°-15° W.	12°
"	Greensburg, Clark's quarry	N. 20° W.	10°-15°
"	Greensburg, James Green's quarry	N. N. W.	10°-15°
Shale	North of Titusville and near Fidler's creek	N. N. W.	15°-20°
"	Southwest end, Bald Pate hill	N. W.	20°
Indurated shale	North slope of Goat hill, Lambertville	N. 35° W.	22°-25°
Red shale	Bridge street, in Lambertville	N. 35° W.	20°
Sandstone	Brookville, near mill	N. 45° W.	20°
"	Brookville, old quarry	N. 25° W.	20°
Shale	South of *New Hope, Pa.*, in river bluff	N. 45° W.	25°
Sandstone	Near blue limestone, north of *New Hope, Pa.*	N. 10° E.	20°
"	Prallsville, old quarry	N. 25° W.	20°
"	Stockton, Best's quarry	N. N. W.	Gentle.
Shale	Rosemont, on Baptisttown Road	N. 22° W.	15°

TABLE OF DIPS—*Continued.*

ROCK.	LOCALITY.	DIRECTION.	AMOUNT.
Indurated shale	Raven Rock	N. 30° W.	15°
" "	One mile northwest of Raven Rock	N. 30° W.	15°
Shale	Southeast of Point Pleasant	N. 40° W.	15°
"	Point Pleasant	N. W.	15°
"	Northwest of Point Pleasant	N. 40° W.	10°
"	*Tinicum creek, Pa*, near Delaware	N. W.	15°
"	Three-fourths mile south of Tumble station	N. 15° W.	15°
"	Tumble station	N. 20° W.	15°
"	Nishisakawick creek	N. 60°–70° W.	8°
"	Frenchtown to Milford	N. 45° W.	5°–8°
Sandstone (Flagstone)	Milford, Clark's quarry	N. 40° W.	20°
Sandstone	Milford, along creek	N. W.	15°
"	Robbins & McGuire quarry	N. 35° W.	20°
"	One mile above Milford	N. 60° W.	15°–20°
Siliceous conglomerate	Pebble bluff, northwest of Milford	N. 60° W.	15°
" "	Pebble bluff, near road to Spring Mills	N. 70° W.	15°
" "	Pebble bluff, west of last station	N. 60° W.	20°
Sandstone	*Grand Rock, Nockamixon cliffs, Pa*	S.	Gentle.
"	*East of cliffs, on river road, Pa*	S.	Gentle.
"	*River bluff, Pa.*, south of Johnson's ferry	N. 60° W.	30°
Calcareous conglomerate	Near Presbyterian Church, Johnson's ferry	N. 60° W.	35°–40°
Siliceous conglomerate	Northwest of Holland station	N. 50° W.	15°
" "	On road, west of Gravel Hill	W. N. W.	Gentle.
Shale	West of Mount Pleasant on Amsterdam road	N. 30° W.	20°
"	Near Hakihokake creek	N. 30° W.	25°
"	One-quarter mile southeast of Spring Mills	N. 30° W.	30°
"	One mile southwest of Little York	N. 20° W.	40°
"	Milford road ¼ mile south of last station	N. 15° W.	32°
"	Baptisttown	N. W.	5°–7°
Indurated shale	Near Milltown (near mill)	N. 20° W.	15°
" "	Lackalong creek, below Milltown	N. 20° W.	15°
" "	Northeast of Point Pleasant	N. 30° W.	10°
Shale	East-northeast of Flemington	N. W.	60°–70°
"	Near Bushkill creek east of Flemington	S. 80° W.	Steep.
Indurated shale	Northwest of Flemington on road to Croton	N. 50° W.	10°
" "	West of last station	N. 35° W.	15°
" "	Near Walnut Br., west southwest of Flemington	S. 35° E.	10°
Sandrock	Three miles north of Flemington	N. W.	....

TABLE OF DIPS—*Continued.*

ROCK.	LOCALITY.	DIRECTION.	AMOUNT.
Shale	On South Branch, near Barley Sheaf	N. W.	....
"	Klinesville	N. W.	Gentle.
"	From the South Branch to Stanton	N. W.	....
Indurated shale	One mile west of Stanton	N.	Gentle.
Silicious conglomerate	Two miles northwest of Stanton	S. 25° W.	Steep.
Sandstone	Johnson's Mill on South Branch (quarry)	S. 85° W.	30°
Silicous conglomerate	Near Prescott Br., southwest of Allerville	S. 85° W.	Steep.
Brecciated rock	Near and east of Allerville	S. 60° W.	Steep.
Indurated shale	Near Prescott Br., southwest of Round valley	N. W.	Gentle.
" "	South of Round valley	N. 30° W.	20°
Shale	South of Allerville	N. 20° W.	50°
"	One-half mile south of Allerville	S. 85° W.	Steep.
"	Southeast of Leigh's manganese mine	W. N. W.	Steep.
"	Leigh's manganese mine	N. 80° W.	80°
"	West of Clinton a half mile	N. 85° W.	58°
"	Sidney Mills	W.	20°
Calcareous conglomerate	E & A. R. R. cut near Sidney Church	N. 20° W.	15°
Shale	E. & A. R. R. cut near Sidney Church	S. E.	5°–10°
Calcareous conglomerate	Old quarry near Sidney Church	S. 55° E.	....
Shale	Northwest of quarry near Sidney Church	S. 50° E.	35°
"	One quarter mile southeast of Pattenburgh	N. W.	....
"	One mile east of Perryville	S. 45° E.	10°
Limestone	Dunham's quarry west of Clinton	S.	20°
"	Bonnell's quarry northwest of Clinton	S. 75° W.	22°
Shale	Round valley, eastern end	N. 10°–15° W.	15°
"	Round valley, southwest side	N. 30° W.	25°
"	R. R. cut three-eighths mile east of Lebanon	N. N. W.	25°
"	R. R. cut one-half mile east of Lebanon	N.	18°
"	Lebanon	N.	Gentle.
Calcareous conglomerate	Quarry of Hoffman northeast of Lebanon	S.	Gentle.
" "	Quarry one-half mile north of Lebanon	S. 45° E.	15°
" "	Ramsey's quarry northeast of Lebanon	W.	10°
" "	Van Syckle's quarry northeast of Lebanon	N. W.	Gentle.
Shale	On road to Potterstown west of North Rockaway	S. 30° W.	....
"	Near Schl. west of New Germantown	S. 30° W.	....
Calcareous conglomerate	Melick's quarry northwest of Silver Hill	S. 20° W.	75°
" "	Old quarry northeast of New Germantown	W. N. W.	20°
" "	Melick's quarry northeast of New Germantown	W. N. W.	Gentle.

TABLE OF DIPS—*Continued.*

ROCK.	LOCALITY.	DIRECTION.	AMOUNT.
Calcareous conglomerate	Robert Craig's quarry N. E. of New Germantown	W.	Gentle.
Shale	Southeast of Silver Hill	N. 60° W.	Steep.
"	North of New Germantown	N. W.	Gentle.
"	One mile southwest of New Germantwon	N. W.	....
"	Near New Germantown (north)	W.	20°
Calcareous conglomerate	East northeast of Pottersville	W.	....
Siliceous conglomerate	Northwest of Peapack near Morris county line	S. 80° W.	40°
....	Union Grove S. H. west of Peapack	W.	....
Shale	Mount Paul	S. E. (?)	Steep.
"	Raritan river south of Somerville	N. 40° E.	8°
"	R. R. cut one mile east of Somerville	N. 50° E.	4°
"	R. R. cut one mile west of Raritan	N. 15° E.	4°
"	R. R. cut near North Branch	N. 40° E.	8°
"	R. R. cut one-half mile southeast of White House	N. 35° E.	21°
Indurated shale	R. R. cut ¼ mile northwest of White House	N. 15° E.	45°
Sandstone	R. R. cut 1½ miles west of White House	N.	30°
Shale	North of White House	N. E.	10°-20°
"	White House to Scrabbletown	N. N. E.	35°
"	East of Round Valley mountain	N. 30° E.	15°
"	Scrabbletown	N. E.	Gentle.
"	Pleasant Run to Stanton	N. N. E.	....
"	Near northeast end of Sourland mountain	N. 15° E.	15°
Indurated shale	Bridgewater copper mine northeast of Somerville	N. 60° E.	Gentle.
Shale	Somerville—Pluckamin road	N. E.	Gentle.
Sandstone	Bartle's quarry, Martinville	N. N. E.	10°
"	Martinville	N. 50° E.	5°
"	Dow's quarry east of Pluckamin	N. 30° E.	10°
"	Beach's quarry east of Pluckamin	N. 40° E.	Gentle.
Shale	Vanderveer's mills south of Lesser Cross Roads	S. 70° E.	....
"	Near Schomp's mills north of Lesser Cross Roads	S. S. E.	20°
"	On road north of last station	S. 25° E.	20°
"	On road to Bernardsville southeast of Peapack	S. E.	15°
"	Near Mine Brook Schl., Bernard township	E. S. E.	Steep.
"	East of last station	S. S. E.	Steep.
"	One mile southwest of Liberty Corner	N. 20° E.	15°
"	Near and south-southwest of Liberty Corner	N. N. E.	Gentle.
Sandstone	Millington, old quarry	N. 20° E.	15°
Shale	West of and near Millington	N. N. E.	Gentle.

TABLE OF DIPS—*Continued.*

ROCK.	LOCALITY.	DIRECTION.	AMOUNT.
Shale	Near Passaic river east of Millington	N. 20° E.	13°
"	Basking Ridge		Horiz'nt'l
"	Harrison's brook, S. S. W. of Basking Ridge	W. S. W.	Gentle.
"	Northeast of Basking Ridge on Morristown road	N. E.	10°
"	Northwest of and near Basking Ridge	N. 75° E.	30°
"	Madisonville	N. W.	10°–15°
"	West of New Vernon, near gneiss	N. 70° W.	Gentle.
"	East of New Vernon	S. S. E.	Gentle.
"	Northeast of New Vernon on Morristown road	S.	Gentle.
"	West of —— Mills	S. 85° E.	8°
"	Northwest of —— Mills, southwest of trap	S. 85° E.	7°
"	Near last station, southwest of trap	N. 80° E.	Gentle.
"	Rockaway river, below Boonton	N. W.	10°–20°
"	Along Rockaway river near old Boonton	S. 70° W.	9°
Silicious conglomerate	Montville	W. S. W.	10°
Sandstone	Vreeland's quarry, Hook mountain	N. W.	7°
"	Hook mountain, east of last station	N. 50° W.	Gentle.
Silicious conglomerate	East of Pompton Furnace on the Paterson road	S. 60°–70° W.	10°
" "	North of Pompton Furnace near pond	S. 60° W.	25°
" "	Northeast of last station	S. 75° W.	30°
" "	Ludlam's quarry northeast of Pompton	S. 70° W.	25°
Sandstone	Ludlam's quarry northeast of Pompton	S. 80° W.	25°
"	Northeast of last station	S. 75° W.	10°
"	Near Franklin lake	S. 50° W.	Gentle.
"	O'Neil's quarry near Haledon	S. 75° W.	10°

Various theories have been made to explain the present inclination of the strata. The one most commonly stated is that the beds were deposited in the present position. There are several serious objections to this explanation. And the first of them is, that the dip is in general greater than the average descent or slope of the off shore sea bottom on our Atlantic coast. The slope of the bottom in all our larger sounds and estuaries is generally very gradual—usually from 3 to 10 feet per mile—excepting over very short distances. And as an example of a steep descent, the bottom on a section off Barnegat, at 75 miles out, falls from 83 to 267 fathoms in 1.5 miles, or at a rate of 740 feet in a mile, equivalent to an angle of 8°. And on all sandy shores such slopes are very gradual. It is only along the more rocky, precipitous coast lines or around small islands of volcanic origin that any bottoms are found whose descent is as great as the dip of our red sandstone. The materials of the beds in this formation are largely of a coarse, granular nature, and such as would be deposited in rather shallow waters. They are not a deep water formation. If laid down near the shore line they were most probably deposited on a sloping bottom not any steeper than those of our Atlantic coast.

Another objection to this theory is that the footprints and the imbedded remains of fishes and of plants would have indicated the descent if they had been made in such sloping surfaces. On the contrary, the footprints which are found both in Massachusetts and in New Jersey, look as if the surface, when traversed by the animals making them, was horizontal, or nearly so, at least not greater in descent than many of our mud flats and shelving strands. President Hitchcock has referred to this objection fully in his "Ichnology of Massachusetts," 1858.

This theory involves the necessity of an extensive system of faulting and subsequent upheavals, or the successive formation of newer beds from the older and underlying strata, against which there are almost insuperable objections. There is no evidence of faulting on so extensive a scale as this theory would require. Nor do the higher beds appear uniformly to have been derived from those lower in the series.

If the strata were laid down as we find them, the materials forming them must have come from the southeast and east. That the source was not wholly on this side is proved by the materials themselves, which in many places have evidently been derived from the northwest. They point to the older rocks on each side as the sources for the shale, sandstone, &c. And the steeply dipping conglomerates on the northwest border were made from limestone, sandstone and gneiss on that side.

The trap-rocks have been pointed out as the cause of the upturning of the shales and sandstones. There might seem to be some plausibility in this hypothesis, when it is remembered that their dip corresponds to the form of the trap-rock ranges, as indicated above in the exceptions to the prevailing northwest and west directions. That the outflow of the trap-rock had some influence in elevating the beds of shale and sandstone near them cannot be denied. It would be expected. But that this uplifting effect should be felt throughout the whole breadth of the formation and should produce so great uniformity in the direction as well as in the amount of the dip, is altogether improbable. On the contrary, the general absence of any disturbances in the bedding near the trap-rock is very remarkable. At many points of contact the shales are apparently unaltered as well as undisturbed in position. But, generally the dip is a little greater in amount near the trap-rock.

The faulting of the strata has already been referred to as a phenomenon belonging their elevation, and in part explanatory of the uniformity in dip. Faults are, however uncommon, notwithstanding the numerous fine sections in bluffs and quarries, and those which are known are short, the amount of displacement in no case exceeding a few feet. Many of the quarry faces along the Delaware, at Greensburg, appear to be repetitions of the same series of beds, but there are no evidences of faulting between them. The rolls in the surface, going west from the Hudson, in Bergen county, and Rockland county, New York, also appear as if caused by a succession of faults, which, running north and south, have raised a coarse-grained sandstone into successive ridges. To explain the dip over the whole breadth of the formation by recourse to faults does not simplify matters. The agent asked to do the work is more difficult to understand than the effects before us.

The more probable theory is that the strata were deposited nearly horizontal, or but slightly inclined. During the long ages in which this deposition was taking place, a gradual subsidence was in progress, and consequently the accumulation of strata was correspondingly great, and some thousands of feet thick. It is not necessary to assume that this subsidence was uniform everywhere in the area now occupied by these rocks. Most likely it was not. And an unequal rate of subsidence may have had much to do in causing the upturning. Looking at the dips we note a large ellipsoidal area in which the strata dip towards the major or longer axis. The sinking of such an area would tend to break the crust in concentric, ellipsoidal lines, and allow the more easy outflow of the trap-rock on these lines than elsewhere. In this subsidence it is assumed that the rate was faster in the center than on the circumference, and the unequal pressure would in places fracture the strata. The eruptive masses coming up through the breaks would then flow out between the opened strata as we now see them. The First and Second mountain ranges of the trap-rocks are the more continuous outflows on the outside of this area. The Long Hill and

Hook mountain ranges are interior and approximately parallel to the outer ranges.

As already stated, there is much variation in the shales and sandstones of this formation. And this variation is observable both in the nature of the materials and in the degree of fineness in which the constituents appear. Following the lines of strike, the same beds may be seen to change, the shale becoming a hard, compact sandstone or conglomerate, and vice versa. Crossing the strata, in the direction of the dip, the successive beds are rarely of the same nature for any great distance. Shales and sandstones alternate irregularly. In fact there is not a quarry where both sandstone and shale may not be found and with them often conglomerates also. Notwithstanding these frequent and sudden changes in the successive strata, there are in certain districts and belts prevailing types of rock which give character to them, although at present it is not practicable to represent their areas upon the geological maps. A very detailed survey may discover the boundary lines or limits of such well marked subdivisions. Some of these characteristic rocks and their outcrops are here described.

It may be stated at the outset that on both the southeastern and on the northwestern borders the rocks are mostly coarse-grained and conglomeratic. And their composition points to the older rocks on each side as their source. Further away from these borders and nearer the middle of the belt, the rocks are more commonly finer-grained and shales predominate. The materials composing the beds were derived from more distant sources. To these general statements there are, as may be understood from the shape of the formation and from subsequent changes in its uplifting, many and large areas which are apparent exceptions. The coarse-grained sandstone, or arkose of the Palisade range was evidently derived from the wear of older, feldspathic gneisses and other Archaean rocks to the eastward. From Staten Island southwest to the Raritan river the few outcrops on this southeast border are all of shaly nature. So, too, on the northwest, at the foot of the Highlands there are many outcrops of both siliceous and calcareous conglomerates, but between them there are gaps where the prevailing type of rock is true shale.

The grayish-white feldspathic sandstone at the base of the Palisades is a very marked variety of rock and is seen cropping out at many points between Hoboken and the State line. The bluff where the West Hoboken boulevard ascends the hill, the ledges recently uncovered by the New York, West Shore and Buffalo Railroad and the exposures in the roads from the river to Englewood and to Alpine are excellent localities for its examination. At Weehawken, the rock is in some of the strata coarse-grained and quite friable, breaking readily under a light blow and falling down to a granular mass of quartzose and feldspathic materials. There are here some beds of very hard, dark-colored indurated shales. These can be seen from the N. Y., Lake Erie & Western R. R. docks for a mile northward. They are interstratified with the more granular varieties. Occasionally the beds are sparsely conglomeratic and contain pebbles of quartz and feldspar. At the eastern end of the new tunnel the shale in contact with and under the trap-rock is much altered.

In this feldspathic sandstone the feldspar is generally, if not always, partially kaolinized and in slightly rounded, rhomb-like grains; the quartz is in irregular, rounded grains and mostly transparent. There is a wide range in the size and in the shapes of both of these constituents.

On the top of the Palisade range of trap-rock the sandstone which appears at a few localites is also feldspathic and much like that under this sheet of rock. It does not, however, appear to lie immediately in contact with the latter, but is separated by the indurated rock.

The absence of this peculiar feldspathic and coarse-grained variety of rock through Middlesex county may be explained on the theory that there the border is concealed by the later beds of Cretaceous clays. Going southwest we approach the gneiss again on the southeasterly side of the formation and the feldspathic rock is again recognized. The first locality is in the quarries, near the canal, south of Princeton. The greater part of the quarry stone is a red sandstone, containing in certain horizons more or less altered feldspars. Thence to the Delaware the coarse-grained type prevails, and there is less of the red shale. North of Trenton and near the Shabbakonk creek, the sandstone consists of a loosely cemented, granular mass of quartz, feldspar and mica, evidently derived from the Trenton gneiss which is near it on the south. Along the canal feeder a short distance north of Trenton, the material is so crumbling that it has been extensively dug into for filling and for canal bank construction. Thence northward the red sandstone alternates irregularly with this coarse-grained gray stone. There are some strata of conglomerate also. The quarries at Greensburg offer fine opportunities for studying the strata, although the gaps or concealed intervals between them do not permit the observation of an unbroken succession of beds. And the resemblance between the beds of the several quarries have led to the belief that they were repetitions due to faults somewhere in the intervening breaks or gaps. Whether or not such be the fact, the prevalence of gray, thick-bedded and rather coarsed-grained rock, and some pebbly strata corresponds with what is seen on the eastern side of the State and near the Palisade range.

What may be the breadth or where the northwest limit of this variety of rock is to be located, is uncertain. It does appear as the southeastern and oldest belt or subdivision, and its materials came from the older gneisses which border it on that side.

To the west of the first or oldest belt there is in Bergen county a remarkable succession of north and south ridges made up of brown to dark-red colored coarse-grained sandstone, and some beds of fine pebbly conglomerate. These ridges increase gradually in height, from east to west, and on the State line near Sufferns attain an elevation of 627 feet above tide level. They are represented upon the topographical maps of the northeastern part of the State, and the peculiarity of this structure is evident in the drainage of that district. The Hackensack, Saddle and Pascack rivers all flow in valleys separating these ridges. The dip of the sandstone in them is uniformly to the west, or west-northwest, and the strike corresponds to the trend of the ridges very nearly in all cases that were observed. But there are no differences in the rocks whose outcrops have been found which will explain this peculiar structure. In consequence of the glacial drift and the diluvial deposits of the valleys, the outcrops are neither many nor of much extent. Hohokus, Pascack, Paramus and the valley of Saddle river and Schraalenberg are the best localities for examining the strata. The ridges running north into New York are still more prominent, and the stone there is coarser-grained. A possible explanation of these features is that there are axes of uplifts or elevation running nearly due north and south, and that the ridges are monoclinals, or with a uniform westerly dip, and that the valleys are either on the lines of faults, or, what is more probable, are on the lines of anticlinal axes. In the latter case the dips on the northwest slopes should be somewhat steeper than they are on the southeast sides of the ridges. The hypothesis of close folds with axes all dipping westerly would thus meet the requirements of fact. A simpler origin of the valleys would be that they are the results of erosion. But while the action of surface water continued through long ages is sufficient to do the work, the general slope of the country would have determined their flow along more southeasterly lines than the present water-courses have. It is difficult to conceive of any other cause than some differences in the structure which determined their general direction.

Going southward, the formation in Passaic, Essex, Morris and Union counties does not present the same features of structure nor the continuation of so coarse-grained, brown sandstone as in Bergen county. The ridges are traceable across a part of Passaic and Essex, east of the Watchung mountains, but they are much lower than at the north. Besides, the streams flow more in easterly or southeasterly courses. There are very many quarries and other outcrops where the strata can be studied to advantage. Thick-bedded sandstones are seen, as at the Paterson, Belleville and Newark quarries, and some of them contain feldspar, though not in so large proportion as further east, in the foot of the Palisade range. Red argillaceous sandstone and red shale also occur, and are probably the more common types of rock. The glacial drift on the hills and the alluvial deposits in the Upper Passaic valley so cover the rocks that a few outcrops only are found where it can be examined. The Artesian well bored at the Passaic Rolling Mill, in Paterson, passed through 2,100 feet of sandstones and shales. An apparent exception to this uniformity is the occurrence of a conglomerate in Paterson. The locality is in what is known as Morris hill, and near the Passaic, below the Falls. The conglomerate is interbedded with sandstone under the trap-rock. The greater number of the pebbles are from a quarter to an inch in diameter, although a few are as much as six inches long. They are imbedded in a siliceous matrix and are nearly all of quartz; there are some of the quartzose conglomerate; a few of red shale and red sandstone; and a still smaller number of blue limestone. They are disposed irregularly in lines in the sandy matrix and at one point these lines are nearly horizontal—that is they are oblique to the plane of bedding. This conglomerate points to the sources of these pebbles as not very far away. Blue limestone must have furnished its pebbles. In the absence of any ledges or outcrops of the rock anywhere near Paterson, the assumption is that it has been covered by the more recent strata, and that the conglomerate deposit was not far from it. Here, then, we cannot be very far from the base of the formation, one side or the other.

The valley of the Raritan, or the parts of Somerset and Middlesex within the limits of this formation, with the eastern part of Hunterdon, may be said to be the *red shale* district or subdivision. The section up the river from New Brunswick to Somerville, and then the line of the Central Railroad to White House, traverses it and shows numerous exposures of the strata. Shale and shaly sandstone of the prevailing and characteristic red color are typical of the subdivision. From the heights of the trap-rock ranges on the east and west, it is quite evident that the present surface is the result of denudation much more extensive than can be seen elsewhere in our red sandstone formation. Hundreds of feet in thickness have been removed. It is noteworthy that here the whole breadth can be crossed, from the clays on the southeast border to the Highlands on the northwest, without meeting any outcrop of trap-rock. The deposition of beds of shale and shaly sandstone may be evidence of the greater distance off shore, and they may be newer than the coarser-grained and pebbly beds further east and northeast.

It should be understood that the outlines of this peculiarly *red shale* area cannot be traced so as to include outcrops of the more argillaceous varieties of rock only. There are quarries at Pluckamin, Martinville, and in Washington valley, near Plainfield, where the stone is more arenaceous and adapted to purposes of construction as a good building stone. And near the trap-rock the alteration in the shales has made them very hard and compact. Throughout this area or subdivision the strata are gently inclined, and the angle of dip rarely exceeds 15°, while the greater number of observations show angles less than 10°. In this respect it differs from the region further to the northeast, where the average dip may be said to be 20°. The formation here is broader than in Bergen county or than it is across Essex and Morris counties. There has been less disturbance by trap-dikes. And it is properly a great plain. Standing upon the end of Sourland mountain or on Round Valley mountain, the spectator grasps at once this statement as he surveys the whole breadth of the formation from the Highlands to its southeast limit, where it is overlapped by the more uneven gravelly drift surface.

The section along the Delaware river presents an almost continuous series of outcrops or exposed ledges from near Trenton to Johnson's Ferry, a distance of thirty miles. And this series of beds represents approximately all the whole breadth of the formation for several miles back from the river. The portions of Mercer and Hunterdon counties within its limits may be fairly represented by such a section. Proceeding north, or up the river from Greensburg, the red shales and sandstones predominate with indurated shales near the trap-rocks, as far as Brookville, or within a mile of Stockton. And throughout the northern part of Mercer and the southern part of Hunterdon counties these rocks make up the greater portion of the outcrops other than the trap-rocks (noticed elsewhere), and a narrow belt of coarse-grained, gray to red sandrock on the south of Sourland mountain, and known locally as Peach ridge. The belt does not appear to come to the Delaware. The average inclination of the beds in this part of the formation is 10° to 15° towards the northwest.

Opposite Brookville the magnesian limestone belt comes to the river on the Pennsylvania side, but is not traced across it into New Jersey. This older formation has been exposed by the denudation of the newer rocks, and the sandstones and conglomerate near it on the northwest appear to be close to the bottom, containing, as they do, pebbles of white sandstone, which look like the Potsdam rock of the range further to the southeast in Buckingham mountain. The gray and reddish thick-bedded sandstones and conglomerates, which are quarried at Stockton and at Prallsville, belong to this belt of rock. And these quarries afford good sections of it. The conglomerate at Brookville is coarse-pebbly and contains pebbles, one to three inches in length, which are mostly of white, opaque quartz and some of reddish quartz. At the old quarries at Prallsville, the thick-bedded conglomerates occur with some thin beds of red, shaly sandstone. In this rock there are occasional pebbles of blue, calcareous rocks and of red shale mingled with the quartzose ones. The succession of the shaly and coarse-grained beds show sudden changes when deposited. The lines of pebbles conform to the planes of bedding so far as observed at the quarries. This belt of coarser-grained sandstone can be traced eastward from the river by Sergeantville and Sand Brook; Sand Ridge Church and Headquarters are near its south border. The northeasternmost locality where it has been seen, is three miles north of Flemington, on the Klinesville road. At the latter place the rock is a grayish-white crumbling mass, which is dug as sand. The quartz grains are mixed with feldspar in a partially kaolinized condition. The stratification is apparent and the dip is to the northwest. It is to be observed that this locality is only four miles from outcrops of Potsdam sandstone east of Allerville. The gray sandstone southeast of Hamden and near the South Branch may be in this range of rock. Along the Delaware the average dip in these grayish sandstones and conglomerate outcrops is about 20°.

Next north of the last described belt is a broad and rather well defined one of altered shales. The Delaware crosses it between Point Pleasant and the mouth of Copper Creek, a breadth of about six miles. The strata make the bold bluffs along the narrows. Their dip is very uniform and at angles of 13° to 15° towards the northwest. Rosemont is near the south border of this belt, on which are Kingwood, Locktown, Croton, Oak Grove. The district has been known as the *Swamp*, on account of its cold, wet soil, derived from these shales. The underlying rocks are dark-purplish to black, excessively hard and breaking with a conchoidal fracture and ringing when struck by the hammer. In consequence of their hardness they have resisted denudation better than the red shales, and the elevation of the area occupied by them is 400 to 700 feet above tide level. Excepting at Point Pleasant no trap-rock has been found in it, although the wide spread induration indicates its probable existence.

From Frenchtown to Milford there is a belt of red shale, which is remarkable for its low dip, averaging less than 10° and to the northwest. It is also marked by the lower line of bluffs on the New Jersey side of the river and bordering the river plain. This shale does not, however, appear so well marked back from the river, and its limits cannot now be given. Mount Pleasant, Everittstown, Pittstown and Sidney are on a red sandstone area, but the rock at these places is more sandy than that of the river bluff.

As stated above, conglomerates and coarse granular rocks characterize the northwest border of this formation. They are either calcareous or siliceous, according as the predominating constituents are limestone or quartzose. Of the latter Pebble bluff, one mile northwest of Milford, is the most noted locality. In it the beds are 10 to 15 feet thick and dip towards the northwest. The matrix is siliceous and of reddish color. The lower layers are a brecciated conglomerate. Further west and higher in the series the rock is a conglomerate. The pebbles are nearly all of quartz of reddish to grayish-white color and subangular, and from a quarter of an inch to six inches long. By far the larger number of the pebbles and cobblestones are of a reddish quartzose rock. There are some of red sandstone. Towards the northwest the number of blue limestone pebbles increases, but they are not numerous enough to make it a calcareous rock. Going west, the conglomerate grows coarser, and there are included masses 15 to 18 inches long. These larger bowlders lie with their longer diameters in a northeast and southwest direction and inclined slightly to the southwest, as if the current carrying them had moved in a southwest direction. No gneissic or granitic rocks have been found in this conglomerate. On the southeast there are beds of red sandstone interbedded with the conglomerate, but to the west they are not seen.

The hill north of Pebble bluff, known as Gravel hill, and that west of Holland, are apparently of quartzose rock in form of a conglomerate. As there are no good exposures of the strata in them, the quartzose materials of the surface look like the outcrops of such siliceous conglomerates. Both of these hills and one on the Pennsylvania side of the river, southwest of Monroe, have their greatest lengths from north to south. They all stand out prominently above the adjacent sandstone areas. The ridge or divide east of Little York and west of Pattenburg is of the same general character. And to the northeast the conglomerate ridge west of Peapack and that to the north, known as Mount Paul, are also much like these here described. It is remarkable that all of them have a general southward trend from the Highlands border. They also may be proofs of axes which run north and south from the Highlands into the red sandstone formation. At Montville there is an outcrop of the siliceous conglomerate which is a coarsely agglomerated and loosely cemented mass of quartzose, sand with pebbles and cobblestones, which are not much rounded. They are mostly of reddish quartz and of gneissic and granitic rocks. No limestones or serpentine have been observed in it. Micaceous and feldspathic rocks predominate. And thin but short layers of sandstone occur in the conglomerate. From the limited outcrop of this rock it is evident that the conglomerate is not thick. It lies close to the Highlands, and its materials have come from that direction.

The conglomerates at Pompton are also siliceous. Thin-bedded, red sandstones and red shale are here irregularly interbedded with the gray conglomerate. Some of the strata are very coarse conglomerates, containing cobblestones up to a foot long. Most of them are of quartz. There are some of grayish grits and a few of blue limestone. The thickness of this very coarse *bowlder* conglomerate is only about 20 feet. It is not more than two miles from the Highlands border. To the northwest of these ledges and near the end of the Third mountain range, there is a very small outcrop of brecciated, calcareous conglomerate, in which limestone amounts to a sufficiently large proportion of the whole mass to make it answer for lime burning. The materials are scarcely rounded at all, showing that they came from ledges near at hand.

Siliceous conglomerates are seen at Hohokus and in the valley of Saddle river, but these are more nearly related to the coarse brown sandstone, and the pebbles are more sparsely scattered in the mass.

Calcareous conglomerates occur at several places and in very narrow outcrops on the Highlands or northwest border of the formation. At Johnson's Ferry, at the Delaware, a brecciated conglomerate crops out, abutting against the magnesian limestone, in which there is a great mixture of pebbles and rock fragments. The materials are largely of blue limestone, and with them, scattering pebbles of gneissic rocks. Many of the fragments are angular, or but little rounded. Going south, or further from the magnesian limestone outcrop, the number of calcareous pebbles diminishes, and the rock becomes siliceous. The dip at this locality is 35° N. 55° W., or towards the almost vertical limestone strata. It grows less to the south.

A few knobs of calcareous conglomerate appear near Little York and on the Duckworth farm.

Near Sidney Church the Lehigh Valley Railroad cut exposes a conglomerate interstratified with sandstone. Most of the pebbles here are of quartz and sandstone. The blue limestone near the railroad appears to be the bottom, or rock floor, upon which the sandstone was laid down; and this conglomerate is, therefore, near the base of the formation.

The most extensive outcrop of calcareous conglomerate is between Lebanon and the Lamington river; and the rock is quarried at a number of places for use in lime making. The greatest breadth of this range is not more than one mile, and its length is about five miles. The pebbles are nearly all of blue and of yellowish limestones, cemented by a reddish and blue calcareous material. A few of red sandstone, and some of reddish flint, occur with the limestones. Less common are those of whitish quartz; and very scarce are gneissic rocks. In some places the matrix is a blue calcareous mass and the imbedded pebbles are also of blue limestone. In size the fragments and included pebbles range from one-fourth of an inch to a foot in length. The prevailing direction in the dip of these conglomerates is towards the southwest, or in that quarter. Full details of the conglomerate of Lebanon and New Germantown may be found in the "*Geology of New Jersey*." The pebbles and fragments in this conglomerate have been derived from the magnesian limestones bordering the Archaean rocks of the Highlands; and the disposition of these outcrops along this border is peculiar, in that they appear where the blue limestone belts are wanting. Reference to the map will show this relation of these various rocks on the northwest border of this formation.

It is pertinent here to refer to a calcareous conglomerate in the Mahwah valley, about four miles northeast of Sufferns, which is close to the gneiss, and which is remarkable for the size of the imbedded stone. The limestones are magnesian and are varying in size from three to ten feet in diameter. In their large size and in their arrangement the appearance is that of a glacial driftbank. The nearness to the Highlands and the large size of the imbedded stone are remarkable, and indicate close proximity to the parent ledges whence these materials were derived.

LIMESTONES.

An impure blue limestone occurs near Feltville, in the valley between the First and Second mountain ranges, but the outcrop indicates a very narrow and short extent, and that apparently interstratified with the shales. A little was once quarried near Martinville, in the same valley. But these outcrops are too small to be shown on the map, and the rocks are unimportant in an economical point of view. They belong, apparently, with the sandstones, and are indicative of deeper water, where, for a short period, the conditions were favorable to the deposition of these more calcareous beds. Excepting them, the formation throughout all its southern and central portions is characterized by the predominance of sandy and shaly beds and the absence of any calcareous rocks whatever. The limestones on the northwest are all conglomerates, excepting the very small and isolated outcrops near Sidney Church and west of Clinton. There are three of these patches of blue limestone. That near Sidney Church is opened in a very small quarry at the side of the Lehigh Valley Railroad. The rock is dark colored, in places banded, black and grayish-blue in alternate stripes. In the adjoining railroad cut there is a single thick bed of dark-colored stone, lying between black shale on the southeast and a thin-bedded dark-blue limestone on the northwest, all dipping at about 60° towards the southeast. This exposure is 100 yards long, measured obliquely across the strata. Little more than 100 feet to the southeast, the next railroad cut exposes red, shaly sandstone and siliceous conglomerates, dipping only about 5° to the southeast.

The Dunham and Bonnell outcrops are two miles west of Clinton and near the Perryville road. At the former the rock is very thin-bedded, black, solid, and makes a good lime. Its dip is to the south.

The Bonnell outcrop is north of the old Perryville road. The beds are one to four inches thick. On the east, they dip steeply toward the east; to the west, the dip is 22° S. 75° W., showing the existence of an anticlinal here. The stone is dark colored, very solid and hard, and is used for lime.

The only other outcrop of these dark-colored limestones lying within the sandstone bounds, is one mile west of Pattenburg, where the stone has been quarried in a very small opening and used for lime. It also occurs in thin beds and they dip towards the southeast at an angle of 40°. The relations of these four small and separate outcrops within the sandstone formation to the surrounding rocks is somewhat uncertain, as there are no contacts known, and the varying dips add to the uncertainty. In the "*Geology of New Jersey,*" three of them were referred to the older magnesian limestone. Subsequent examinations have brought out differences in lithological characters which lead to the opinion that they belong to this formation, and are similar to the Feltville and Martinville outcrops in their rocks. The absence of any fossils, so far as examined, leaves the matter in much doubt. Another hypothesis is that they are of the Trenton age, and are the bared patches of the underlying rock floor removed in these four places by the denudation of the sandstone. The discovery of fossils is much to be desired, in order that the question may be settled.

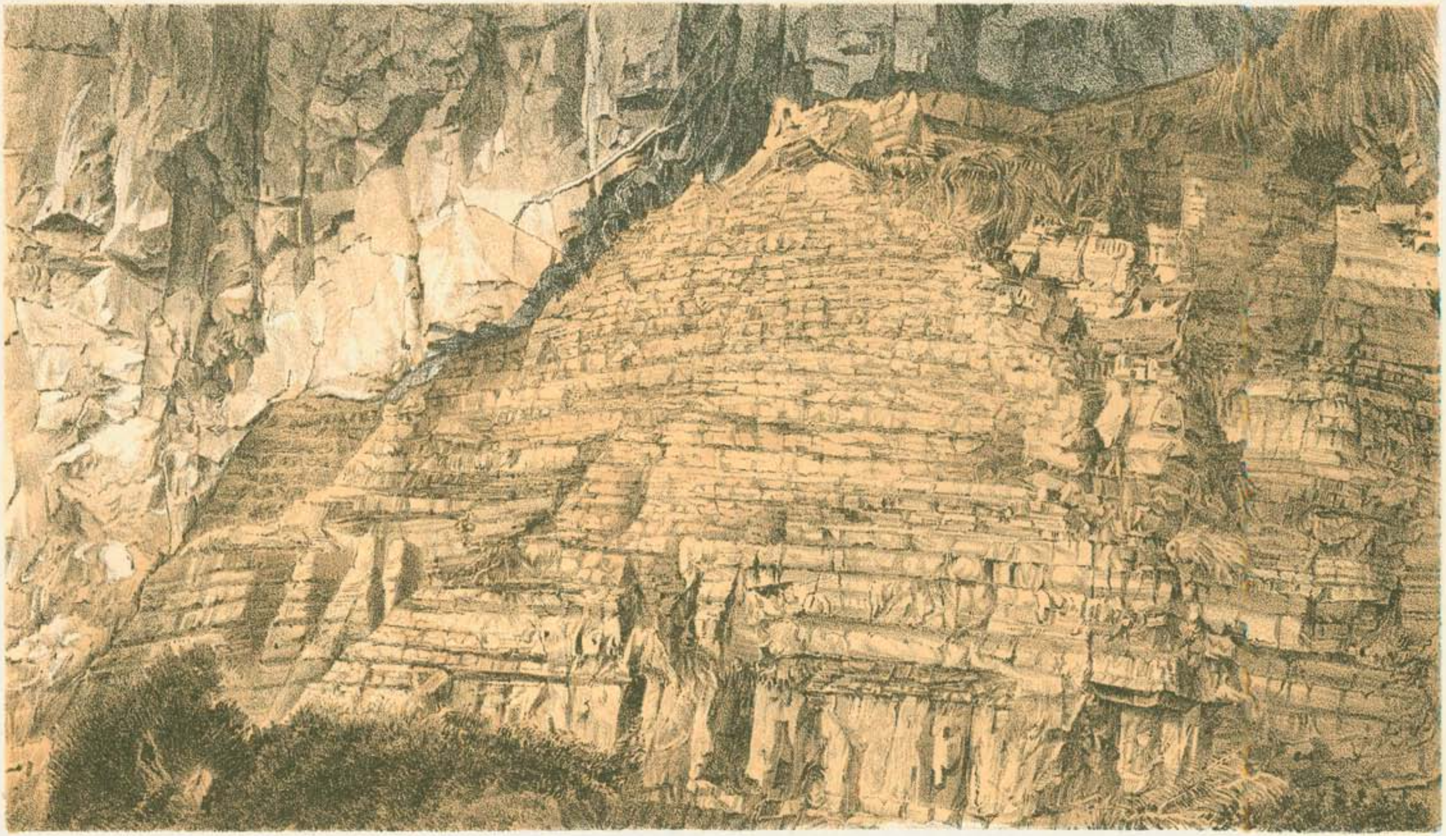
TRAP-ROCKS.

The several trap-rock outcrops have been described in the "*Geology of New Jersey,*" and their boundary lines have been represented upon the maps of the survey. Geological and topographical surveys, covering some of these ranges of the trap-rocks, require some additional notes on their occurrence and some slight changes in their locations on the geological map which accompanies this report. The following brief descriptions of the several outcrops are here presented as pertinent and best adapted to suit the more popular want of the people.

Beginning at the northeast and proceeding west and southwest, the first range to be described is:

THE PALISADE MOUNTAIN RANGE.

This range is partly in New Jersey and part in New York. It may be said to start near the Highlands, west of Haverstraw, in Rockland county. At first, a narrow and single ridge but little higher than the red sandstone country bordering it on the south, it rises rapidly as it trends eastward, attaining an elevation of about 1,000 feet in the High Torn, near Haverstraw. Thence it bends toward the south and comes to the river and forms the bold and massive ridge which bounds the Tappaan Zee on the west and holds at its western foot the beautiful Rockland lake. Although so high in the Torn and north of Nyack, it does not have the precipitous, mural front which characterizes it from near the State line to Jersey City, and which is known as the Palisades. The range is continuous to Bergen Point. It re-appears south of the Kill Von Kull on Staten Island, and finally disappears near the Fresh Kills. Its total length from Ladentown, New York, to the Staten Island Sound, is fifty-three miles. The range north of Nyack is locally known as the Hook mountain; the Palisades designates that part from the New York line quite to Weehawken. South of Weehawken there is no distinctive name for the whole ridge other than Bergen hill, which belongs to it within the limits of Jersey City. Its breadth varies from three-fourths to one and three-fourths miles. Its elevation in New Jersey increases very gradually from Bergen Point northward, reaching 100 feet in Bergen hill, 240 feet in West Hoboken, 300 feet at Fort Lee and at the Englewood Mountain House, 460 feet at Alpine, and a maximum of 547 feet near the State line. This range is remarkable for its uniformity of slope on the west, as well as for its Palisades on the east; and the westward slope corresponds nearly with the dip of the sandstone. Along the higher part of the range the wall-like front on the river is almost vertical for over 300 feet; and throughout, it is bordered by a talus of fallen rocks and earth, which in places extends



Julius Bien & Co. lith. N.Y.

TRAP-ROCK, BREAKING ACROSS THE BEDS OF RED SANDSTONE.
AT WEEHAWKEN.

to the water's edge. The quarrying from Jersey City to Guttenberg has altered the face of the cliff somewhat, and further north the talus has been bared of its timber and loose stone for dock filling, &c. Originally this sloping surface was a mass of huge rocks confusedly tumbled upon one another. The sandstone appears at many points at the base of the Palisades from Hoboken to the State line. The trap-rock is seen in contact with it and overlying it. It can be seen finely exposed with the sandstone at Weehawken and on the boulevard to West Hoboken; at the eastern entrance to the tunnel of the N. Y., W. S. & B. R. R.; at Bull's Ferry; at Alpine and near Sneden's Landing. The talus has concealed the junction of the two rocks much of the way along the Palisades. The cutting of the trap-rock across the strata of altered shale and sandstone at Weehawken, is shown in Plate No. 3, which is from a photograph of the locality. The dip of this rock is towards the west and west-northwest and at angles varying from 8° to 20°. The trap-rock immediately over it has a bedded structure. On the west slope, at Belmont, there is a subordinate ridge of trap-rock east of the Northern Railroad and west of the Hackensack road. Its eastern face is steep; that to the west is more gentle. Its height is 60 feet. In Bergen hill the trap-rock appears in two ranges, separated by a belt of sandstone. The Bergen cut exposed this intervening sandstone by uncovering the drift which concealed the outcrop. The sandstone is exposed in Bayonne City and near the Morris canal, on 44th street, between the two lines of trap-rock. Elsewhere the range is apparently all of trap-rock, excepting the comparatively small and isolated outcrops of sandstone which lie on its western feet. Of these outcrops, that at Homestead station is remarkable for its alteration, or induration, the rock being very hard and jaspery-like in appearance. At the western entrance to the tunnel of the N. Y., W. S. & B. R. R., the sandstone is cut into for a distance of several hundred yards. The rock is gray, and some of it is very friable and crumbling. At Belmont, the cut of the N. Y., W. S. &

NOTE.—The view given of the eruptive trap-rock crossing and terminating the beds of red sandstone, was taken at the coal docks of the Erie Railway, at Weehawken. It is one of the best and most accessible localities at which to examine the two kinds of rock at their meeting. Usually the trap-rock comes to the surface in beds or great tabular layers, intruded between the beds of sandstone.

B. R. R. affords a good section of a short sandstone ridge, which conforms in direction to the trend of the Palisades and ends at Fairview. Sandstone of a feldspathic nature is abundant at Englewood and northward to Tenafly in large masses, loose, in and upon the soil and surface earth. The great prevalence of this rock indicates its existence in the vicinity, probably under the drift hills and masses which are here thick and heavy. The gray, feldspathic sandstone is seen in a road cut about 100 yards southeast of Cresskill station. An indurated shale occurs upon the west slope of the mountain one-quarter mile west of Alpine. It can be seen in the road cutting, a short distance below the crest of the mountain, on the road to Closter. The rock is of a dark-purplish shade, and very hard and fine-grained. Further west, and lower on the mountain side, there is an outcrop of feldspathic sandstone and siliceous conglomerate, which appears, from its dip, to lie above the indurated rock. The altered shales and sandstones will probably be found at other places near the west foot of the range and lying upon the trap-rock.

The thickness of the Palisade mountain sheet of rock may be measured approximately by the perpendicular distance from the base of the Palisades or top of the sandstone to the crest. From the elevation of the sandstone at Alpine, and the height of the mountain, it is estimated to be about 400 feet. At Weehawken, it would not seem to be much more than 200 feet—measured from the sandstone basis to the top of the range. But the erosion of the surface has so altered the original shape that such estimates cannot be regarded as beyond question. The columnar structure of the trap-rock in the Palisades is remarkable. The rudely pentagonal columns are of great length and size. They are to be seen on the top of the cliff from the State line southward for several miles. They are from one to two feet on a side. In some cases they stand out quite separate from the main wall of rock. The sides are rarely uniform, but more often unequal and sometimes indistinct. At many places the tendency to a prismatic structure is apparent in the joints only, and there is no separation into well defined columns. The Palisade front, when viewed from the brink of the precipice, is not a straight wall of rock, but a serrated or corrugated rampart, due to the varying angles of these columns. Their size can be fully appreciated only by this close view. Occasionally one of them or a part of one falls, crashing down through the trees and rocks to the talus below.

The rock of this range is also remarkable for its uniformity in composition. It is of a deep bluish shade, very hard and tough. It is rather fine crystalline in its arrangement of minerals. Its composition has been referred to (see page 22). This rock breaks equally well in all directions and is adapted to making of blocks for pavement. And it is largely employed in this way. Some of the stone on the western brow of Bergen hill is darker colored and finer crystalline than that along the Palisades front. There are other grades which are lighter gray shade and resemble somewhat some granites. In the absence of any microscopic examinations, no lithological divisions can be made. But there are no sharp or well defined lines of boundary, limiting the occurrence of these varieties here mentioned. And as examined by the eye unaided, the rocks of this range can be said to be remarkably uniform in their general characters.

BIG SNAKE HILL AND LITTLE SNAKE HILL.

Snake hill and its companion hill are two isolated outcrops of trap-rock in the Hackensack meadows. They are prominent features in the landscape and familiar to all travelers on the several railway lines which converge as they cross the meadows towards Jersey City. Snake hill is properly the southwest end of the Secaucus upland, although separated from it by a narrow strip of meadow land. Its greatest diameter is from northeast to southwest—about a half mile. The southern and western sides are abrupt, almost precipitous; that to the north is gentle. The height above tide level is 203 feet. Red sandstone and indurated shales makes up the lower third of the northern and northwestern slopes. The rock at the base is red sandstone. It is succeeded by a grayish-colored, indurated rock, which, in turn is capped by the trap-rock. At the south side of the hill, the cut on the New York and Greenwood Lake Railway exposes a mottled, shaly rock, whose dip is towards the northwest. The dip of the shale north of the hill, at Secaucus station, is also towards the northwest.

Little Snake hill is one-quarter of a mile east-southeast of Snake hill. It is much smaller than the latter, and is 76 feet high. It is circular, and its sides are precipitous, except on the south, which is very steep. The greatest diameter is 360 feet. The only rock exposed is trap.

Both of these hills are outbursts of trap-rock through the shale, rising abruptly above the general level and apparently not connected with any other elevations or outcrops of this rock. From their heights and shape it would seem as if these outflows had not followed the stratification of the shale, but had broken across the strata irregularly and accumulated in these two localities, unless we may suppose that the erosion has here been so excessive as to leave them. But from their circular and ellipsoidal shapes, it is not likely that there has been any erosion to that extent.

WATCHUNG, OR FIRST AND SECOND MOUNTAINS.

Under this head are described the two long and parallel ranges of trap-rock which, bearing local names in their different parts, run from the Highlands in Bergen county, in a southeast course, to Paterson and Little Falls, and then bending south and southwest, cross Passaic, Essex, Union and Somerset counties, and turning to the northwest, near Bound Brook, approach again the Highlands. This grand sweep encloses the Upper Passaic valley, and made the barrier which, in post-glacial times, held in *Lake Passaic.* [See *Ann. Rep. for 1880.*] The outlines of the ranges are indicated upon the geological map. In consequence of a probable connection between the First mountain range and the trap-rock hills further north, in Franklin and Hohokus townships, our descriptive notes begin with the latter.

TRAP-ROCK HILLS OF RAMAPO VALLEY.

These outcrops of trap-rock are east of the Ramapo river and between two and three miles west of the Erie Railroad. The northernmost is a narrow, north and south ridge, and less than half a mile from the south and larger hill. Its length, from near Darlington, south, is two miles. The eastern face is very steep and shows some columnar rock in a low escarpment. It may be connected with the south ridge, although there is no visible continuous outcrop between them. Its greatest elevation is 500 feet. The neighboring hill is of much greater size and its height is 750 feet. The valley road from Darlington to Oakland runs near its western foot, and, near Oakland, passes over the trap-rock. The road from Oakland to Hohokus is about on its southern limit. Like the north ridge, it presents its steeper face to the east, and near the summit there are low walls of columnar trap. The next outcrop of trap-rock is at Crystal lake, where the rock is exposed in the cut of the New York, Susquehanna & Western Railroad, a few rods west of the station. It is fine-grained and reddish-gray color, resembling some altered shales. At the saw mill, about 100 yards south of the station, there is a small area of exposed trap-rock on the west of the road. Thence, southward, the ridge west of the Franklin lake road shows trap-rock on one of its highest points. Beyond, to the south, the drift obscures all the strata, and it is unknown if there be any connection between the outcrops here described and the First mountain. It is certainly quite reasonable to suppose that the Darlington, Oakland and Crystal lake hills make the northwestern end of the First mountain, thus reaching quite to the Highlands, as does the Second mountain. If such be the case, Franklin lake lies in the valley between the two ranges, and the ponds are in the drift-covered portion of the same valley.

The First mountain, or outer range of the Watchung mountains, starts near Siccomac, in Bergen county. The ridge trends southeasterly and then south, to Paterson, where the Passaic crosses it in a broad depression, or gap, and at a height of 120 feet. Rising south of Paterson abruptly, in what is known as Garret rock, its course thence to Milburn is to the south-southwest and almost straight (very slightly convex to the southeast) for fifteen miles. From Milburn the trend is nearly due southwest to the Chimney rock gorge, north of Bound Brook. In this part of the course, also, there is a very slight curve to the west. From the Middle brook gorge, the range has a northeast course to Pluckamin, where it ends. The length of the sweep around from Siccomac to Pluckamin is forty-four miles. Its breadth is quite uniform, from one to one and a half miles. Excepting the gaps at Paterson, Great Notch, Milburn, Scotch Plains, Plainfield and at Chimney rock, the elevation of the crest line is quite uniform, ranging from 400 to 662 feet. The heights of some of the more prominent points in the range, above sea-level, are as follows:

Goffle	611 feet.
Garret rock	500 "
Crane (U. S. C. S. station), north of Montclair	662 "
Turk Eagle rock	620 "
Springfield mountain	546 "
Washington rock	539 "
Bound Brook mountain	481 "

The gaps are not breaks in the continuity of the rock, as might be supposed, but depressions. And through them the drainage of the valley between the First and Second mountains finds its outlet. The Passaic crosses the Second mountain range also. Otherwise there are no corresponding breaks in that range, and all the drainage of the enclosed Upper Passaic valley is through that stream. The depression in the Great Notch is 300 feet.

At Milburn	150 feet.
Green Brook, north of Scotch Plains	170 "
Stony Brook, north of Plainfield	180 "
Middle Brook, north of Bound Brook	160 "

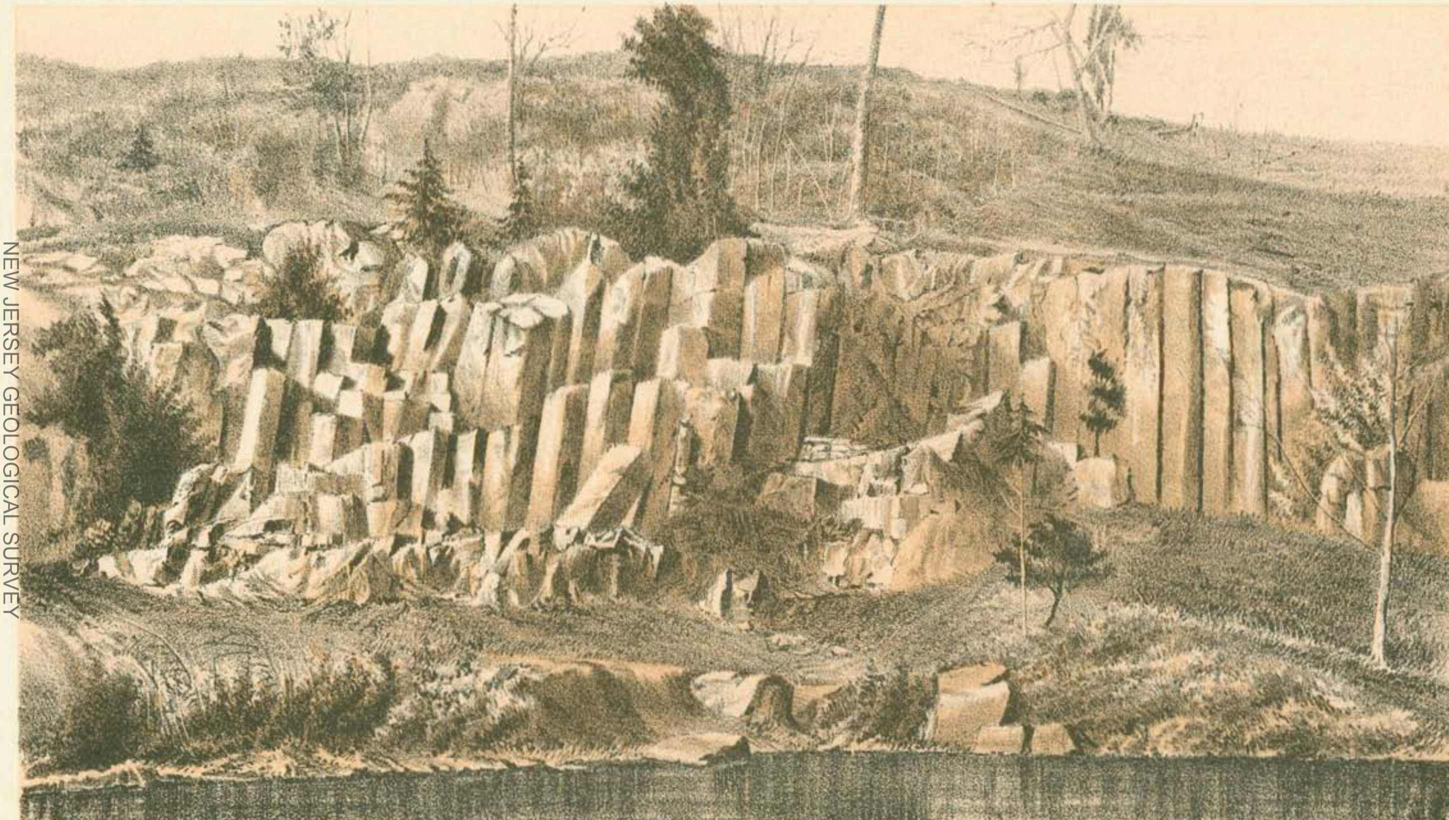
The correspondence in the heights of these gaps is remarkable, and points to some common origin other than that of the erosive wear of water. In fact from the action of the latter alone, we should have anticipated greater differences. The outflow at these points in the line may have been less than elsewhere, and the original height not very different from what it is at present. The streams do not appear adequate to the formation of such depressions. Besides they are not the V-shaped, but rather U-shaped gaps.

A characteristic feature of the structure of the First mountain is the great difference in its outer and inner slopes. The former is steep and in places precipitous, particularly near the the crest. The lower part of the slope, consisting of red sandstone, is much more gentle, although steeper than the inner, or slope towards the Second mountain. The latter corresponds nearly (although not everywhere so steep) to the dip of the sandstone. This peculiarity of structure is owing to the relative positions of trap-rock and sandstone. Both the outcrops and the openings made in copper mining indicate the trap-rock as a great sheet lying between the altered shales and sandstones. The dips of the latter on the outer slope vary in amount from 7° to 15°. The inclination of the sandstone and shale over the trap-rock is at the same angle. The direction is in general at right angles to the trend of the mountain, or in other words, the strike corresponds with the axis of the range. North of Paterson the dip is west-southwest and west; thence to Bound Brook it is towards the northwest; beyond to Pluckamin the direction is to the northeast quarter.

The junction of the sandstone and the trap-rock is to be seen at Paterson, in Morris hill, and also in Hartley's quarry south of that city. In Morris hill the exposure of sandstone, conglomerate, bedded and prismatic, or columnar trap-rock is very fine. The sandstone at the foot of the hill is succeeded by a siliceous conglomerate, in which the average size of the pebbles is from one-quarter to an inch in length. There are some of larger size, up to six inches in length. They are mainly quartz, with red shale and sandstone, a few of blue limestone, and rarely one of gneiss. They are disposed in irregular lines in the sandy matrix, and in some of the beds these lines of pebbles are more nearly horizontal than the bedding. Resting upon the conglomerates and sandstones there is a thickness of 25 feet of trap-rock which appears as a bedded rock, having planes of division parallel to the stratification of the underlying sandstone. Upon it is the prismatic or columnar trap-rock, 50 to 60 feet high, and forming the top of the hill. The prisms and columns are inclined from the vertical towards the west, that is, their longer axes are at right angles to the bedding planes of the strata under them. The two rocks are grandly exposed in Hartley's quarry, where, by the removal of the talus of earth and stone and the quarrying of the sandstone, a wall of rock about 180 feet in height is to be seen. It is seen to good advantage from the depot of the Delaware, Lackawanna and Western Railroad Company, and also from the line of the Paterson and Newark Railroad. The removal of the talus has left the lower portion of the trap-rock of a yellowish shade. That at the top (the natural bluff) is gray. The characteristic red of the lower part of the wall indicates the sandstone. Neither here nor in Morris hill does there appear to be any alteration in the sandstone to any extent, more than one or two feet from the line of contact. The old copper mines north of Plainfield also worked on the line of contact and in the altered shales immediately under the trap-rock. On the upper slope the Field mine, near Warrenville, penetrated 10 feet of red shale; then 8 feet of a gray sandstone, with some layers of shale; then a black shale containing fish remains; and, at bottom, a hard, gray sandstone impregnated with copper ores, and evidently close upon the trap-rock. The thickness of the overlying shales and sandstones was found to be about 30 feet. In the openings of the American Copper Mining Company, northeast of Somerville, the copper-bearing shale directly under the trap-rock has been worked in some distance, on a dip of 10° or 12° towards the northeast. The northwest slope of this range shows generally trap-rock outcrops, and shale only on the lower part of it near the valley. On the outer slope the sandstone rises higher. At Paterson it is within 150 feet of the summit; on the Mount Pleasant turnpike, west of Llewellyn Park, it is over 500 feet high and 100 below the crest. Southwest of Milburn and around to Pluckamin the sandstone does not make up so great a proportion of this slope. The boundary of the trap-rock, shown by the geological map, follows this line of gentler and steeper slopes.

The Second mountain is parallel to the First mountain and is separated from it by a narow valley. Red shale and sandstone are the rocks cropping out between the trap-rock slope of the First mountain and the steeper face of the Second mountain. The breadth of their outcrop varies from one-quarter to three-quarters of a mile. The length of the range from the Ramapo river, near Pompton Furnace, to Bernardsville, is forty-eight miles, and its breadth from one to three miles. Its greater length and breadth, and its greater curves at each end, are notable as compared with the outer, or First mountain. It is remarkable for the greater irregularities in its crest line, its double crest in places, its greater elevation, and the absence of depressions or gaps, excepting where the Passaic crosses it, at Little Falls. The greatest height is in High mountain, five miles northwest of Paterson, where the elevation is 879 feet—about as high as the front or southeastern border of the Highlands. The depression at Little Falls is wide and 160 feet high. East of Caldwell it is 691 feet, and the range is broad and double-crested. There is slight lowering at Summit to 318 feet. Thence southwest and westerly the elevations are 400 to 500 feet, rising to 600 feet near Mount Horeb. A cross section of the range with its characteristic features, would show a steep slope towards the valley and the First mountain, and a somewhat broad summit with the two crest lines and a long slope towards the enclosed or Upper Passaic valley. The rock structure is essentially like that of the First mountain. The red sandstone and shale is capped by a sheet of trap-rock, and that, in turn, covered in large part by drift. The red, shaly surface near Mount Horeb, and the double crest indicate the possibility of an interval between two sheets of trap-rock, occupied by shale or sandstone, particularly where the range is broad. But owing to the amount of drift concealing the strata, no such body of intervening rock has been as yet discovered. The sandstone underneath the trap-rock is to be seen on the left bank of the Passaic, below Little Falls. The old quarries were in the sandstone

PLATE V.



Julius Bien & Co. lith. N.Y.

COLUMNAR TRAP-ROCK.

ON THE LEFT BANK OF PASSAIC, I MILE BELOW LITTLE FALLS.

close under the trap-rock. On the Keelin place, one mile below the village, the latter rock is columnar in structure. At this place the unaltered shale appears under the trap-rock and in contact with it; then a bed of fine-crystalline trap-rock, three feet thick, above which rises the columnar mass, represented in Plate No. 5. This rock also is fine-crystalline. The prisms are mostly pentagonal, although a few are hexagonal in cross sections, and they are from one to three feet in diameter. Where broken off, the tops are concave. The longest of them does not exceed 15 feet in length. They lean a little to the north-northwest, or stand perpendicular to the plane of the dip in the underlying sandstone. The engraving of Plate No. 5, is from a photographic view taken from a standpoint a few rods southeast of them. The same columnar structure is observable in the bluff—south from this locality. At Little Falls, the prismatic structure is very marked in the ledges below the falls and on both banks of the stream. Plate No. 2 exhibits something of it, in connection with the joints which traverse the rock at right angles to the prisms. These prisms are from two to ten feet long, and usually one to six inches across. They are quite irregular in cross section, and the forms vary from flattened triangular to hexagonal. Another noted locality of columnar trap-rock in this range is at a small quarry southwest of Little Falls, and near Green Brook. They are very large and regular in cross section, but they are not so exposed to view as at the Keelin place. Generally the outer slope of this range is not so steep as that of the First mountain, and there are no mural walls of much height. There are some abrupt ledges on the northeast side of High mountain and in the range west of Paterson, but to the southwest of Little Falls the slope is steep, without being precipitous.

The rocks of the First and Second mountains are mostly fine-grained, compact and tough, and grayish to dark-blue in color, apparently dolerites, like the Bergen hill rock. In some of the outcrops on the upper surface the amygdaloid structure is observed; also, the cellular has been recognized. The latter is evidence of cooling without pressure, as if the outflow had passed beyond the shale strata. The great changes which the shale has undergone near the trap-rock, as seen in the copper mines of these ranges, is evidence of the subsequent outburst of the igneous rock and coming out through the parted shale and sandstone strata. The copper ores appear to have had their origin about the same time, as they are confined to a narrow belt of few feet in width at the plane of contact.

But the most remarkable fact in these ranges is their parallelism for so long a distance, and their uniformity of breadth and height. We cannot help believing that their origin was brought about by like causes and was contemporaneous.

POMPTON FURNACE TRAP-ROCK HILL, PACKANACK OR PREAKNESS MOUNTAIN, AND TOWAKHOW OR HOOK MOUNTAIN.

These several names are given to the different parts of a continuous range. The trend from the northwest, at Pompton, is first southeast and then south, curving to southwest at Mead's basin; thence west to near Lower Montville, where it bends again to the south and disappears beneath the alluvial and drift beds of the Passaic valley near Pine Brook. The length of the range is 16 miles, and its breadth is from an eighth to three-fourths of a mile. For its more accurate delineation, reference is made to the geological map. From its curving trend we infer that for a part of its course the strata of sandstone have been broken across, as it is scarcely probable that the beds of the latter dip in so many directions in so short a distance. The shape is that of two reversed, crescent forms connected. Owing to the drift, there are only a few outcrops of sandstone to decide as to its position or its relations to the trap-rock. The ridge at Pompton Furnace is very narrow and its sides are both steep. The calcareous conglomerate appears on the northwest foot of the ridge, dipping to the west-southwest, under the trap-rock; and under the conglomerate there is a sand-stone, also dipping to the southwest. East of the lake it rises and the greatest elevation attained is 478 feet near where the Pompton and Paterson road crosses it. The Preakness part of the range has a maximum height of 489 feet. Towards the south and west it is narrow and lower, sinking down, at the Pompton river, to 170 feet. Here the gap is about a half mile across, and the rock connection is not apparent. The crest of the Packanack, or Preakness ridge, is of trap-rock; the slopes are so drift-covered that no outcrops are to be seen. The Towakhow, or Hook mountain, is the reversed curve of this range and has its convex front towards the northwest. This mountain is narrow, excepting at the west, where the trap-rock outcrop attains a breadth of one mile and an elevation of 459 feet. The slope up from the Passaic river valley on the southeast is steep, whereas those to the north and west are much more gentle; and while the latter are of trap-rock, the former is sandstone quite two-thirds of the way from base to crest. The Morris Canal and the Boonton Branch Railroad line cut into the rock of this range, more or less, all the way from Mountain View, or Mead's basin, to near Montville. In consequence of the drift mass west of Preakness, and the alluvial beds in the Mead's basin gap, there are few sandstone outcrops on the flanks of the ridge, and the mode of the outflow of the trap-rock, whether across the strata or conformable to them, is not certain. At the northwest, near Pompton Furnace, the trend of the ridge corresponds to the stratification of the sandstone; but for one mile each way from Mead's basin there are no strata visible. It seems reasonable to believe that the curve consists of a series of offsetting northeast and southwest dikes connected by outflows through fractures across the strata.

This trap sheet, or series of sheets, making up this mountain, is not so thick as that of the Second mountain, or that of the First mountain. From the height of the mountain and the known elevation of the sandstone at Vreeland's quarry, the thickness is apparently not less than 300 feet.

The rock of the Hook mountain is cellular near Mountain View, particularly that on the lower part of the southern slope. But generally it is dark-colored and fine-crystalline, or even crypto-crystalline; and, in general, the rock is much finer than that of the outer ranges. At some localities near the Pompton and Paterson road the rock is coarser-crystalline and contains a notable percentage of magnetite. It weathers to a rusty-brown rolor. The chemical composition of specimens of it analyzed, show more ferreous oxide and less alumina than the grayish-blue rocks of Bergen hill.

WEST OF POMPTON PLAINS.

There are two trap-rock outcrops, but of very limited areas, northeast of Montville, and close to the Highlands. The first to be noticed is about one mile from Montville, and near Waughaw. The boundaries of the outcrop make it almost circular, but owing to the drift hereabouts, there is much uncertainty about their location. The rock is gray and medium fine-crystalline. The other range is northeast of the last, and runs west of the hamlet of Jacksonville, and west of Pompton Plains. It forms a part of its length, a rocky surface, particularly that on the west, and it is close to the gneissic rock slope.

The eastern side of this range is obscured by drift deposits. Its length from southwest to northeast is one mile. Both of the outcrops are shown on the geological map. What, if any, connection these outcrops have towards the other trap-rock ridges to the east and south, is rendered altogether uncertain by the diluvial formation of Pompton Plains. They *appear* as isolated, low hills on the border of the Highlands.

RIKER'S, OR MOREHOUSE HILL.

The length of interval from the south end of Hook mountain to Riker's hill, is two and a half miles. In the absence of any outcrops above the level of the Passaic valley alluvium, it is uncertain about their connection. From the general level, common to the shale east and west, it does not appear probable that the trap-rock is continuous, although the trend of each would indicate one line connecting them. If continuous, the rock is covered by the alluvial beds of the wet meadows south of Pine Brook. Riker's hill is a single ridge, having the features of steep easterly and gentle westward slope, characteristic of the trap-rock ranges on the east. Its course also corresponds to them. It is three and a half miles long and a half a mile across. The greatest height is 473 feet. The shale crops out high up on the eastern face; on the west there is considerable drift.

LONG HILL.

Long hill is well named, as it is a long, narrow ridge, having a general southwest course, from Chatham to Meyerville, and then a west-southwest course to the Passaic, at Millington, beyond which it runs on nearly to Liberty Corner. Its length is eleven miles, and its mean breadth of trap-rock outcrop between a quarter and a half a mile. The height of the crest line is remarkable for its uniformity, the several higher points on it being 485 feet, 472 feet, 412 feet, 432 feet, 445 feet and 450 feet, respectively, or a variation of 73 feet only at six stations in eleven miles. Its course is about parallel to the Second mountain. At Millington, the Passaic crosses this range of rock in a narrow and deep gap, which is 200 feet deep and but a half mile wide at the top. The trap-rock crops out in the crest and makes up the northwestern slope of the hill; the shale rises nearly to the crest on the southeastern face, leaving the thickness of the sheet of intrusive rock less than in the mountains to the southeast. Owing to the absence of glacial drift on the hill, the rocks of the surface are much weathered and of a dull brownish shade. In composition they are like the rock of south end of Hook mountain. The shales under the trap-rock are apparently unaltered, except very near the plane of contact. On the northwest slope there is scarcely any shale or sandstone to be seen, and the foot of this slope is buried beneath the drift and alluvial masses of the Great swamp.

BASKING RIDGE TRAP-ROCK.

There is much uncertainty about the extent of this outcrop and its relations to Long hill on the south and the Second mountain range to the west. The maps of the survey have represented it as a separate outcrop of triangular shape, the apex of the triangle being pointed towards the north and near the village of Basking Ridge. The limits of this trap-rock area have been retained essentially as given upon the map, although the northern end of it is a little nearer to the village than represented on the map of 1867. From the absence of any shale outcrop between it and the eastern end of the Second mountain range it is not unreasonable to suppose that these are connected. In that case this outcrop is the end or horn of that long crescentic range.

One mile east of Bernardsville there is a trap hill or ridge, a half mile long, extending northward, from the Bernardsville and Morristown road to the Highlands. Its slopes are smooth and regular, but the surface is very stony. This outcrop is not apparently connected with either the Second mountain or the Basking Ridge outcrop. The rock of the summit is fine-crystalline; that of the eastern slope is more cellular.

NEW VERNON AND LOANTAKA TRAP-ROCK.

These two names are given to two ridges south of Morristown, in Passaic and Morris townships, which together form a horse-shoe shaped range with New Vernon in the enclosed valley. The Loantaka ridge runs from near the Basking Ridge road, one mile south of Morristown, in a southeast course to Green Village. The Loantaka brook flows at its eastern foot for three miles nearly. And the slope towards it is not so steep as that towards the enclosed valley. It is trap-rock; that to the west and south is shale and then trap-rock.

The maximum elevation of this ridge is 427 feet. There is a gap a half mile from the west end which is 280 feet high.

The New Vernon range runs from Green Village in a westerly direction to the valley of Primrose brook, near the Highlands slope. It is broader than the Loantaka outcrop and higher, rising to a height of 467 feet near New Vernon. Like the other ridge, its slopes are of unequal descent. The outer, or southern, going down to the Great swamp level of 240 feet; that towards the north is steeper and shorter. The two are thought to be connected by rock, covered by diluvial beds, a short distance west of Green Village, where the height of the surface is only 270 feet. The interval of concealed rock is very short. The ranges are connected upon the geological map with this report. The rock is generally fine-crystalline. On the surface it is much weathered, and in places assumes a cellular aspect. The relations of the shale to the trap are not altogether conformable, and it is highly probable that some of the trap-rock has broken across the shale. The general parallelism to the outer concentric, curved ranges is noteworthy. This one is the innermost and smallest.

MARTIN'S DOCK.

The trap dike at Martin's dock is so characteristic that it is included in this list, although it is of limited extent and not large enough to be represented upon the geological map. The outflow is about one-eighth mile up the river from the dock and on the left bank. The following cut (Plate No. 6) is from a photograph of the bluff taken last autumn. There are here two apparently unconnected masses of trap-rock interbedded with the red sandstone, as shown in the engraving. The total thickness from the river, or water level, to the top of the bluff does not reach 30 feet. The sandstone separating these two beds may be two feet thick. The beds descend towards the northwest at an angle of 10°. About 200 feet west of where the view was taken, the bedded trap-rock disappears beneath the tide water of the river, and no more is to be seen of it in that direction. The shale in contact with this interbedded trap-rock is of yellowish color and somewhat indurated. The trap-rock is fine-crystalline and shows, near the center, a tendency to a prismatic structure. Near the shale it assumes a bedded appearance. Its greatest thickness is about 12 feet. Both to eastward and also west the river bank is red, shaly sandstone, and apparently

PLATE VI.

Julius Bien & Co. lith. N.Y.

SANDSTONE WITH INTRUDED TRAP-ROCK.

MARTINS DOCK, LEFT BANK OF RARITAN, BELOW NEW BRUNSWICK.

unaltered. No signs of this dike have been observed on the surface at any distance from the river.

Down the river one mile, and opposite Whitehead's dock, the dredging operations and submarine blasting of the top of a reef have proved the existence of an indurated shale about 500 feet wide, crossing the river on a northeast and southwest course and 5 to 12 feet below level of low water in the river. But no trap-rock has been found at this locality. It does not seem to be at all connected with the outflow at Martin's dock.

Southwest of the Raritan river the trap-rock was found in the cut of the New Jersey Railroad Company, about two miles west of New Brunswick, and on the surface in a ravine a few rods northwest. The same rock was encountered in the old copper mine three miles west of the town, although it was not seen upon the surface.

These trap dikes and altered shales near New Brunswick indicate a very general disturbance along this border of the formation, excepting the interval from Staten Island sound to the Raritan river.

TRAP-ROCK OF LAWRENCE BROOK, TEN-MILE RUN MOUNTAIN AND ROCKY HILL.

The boundary lines of this extensive outcrop have been described in the "*Geology of New Jersey.*" They are shown on the geological map also. A peculiarity of much of this range is its evenness of surface with the country bordering it. It is not above the general level at any point east of the Pennsylvania Railroad line. The Ten-mile Run mountain has its outer slopes well marked, and the shale and trap-rock line is plainly marked, but the inner border is obscured by the Sand Hills drift, and it is not much higher than these hills of drift. The Lawrence brook and the Ten-mile Run mountain together make a semi-circular range with its convex front to the west. But the Rocky Hill range, which is connected with it across the Millstone, appears as a second arc with its convex side to the south. The northwesterly dips in the shale surrounding this trap-rock outcrop do not indicate a conformity to the strike of the shale in these outflows, but the existence of cross fractures, somewhere in the line, and particularly in the Ten-mile Run mountain, southeast from Rocky Hill, to Dean's. The Rocky Hill ridge stands out much more prominently above the general level of the red shale country north and south of it. It is about 400 feet high north of Princeton. In Mount Rose it attains an elevation of 409 feet. It is to be observed that the northwestern end of this range points towards the Sourland mountain and is two miles only from it. The New York and Philadelphia New Line Railroad cuts across the extreme western end of this range near Hopewell Junction. No connection is apparent in the surface between the Sourland and Rocky Hill ranges, although so near together.

The trap-rock of this range is mainly a quite coarse-crystalline dolerite. Near Rocky Hill it has been quarried extensively for paving blocks and for road materials. It has escaped glaciation, and the surface is very generally much weathered or covered by the decomposed rock materials. There are, consequently, fewer outcrops than on the Palisade and Watchung mountain ranges.

Near the trap-rock the shales are much altered, being generally of a dark-purplish to bluish shade and hard. And the alteration induced in the shale is traceable, in places, for many rods from the trap-rock. At Rocky Hill the nodules of epidote are observed in the shale north of the trap. At the Griggstown copper mine the altered shales are penetrated by the shafts of the mine and the ore is found in them. The Rocky Hill trap-rock is bordered on each side by a belt of the indurated shale; and the railroad cuts, west of Hopewell, afford excellent sections of these shales indurated near the trap-rock.

PENNINGTON MOUNTAIN.

This outcrop of trap-rock makes a bold, sharp ridge, standing isolated in a red-shale district, but on a line connecting Rocky hill and Bald Pate hill. The course of the ridge is northeast and southwest, and is nearly three miles long. Its height is about 400 feet.

BALD PATE HILL.

Bald Pate hill is bounded by the shales of the Moore's creek, Jacob's creek, and Fidler's creek valleys, and on the west by the Delaware river. The extent of this outcrop, back from the river, is between two and three miles. Its height is about 400 feet above the level of the canal feeder, or 460 feet above tide level. The slope to the northwest is rather gentle; that to the south is abrupt; and so is that towards the river. There is a trap hill on the Pennsylvania side which corresponds to this hill as its southwestern extension. The rock of Bald Pate resembles, in general, that of Goat hill. It is coarse-crystalline. The surface is, in many outcrops, somewhat weathered. The shale near it, on the south slope, is hard and much altered.

BELLE MOUNTAIN.

Belle mountain is the name given to the isolated hill between Bald Pate and Goat hills. It is apparently unconnected with any other trap-rock outcrops around it. The side towards the river is a wall of rock abrupt for over 100 feet up from the river plain. The trend of the hill is about north 20° east. The Delaware here runs to the southeast, or almost at right angles to the strike of this range. The height of the hill above the Delaware is about 250 feet. On the river side the rock is traversed by joints, which divide it into thin plates, or flat prisms; and these joints run on northeast and southwest courses. The surface portions of the rock are much weathered and are grayish-white in color.

SOURLAND MOUNTAIN.

Under this head the continuous range from Goat hill, on the Delaware, to Flaggtown, in Somerset county—a distance of seventeen miles—is described. Its course is nearly due northeast. The boundaries of the trap-rock are shown on the geological map. The average breadth of the outcrop is about one mile. The ridge is between 300 and 400 feet above the plain country on either side, and in Goat hill it rises to a height of 491 feet above tide level. It is peculiar in its structure, consisting of a central belt or core of trap-rock with belts of indurated shales on each side. The slopes are not unequal and are both of shale. The trap-rock constitutes the top. The distance to which the alteration in the shales has taken place is noteworthy. And the bluff east of Lambertville is perhaps the best locality in the State for studying the results of such changes in this rock. Tourmaline occurs irregularly disseminated through the blue, hard rock near the line of contact. Further away the shale has a dark-purplish shade. And in it are nodular masses of essidote. The red, unaltered sandstone is first observed about a quarter of a mile from the trap-rock outcrop. A similar change and the same minerals were observed in the shales north of the trap on the Pennsylvania side of the river. And generally the shale near the trap-rock is very hard, ringing when struck. It breaks into rectangular blocks, and is adapted to rough stone masonry. The breadth of the belts of altered shale is from one-quarter to a half mile each. The dip is uniformly to the north and northwest and at angles of 20° to 40°. Near Snydertown, the shale forms the crest of the ridge, and the trap-rock occupies the southern slope. West of this point the trap-rock outcrop makes a bend to the north, and as far as Rocktown, there again making the crest of the ridge. No gap or evidences of an interlocking of shale with this rock could be found here. From the uniformity in the dip of the shale, the outflow appears to have been between the layers, and the great alteration, both above and below, show that it is an intrusive sheet. The excessively hard shales have resisted weathering, and hence stand up more prominent in places than the intrusive mass. Generally the trap-rock is much weathered on the surface, and it appears in irregularly rounded masses and is not solid. In Goat hill, and also eastward to Rocktown, this rock is a gray, coarse-crystalline aggregate of labradorite and augite with traces of magnetite. In chemical composition it does not vary much from the rocks of Palisade mountain. The soil resulting from the disintegration of the rock and its decomposition has a dark, brownish-red color and is very fertile. This rock has been quarried extensively for paving blocks and for monuments; also for road materials.

ALEXSOCKEN CREEK TRAP-ROCK.

This outcrop of trap-rock is an isolated hill or ridge, rising up abruptly from the river to a height of 250 feet. The length of the outcrop from southwest to northeast is about two miles. It is surrounded by altered shales, which dip uniformly to the northwest, although the lines of division between the shale and the trap-rock are not located accurately on account of the earthy covering. The northwest slope of the hill is gentle; that towards the river is steep and rocky. It appears to be a short and isolated outburst of trap-rock.

FLEMINGTON TRAP-ROCK.

The outcrop of trap-rock at Flemington is small, not exceeding a single square mile. It makes a short ridge west of the town, on which the cemetery is located. Its northeastern limit is near the

Klinesville road, and the southwestern is near the old copper mine, while the Neshanic creek, No. 1, is its western limit. A dike runs across the Stockton road near this stream, and east of the mine.

From the extent of black and dark-colored, indurated shales in the vicinity of Copper hill and in the belt of country northwest of Flemington, it is evident that trap dikes must traverse these shales, although they have not been found cropping out, excepting at the Flemington locality, and on the Delaware, near Point Pleasant.

POINT PLEASANT TRAP-ROCK.

The bluff at Point Pleasant affords a very fine cross section of the indurated shales and included trap-rock at this locality. The shale under this outcrop is almost black, and is very hard, resembling basanite. The trap-rock, also, is very dense and fine-grained. It crops out on the road ascending the hill from the station. Higher up the indurated shale again appears, and still higher the trap-rock again, as if there were two interbedded masses of trap-rock. But the outcrop is not traceable over a mile from the river. The very fine section along the Lackalong creek, two miles further east, shows an unbroken succession of shales only. It is quite probable that this is one of a series of trap dikes traversing the high ground and region of altered shales, which extends from the Delaware, northeast by Croton and Cherryville, nearly to the valley of the South Branch. They have not reached the surface elsewhere, or have not been found, although the country has been carefully examined for them.

Beyond Point Pleasant, northwest, there are no outcrops of trap-rock on the New Jersey side of the river, although there are large areas of such rock on the Pennsylvania side, back of Uhlerstown, and at the Ringing rocks, west of Milford.

ROUND MOUNTAIN.

Round mountain is the name usually given to the rocky ridge east of the South Branch, and south of Stanton, in Hunterdon county. The ridge trends easterly from the river, and the outcrop is little more than a mile in length. The south side is steep and stony; the top is quite smooth, and the north slope is more gentle. The loose trap-rock on the surface marks the area of outcrop. On the northwest, and also on the east, the shales are somewhat indurated, and the varying dips indicate a disturbance of the strata. The barometric observations make the elevation of the summit, above Stanton, about 150 feet, or 500 feet above the ocean. The rock is fine-crystalline and of grayish color.

ROUND VALLEY, OR CUSHETUNK MOUNTAIN.

The Round Valley mountain, so named from the horse-shoe shaped valley which its sweep bounds on the north, east and south, is sometimes know as Pickle's mountain, although the latter belongs more particularly to the northern sweep of the range. Its peculiar shape is shown by the map. The mountain on the north side of the valley is a narrow and sharp rocky ridge. At the southeast the crest lowers, and the road leading eastward out of the valley then crosses in a depression. The mountain south of the valley is high and much broader than that on the north, extending nearly three miles in a south direction. The elevation at the U. S. C. and G. S. station on this part of the range, is 800 feet. According to barometric observations, the summit of the crest line on the north is 700 feet, and at the road on the southeast 420 feet. The slopes outward are, in general, not so steep as those toward the Round valley. The shale and sandstone exposed in the railroad cuts, and other outcrops on the north and east sides of this mountain, dip to the north and northeast. In the valley the dips are towards the northwest, where the direction can be made out with certainty. As on the west, in the valley of Prescott brook, the dips are all westerly, the outcrop of trap-rock is not everywhere conformable to the bedding of the shales, and it appears to be near axial lines in the shale, or the dips in the latter are evidences of disturbances induced by the trap-rock. It seems reasonable to assume that the igneous rock here followed the lines of axes, or just where the rock was the most likely to open and let out the intrusive mass. The shales in Round valley are not altered where they have been observed; but on the outer slopes, at the southwest, there is a belt of dark-colored indurated shale bordering the trap-rock. The Central Railroad cuts, between White House and Lebanon, expose some altered rocks north of the mountain and near its base. The shale of the Round valley is bounded on the northwest by gneissic rocks.

The rock of this mountain is generally of a grayish color and rather coarsely crystalline. There are, on the south, some dark-colored, dense and fine-grained varieties. The surface is very stony and the outcrop somewhat weathered in appearance. The soil, resulting from its disintegration, is noted for its adaptation to some kinds of fruit trees, as well as for its fertility.

NEW GERMANTOWN AND SILVER, OR MELICK HILL.

These areas of trap-rock have been described and represented in the reports and maps of the survey, and there is little to add to what has already appeared in print. The semicircular outcrop near this border of the Highlands is noteworthy, and its resemblance to that of Round Valley mountain is suggestive of like causes in their origin. The variation in the strike and dip of the shale near these hills indicates a cutting across the strata at some point. Silver hill is apparently unconnected with the New Germantown range on the surface. On both of them the shale rises higher on their south and east slopes. Towards the north and west they are all trap-rock. The rock of Silver hill is dark-colored, dense and prismatic in structure, and the surface is largely made up of angular trap fragments. According to barometric observations, the height above tide level is near 500 feet. The rock of the New Germantown hill also is of fine-crystalline nature, and resembles that of the Silver hill. Both are dolerites in composition.

The surface features of this red sandstone formation have been incidentally described in great part in the report on the drift of the State in 1880.* The conformation of the district is shown in part on the topographical map of Northern New Jersey, published in 1882. And the preceding descriptions of the trap-rock ranges and areas of the shales, sandstones and conglomerates refer to the more prominent features of the surface configuration. The geological map exhibits the terminal moraine line as it crosses the formation. It would be a needless repetition to describe here the surface in detail since so much concerning it is already in print. A few generalizations are, however, here proper, to supplement what has already appeared in our reports. The rocks determine everywhere the nature of the surface, excepting where modified by later depositions, either of glacial or modified drift. North of the terminal moraine the surface is of glacial drift,

*Annual Report of State Geologist, for 1880, pp. 39–45 and 58–64.

or of *glacial drift modified* over very large areas. In the Upper Passaic valley there are a very few small outcrops of sandstone and shale. On the trap-rock hills, south of the terminal moraine, the surface is much more determined by the nature of the underlying strata. And nowhere else in the State is there closer connection between the rocks and the soils derived from them. The varieties of shale, sandstone, etc., have made corresponding types of soil over wide areas. Everywhere the trap-rocks are noted for their stony surface. It may be, as on the Palisade and Watchung mountains, the outcropping ledges, or the subangular fragments and rock masses with earth, making a scanty covering of the solid rock, or, as in the case of the Sourland range, as typical of others to the west and south of the glacial drift, the disintegration and decomposition of the rock on the surface and along lines of joints and bedding, has resulted in a reddish, clayey soil and subsoil, with somewhat rounded and weathered masses of rock lying irregularly on, or partly in the soil and subsoil. The stony character prevails, however, throughout. Generally these trap-rock soils are of a deep reddish-yellow to brownish-red color, and clayey. They are retentive and fertile. The conglomerate outcrops are comparatively small. The siliceous varieties make a hard, stony soil, filled with somewhat angular, quartzose fragments. And the soil is thin and not suited to cultivation or tillage without much labor in its preparation.

As the sandstones vary greatly from arenaceous to highly argillaceous varieties, so do the soils on them. The former are rather sandy, or even gravelly, when originating in the coarser-grained or fine-pebbly sandstones. The latter are more like the shale soils, and they grade into the red shale type.

The red shale so readily falls to pieces on exposure that it forms a tolerably stiff soil. There is much variation in it at different places.

Where indurated, the rock does not disintegrate or decompose rapidly, and the rock is sometimes close to the surface. Clayey soils of light colors prevail over the dark-colored indurated shales. The district known as the "Swamp," in Hunterdon county, and the slopes of Sourland mountain, are examples of this type of surface.

2. ERUPTIVE ROCKS OF SUSSEX COUNTY.

During the geological survey of the State by the late Dr. Kitchell, in 1854–5 and 6, his assistant, Mr. E. Haeusser, described a dike of what he called Porphyritic-Hypersthene rock, on the east slope of the Kittatinny mountain as running "from a point one and half miles northwest of Libertyville, without interruption, to its termination, which is one and a fifth miles northwest of Beemersville. It is about a quarter of a mile wide, and a little tortuous in its course, but its general bearing is northeast and southwest."

He describes the rock as "consisting of a coarsely granular aggregate of labradorite and hypersthene, associated occasionally with hornblende, mica, sphene, tourmaline and quartz."

This locality has been visited repeatedly since that time by persons connected with the survey, and, in the autumn of 1881, a survey and map of the dike and neighboring parts were made. In the 23d vol., 3d ser., *American Journal of Science*, p. 302, is a paper by Prof. B. K. Emerson, of Amherst College, "On a great dike of Foyaite, or Elæolite-syenite, cutting the Hudson River Shales in Northwestern New Jersey," and he there describes his visit to Mr. Haeusser's locality and carefully describes the rock and its minerals under the above names.

The rock is a peculiar one, and well worthy of study. Fragments of it have been found at the foot of the same mountain, in Warren county, 24 miles to the southwest. We have searched for the rock in place, but so far without success; the heavy deposits of glacial drift burying all the underlying rocks. There can, however, be but little doubt that the rock will yet be found in other places.

Through the kind assistance and guidance of Wm. S. Vanderuff, Esq., of Deckertown, we have been enabled to visit several other localities of eruptive rocks in the district west of Deckertown, and not far from the Beemersville dike.

One of these is in a hill on the farm of Mr. P. C. Rutan, a mile west-northwest from Libertyville. The hill rises very abruptly (33°) from the meadow, to a height of 150 feet. It is smooth and clear of trees, but covered with grass and cultivated fields. Through the hill there passes a dike of rock, very different from that of Rolason's. It is dark-colored and much finer-grained, and in some parts it is remarkable for the numerous fragments of slate, limestone, sandstone, and gneissic rocks imbedded in it. These are from all the underlying formations that should be found here. The mass of eruptive rock is singularly rough and black, where exposed to the weather, though it disintegrates easily. This locality is an exceedingly interesting one to visit, and the material of the dike seems to be quite different from that in the one first described.

With Mr. Vanderuff, we also visited the old U. Van Auken farm, three miles south of Mr. Rutan's, upon which, in a field east of the road, we saw two other low hills of a material like that in Mr. Rutan's hill. Another hill on the Howell (formerly Wyker) farm, in the field on the southwest side of the road, and a half mile south of the last locality, also there is an exposure of the same kind of rock. This has a little pyrite in it, and a shaft was sunk in it to the depth of 80 feet, a number of years ago. The work was said to have been done in searching for silver or gold. About a mile northeast from the last locality, and on the back of Mr. Jacob Stiver's farm, we were shown two other low, but abrupt hillocks, in which the same peculiar eruptive rock was found.

The rock in all these outbursts is dark-colored—almost black—fine-grained, and rather soft. The fields near the rock have soil of a bright, salmon-red color, evidently produced by the disintegration of the rock itself, or the adjacent altered shale. It has no resemblance to the great dikes at Franklin Furnace, nor to the altered limestones of Augusta.

The locality requires a more careful examination than we have yet been able to give it, and these eruptive rocks in the Kittatinny valley must receive a thorough examination.

3. IRON MINES.

The iron mines of the State continue as productive as in previous years. The total output for the year 1882, so far as can be estimated from the returns of the several lines of transportation crossing the State, and from the receipts by teams at furnaces in the State, amounts to 900,000 tons. The product is 140,000 tons in excess of that for 1881, and larger than ever before.

The condition of the iron-mining industry is so largely determined by the state of the iron market that a review of the latter for the year is in some degree a guide to the former. Of course the iron ore market does not follow all the sharp changes in the prices for iron, since the sales of ore are made in advance, or on long contracts at stipulated figures. It is not at all speculative in its character. Following the course of the demand, we note that in the early part of the year good prices prevailed and a strong market. But a downward tendency soon made itself felt, and early in the spring there was a decline in prices. Through slight fluctuations this general downward course was manifest more or less to the close of the year. The ore market has sympathized with that of iron, and the demand has gradually weakened. As many of our largest mines are either owned or controlled by blast furnace companies in the State, or in the Lehigh and Scranton districts of Pennsylvania, they are worked steadily to supply these furnaces, and very little of their ore is put on the market. This close connection or common interest between the blast furnaces and mines is probably an advantage to the State in the more steady working of the mines. In consequence of the slackened demand in the latter part of the year, a few mines temporarily stopped work. The localities far from lines of transportation, and those where the ores were lean or of inferior quality, or where the facilities of mining were not good, suffered most, and a few of them were temporarily abandoned or greatly reduced their production.

The greatly increased demand for steel in the country has relatively diminished that for iron, and the enlarged production of steel has not produced a corresponding increase in the demand for our home ores, which are suited to the manufacture of steel. Through the importation of foreign ores of great richness and purity, the market has been supplied, and largely to the exclusion of our native Bessemer ores. The greater part of the product of our iron mines is not adapted to the making of Bessemer steel on account of the high percentage of phosphorus. There are ranges of ores which run low in phosphorus, and which may be ranked as steel ores. Their location has been given in the successive annual reports of the Survey, and it is not necessary again to refer to them in detailed descriptions. The Green Pond and the Chester ranges, and the mines in the Pequest belt, yield such ores. There are other localities and single mines in the other parts of the district also suited to making steel. In a full report on the district they will be described, and their relations to the other ores be discussed as soon as the map is completed. The introduction of the Thomas-Gilchrist or basic bottom process into our country ought to find its best materials in the irons made from some of our ores which carry a high percentage of phosphorus. The competition through its introduction would cheapen production, enlarge the demand and make an additional market for such of our ores. In the interest of the iron-mining industry, it is to be hoped that events may so shape as to bring it about. The development of our own resources seems to require not only its introduction, but also some protection against excessive and disastrous competition from outside.

A list of the iron mines in the State was published in the report for 1880, and a supplementary notice appeared in 1881. During the year a few of the older mines have been permanently abandoned. Their permanent withdrawal and final abandonment has come not so much from the lack of ore, or the exhaustion of the *veins*, but from the heavy expenses attending the working of them, making the cost of the ore, in one case, at least, nearly twice its market value. Of the older and larger mines which have been abandoned, are the Byram, Randall hill, and Swedes, near Dover, Morris county. The first named had reached a depth of 1,100 feet, measured on the slope. The vein at the bottom was small, and the shoot a short one, but the ore was rich. It appears proper to put on record the closing of these three mines, as each has had a long history, and they have produced a large aggregate of ore. Many of the smaller and newer openings also have been abandoned, though temporarily, it is believed, in many cases. They await a greater demand and stronger market, or better railway communication. Continued observation of the district confirms the views expressed in last year's report, that there need not be any apprehension of exhaustion, since new localities are developing into productive mines, and the deepening of the older mines shows that the ore extends downwards as far as the working is practicable. For example, the Hurdtown mine slope is already over 2,000 feet long, running down lengthwise on the shoot of ore; the Dickerson has attained a vertical depth of over 700 feet. And both of these mines are apparently not near exhaustion. As the appliances for raising ore and pumping water from great depths are gradually improved and the expenses are relatively lessened, the mines will be worked deeper, and the practical limit of exhaustion will be further away. The value of the ore and the cost of getting it will have much to do in determining how far it can be followed profitably.

No attempt has been made to collect notes of all the changes which have taken place during the year, and a few only of the more important and noteworthy discoveries and openings are here noticed. The topographical survey of the iron ore district has been carried forward to the State line on the north and to the southwest into Hunterdon county, leaving about 150 square miles of the Highlands still unsurveyed. This area is in the northern part of Hunterdon and in the southwestern part of Warren counties. It can be completed next season, and then an accurate map of the whole of the iron ore district can be constructed. The advance upon previous maps will be very great, and the details of mines, openings, lines of attraction, of property, &c., can be delineated thereon with accuracy. Such a map ought to show the true relations of the ores and give the clew to the structure of the whole district; and the solution of this problem has been the end in view in these years of study and surveying. The practical benefits or value of the solution can speak for themselves.

In the southeastern belt of the Highlands there is little to report that is new. At the Board mine some work has been done in prospecting for ore, and good sized *veins* of lean ore have been uncovered. At Midvale much work has been done since it was last visited, and extensive preparations have been made for mining large quantities of a steel ore. In the central belts of the district the larger mines have, as heretofore, furnished the greater bulk of all the ore mined in the State. Among them, the Baker mine alone has been worked as a *steel ore*, although some of the Chester mines and others yield what are known as Bessemer ores. The newly organized Mutual Iron Company is reported to have secured the Davenport and other properties near Charlotteburg, and to be about developing them extensively. In the Pequest belt several localities have been visited and notes collected on the ground. Others have been furnished by persons well acquainted with that part of the district.*

QUEEN MINE.—This mine was opened in the early part of 1882, by Messrs. Hartpence. It is on the Paul A. Queen farm, one mile northwest of Oxford Furnace, and two and a half miles from Butzville. The location was made after surveys with the dipping needle

* As stated at the outset, these notes are incomplete, as it was not possible to go over the district and collect full details of the changes and discoveries. In consequence of this incompleteness it is possible that some noteworthy localities may have been omitted.

had discovered the attraction and traced out the extent of the same. The property has been tested in two shafts with drifts running from them, and in several trial pits. The attraction is in a general east and west belt, which is quite narrow at the pit and shaft No. 1, but is much wider to the east. It is reported to be positive, and varying in amount from 10° to 50°. Shaft No. 1 is vertical, and 75 feet deep, of which 26 feet was in dirt. From the shaft there is a drift 140 feet long, on a general east course, and nearly level. It traverses a body of ore and rotten rock. And when visited recently, the head of the drift was still in the earthy ore. From the main drift two short side drifts show the breadth of the ore body to be at least 25 feet, between a hanging wall of reddish-yellow earth on the south, and the yellowish, clayey foot wall on the north. These walls are, properly, decomposed rocks in place. They dip towards the south, or, possibly, a little to the east of south. The ore from the heading was a brownish-black, granular to earthy mass, according as it had more or less magnetite. South of this shaft 193 feet, a large pit, 70 by 60 feet, and from 8 to 17 feet deep, has been sunk. In it a lean ore was uncovered, with streaks of rich ore. A shaft going down vertically, 38 feet deeper, is reported to have penetrated a body of hard ore and struck at the bottom a reddish clay. The pit seems to show a breadth of 60 feet of workable ore. Shaft No. 2 is 200 feet easterly from the large pit and is 60 feet deep. It penetrates a body of earthy, granular ore. The strike or course of the ore as uncovered in the pit is nearly east-northeast. Its relations to that opened in the drifts from No. 1 shaft are not understood. The dip to the south-southeast ought to carry the beds in the latter below the bottom of the pit shaft, unless the *vein*, or bed, is horizontal. Much more exploring work is necessary to test the probable size of the ore bodies here and their course.

The fine, granular to earthy ore, is washed before shipping. It resembles very much the ore of the Raub place. Analyses report it as containing about four per cent. of manganese. The ores are all quite free from sulphur and are said to carry relatively low percentages of phosphorus. At the time of our visit about 2,000 tons of ore had been raised, of which amount one-half was lump, or solid ore. The washing has been done in the common rotary ore washer, the water coming from springs on the mountain above the mine. There are three engines and a 60-horse power boiler, which runs the steam engines and the steam pump also. Thus far the volume of water has been small. The earthy nature of the ore and of the walls has necessitated close timbering. The shipment of ore was deferred until the branch railroad, two and a half miles long, and connecting with the Lehigh and Hudson Railroad, near Butzville, should be completed. It is now running.

The mine and the adjoining Little property are owned by the Belvidere Iron Company.

OSMUN PLACE.—Trial pits have been sunk during the past year on this place, northeast of the Queen property, by the Messrs. Hartpence. They struck white limestone, and about 300 tons of ore are said to have been raised. It is a manganiferous and fine-granular.

The same parties have been testing the Keyser farm, near Oxford Church. But both of these localities are still further to be tested.

It is interesting to note in this connection the general resemblance between the ores of the Queen and Osmun places and those of the Raub and Little mines in the presence of manganese, and in their earthy to granular nature near the surface.

The Belvidere Iron Company has begun work and is taking out ore on the Deats and Smith places, near Green's pond, and west of Danville, in Warren county.

The discovery of the "Kishpaugh vein" on the Cook farm, west-southwest of the Kishpaugh mine, by A. Pardee & Co., is one of the most remarkable and successful results from the use of the diamond drill in this State. The first boring was west of the last one, and went 103 feet from the bottom of a shaft, 200 feet deep, without striking any ore. The second and successful trial was located about 220 feet further northeast and 23 feet from the road. At a depth of 285 feet the ore was struck, and when last heard from the bore hole had gone 26 feet into the ore, without reaching the foot wall. The work of drilling further was stopped temporarily by the crumbling nature of the ore. It was expected that after puddling and cementing the hole the work could be prosecuted so as to determine the thickness of the *vein*. This result proves a great length to the "Kishpaugh vein," and is encouraging to the Hoagland farm owners, as that property adjoins both the Cook and the Kishpaugh on the southeast, in which direction the ore dips. The property lines are such that they may all cut the ore and so divide the bed into three proprietorships. The further results of searches with the diamond drill are awaited with great interest, showing the increased extent of the ore and the value of the drill in exploring for it.

The Crane Iron Company is sinking a slope on the Kishpaugh to the northeast of their present working slopes, and are finding a thick body of ore in that direction.

The John Corliss farm, adjoining the Kishpaugh, on the northeast, has been leased by the Andover Iron Company, and the work of testing it, lately begun, has discovered some wash ore.

At the Stinson place, west of the Great meadows, and on the east slope of Jenny Jump mountain, the Lackawanna Iron & Coal Company is sinking a shaft on a vein seven feet wide of good ore.

On the east border of the Great meadows, the Andover Iron Company has put down a shaft 90 feet deep on the Green farm. When visited the ore was six feet wide and of good quality.

Northeast of the last named place, the Cummins place has been worked for a part of the year by E. Bulgin. The *vein* is very broad, and dips towards the northwest quite steeply, becoming more flat on going down. The ore is lean, and contains rock mixed with the magnetite. When visited, twenty tons of 40 per cent. ore were being taken out daily.

These scanty notes, collected in part on the ground, and in part furnished by correspondents fully acquainted with the mining developments in the several localities, show that there is considerable activity in the Pequest belt, and that the discoveries are very promising. The completion of the Lehigh and Hudson Railroad makes communication easy with the furnaces on the Lehigh and elsewhere, in New Jersey and Pennsylvania.

4. PLASTIC CLAYS, AND THEIR USES.

The plastic clays of the State continue to maintain their high standing for their varied uses. And the product of the banks and pits, particularly those in the Middlesex county district, is larger than in any previous year of their history. The general excellence of the various grades, and the superiority of our fire clays, in their high refractoriness, have been so fully stated in the previous reports of the Survey that it is not necessary here to do more than refer to them for the details of composition, fire tests and practical uses. It is, however, important and of public interest to call attention to the advantageous location of the clay deposits in Middlesex county, and on the Delaware, with reference to the lines of transportation and accessibility to the large cities, and the great iron manufacturing and other metallurgical establishments, which are easily reached from them. The Middlesex county clay district is washed on the east by the tide waters of the Staten Island sound, and of Raritan bay from the Blazing Star Landing to Cliffwood. It is bisected, as it were, by the Raritan estuary. It is still further traversed by Woodbridge creek, South river and Chesnaquack creek. And there is not a clay bank in it which is more than three miles from water navigation. All the larger ones, as the Woodbridge, north shore of the Raritan, south shore of the Raritan, and the stoneware clay banks, are much nearer, the greater number being within a mile of navigable water. In addition to these facilities by water, the district is now traversed by the Lehigh Valley Railroad, and the New York and Long Branch division of the Central, both running direct to, or in close connection with lines to the Lehigh and Wyoming blast furnace and coal regions. The Woodbridge and Perth Amboy Railroad, and the Camden and Amboy division of the Pennsylvania Railroad, and the Delaware and Raritan Canal afford direct communication with Trenton and Philadelphia, and the iron manufacturing region of the Schuylkill. Probably no other equal area of mining district in our country has such facilities for reaching the largest markets for its products.

The developments of the year attest the accuracy and value of the clay map published by the survey in 1878, and continue to verify its generalizations. The Woodbridge bed still produces nearly all the fine white clay mined north of the Raritan. The large pits in it are being continually extended, and the area worked over is rapidly widening. Among other changes of the year may be noted the re-opening of the Ayres' bank, near Woodbridge, after having been idle for several years, and the extensive workings of the Watson Clay Company and Edgar Brothers, near the Lehigh Valley Railroad and north of Sand Hills. A great need is a cheaper mode of removing the increasing thickness of top earth and clays at some of the banks. The utilization of some of the better sorts of clay in terra-cotta and porous brick, and in sewer pipe and common red brick may, however, enable clay miners to remove thicker stripping than is now done at any of the banks. There is a field here for additional red-brick establishments to take from the fire-clay diggers these top clays. They can be had for the carting, at the most. There are some explorations in progress in the Raritan bed near Bonhamtown, and also on Woodbridge neck; but it is too soon to report results. Continued explorations are, it is believed, sure to discover this bed to be of workable extent and thickness, and capable of yielding clays suited to uses in pottery and terra-cotta, and some fire-clays. The available territory in which this bed can be opened is exhibited on the clay map. Since the publication of the latter, there have been considerable changes in the shape and extent of the pits south of Raritan, where the Amboy fire-clay bed furnishes the white fire-clays and the ware clays; but they are nearly all in the nature of extension and not altogether new openings. In the stoneware clays a noteworthy discovery is that made in the shaft sunk by J. F. Hillman, on his lands southwest of Rose & Son's banks, and south of the Old Bridge road. The shaft penetrated strata of black clay to the depth of thirty-five feet, and then struck a stoneware clay bed six to seven feet thick. The same strata of dark-colored clay and the white ware clay are said to extend to the east, on to the adjoining property of Otto Ernst.

The terra-cotta manufacture at Perth Amboy is assuming large proportions and attracting much attention. The following statement is from Mr. Alfred Hall, of Perth Amboy, who is the founder of the business in this State:

"During the past year the A. Hall Terra-Cotta Company has added several large buildings to their works, and kept a large force of men employed, their orders for architectural terra-cotta having increased in number and magnitude. At this time we are working on the Williamsburgh Fire Insurance Company's building, on the corner of Broadway and Liberty street, and several others. The Perth Amboy Terra-Cotta Company has also enlarged its facilities during the past year. They have made the terra-cotta for the new opera house and the Produce Exchange buildings in New York City, and for a host of smaller contracts. All of this terra-cotta has been made of clays from this vicinity. These clays are also used by the Boston Terra-Cotta Company and the Long Island Terra-Cotta Company, no others having been found to be as reliable. Thed emand for terra-cotta made from New Jersey clays is likely to continue. The public generally begin to appreciate its value, as the most elaborate designs can be executed in a remarkably short time as compared with the time necessary to execute first-class work in stone, while the imperishable nature of terra-cotta and its small cost makes it the most desirable material for architectural decoration. The A. Hall Terra-Cotta Company make in addition to red and buff colors, a terra-cotta of a deep-brown color, which is used with remarkable effect in brown stone buildings. The friezes of the Gramercy Park hotel, from designs by G. W. Da Cunha, architect, were made by our company. This branch of the business has not been pushed hitherto, owing to the great risk in getting a uniformly brown color when burned in kilns built in the usual manner. But the difficulty has been overcome by the construction of kilns, and by the mode of burning, which we have adopted.

"Eighty per cent. of the architectural terra-cotta made in the United States the past year, was made at Perth Amboy. And it is safe to predict that if those engaged in its manufacture at Perth Amboy, give the public the benefit of the natural advantages they possess, a preponderance of this useful and important industry will be secured to that city and district."

The manufacture of porous brick and of *terra-cotta lumber* is a new industry, making use of the dark-colored and inferior grades of clay, and giving great promise of a very extensive utilization of such material in the near future. Two works of this kind have been erected within the year, near Perth Amboy and on the north shore of the Raritan river. Both of them work under the Gilman patent, and use clay and sawdust in the composition of their brick, tiles, and other shapes in which the product is put on the market.

The Terra-Cotta Lumber Company's works are on the site of the Crossman Clay and Manufacturing Company, at Crow's mill, two and a half miles west of Perth Amboy. The works include the old fire-brick buildings, remodeled, and adapted to their present uses, and additional structures necessary for the work. Already six kilns are in use, and an additional number is proposed. The clays are obtained from the banks of the Raritan Clay Company, nearly a mile north-west of the works. Only the top, dark-colored clays, overlying the white fire-clays, are taken. These clays are rich, or fat, and highly tenacious, but they are not sufficiently refractory for the best fire-brick, and hence they have hitherto found only a very limited use in pipe and tile or in common brick. But a great amount has been thrown aside as top dirt of no value. For this manufacture the clays must be free from any coarse sand or grit. But fine sand when intimately mixed in the purer clays cannot be any objection. The clays now employed contain a small percentage of silica in this form. A high degree of plasticity is essential. At the works of this company the usual mixture is two parts by bulk of sawdust to one of clay, or three of the former to two of the latter. At present spruce sawdust is used, and is brought from Hartford, Conn. These constituents are thoroughly mixed in circular wheel pits by means of wheels armed with rotating knives traversing the mass somewhat as in the common brick wheel pit. As little water as possible is put in the mixture. From the grinding floor the prepared mass is carried by elevators to the top, or third floor, where it is pressed by a powerful steam press into rectangular shapes, or blocks, convenient for slitting and cutting into the ordinary sizes for tiles and blocks. The blocks emerge from the press on the second floor where there is a large space for drying. Artificial heat is used to hasten the drying process. They are conveyed thence to the kilns to be burned. The kilns are of the circular, fire-brick kiln style, with flat dome-shaped tops and with down draught. Placed at equal distances apart, round the base, are eight fire holes and two doors. The fuel at the start is coal, and the firing is from the outside. The moisture is gradually driven off, and then with increased heat, the combustion of the sawdust carries forward the baking to the end. The time for a burning varies from 36 to 45 hours. Each kiln will hold about 30 tons of blocks or tiles. When properly burned, the product is straw colored. Under-burned blocks when broken show a black interior or cross section and are pale on the outside. They are rejected and ground up to be worked over again. The burned blocks are slit by circular saws into tiles for roofing, or are cut in any desired shapes for use in floors, ceilings, walls, &c. The machinery for sawing, planing and shaping is driven by steam-power and is on the lower floor of the establishment. The product from the kilns has several valuable properties. It is fireproof; it is light, weighing only 58 to 62 pounds per cubic foot, or scarcely more than half as much as common brick; it is equally strong in all directions, resisting crushing strains, in hard made cubes, two to five and a quarter inches on a side, of 1,835 to 13,037 pounds, varying somewhat according to their sizes, and the composition or proportions of sawdust to clay; it can be sawed or planed into desired shapes, almost as easily as wood, and holds nails, and is used in place of wood; and, it is not affected by coal gases as mortar, nor a good conductor of heat as iron or the metals. These properties make it a very valuable fire-proof material, especially for partitions, floors, ceilings and roof sheathing. It is also adapted to safe linings, refrigerators, &c., because of its non-conductivity of heat. The demand is already large and beyond the present capacity of the company to meet it, and an enlargement of the works is projected. The prices are from $12 to $18 per ton, according to the style of dressing.

The Raritan Hollow and Porous Brick Company also manufacture terra-cotta lumber, or as the title indicates, porous brick, using the Gilman patent. They make hollow brick in addition to the porous brick. Their works are at Keasbey's docks, on the Raritan, and two miles west of Perth Amboy. The works were begun in April, and hence have been in operation for a few months only. There are six circular kilns. And the general plan is much like that at the works described above. In addition to the dock property, the company owns 80 acres of adjoining clay lands. But at present their clay is obtained from Edward Keasbey's banks, near the works. These banks were described in the "Report on Clays," 1878, as belonging to The Woodbridge Clay Company. Only the overlying, dark-colored clay is used. The white clays of the banks go into fire-brick. At present the works are running up to their full capacity, and are using about 60 tons of clay a day. In their porous brick mixture equal volumes of clay and sawdust are used. The output of the works up to the present time is reported to amount to 3,600 tons. Their hollow brick require a clay rather better than that used in ordinary red brick. Otherwise the manufacture is not essentially different from that of the latter. They are made from six to twelve inches deep, and of sizes, and beveled for floors and ceilings between iron beams and girders. They are employed, like the porous brick, where a light fire-proof material is wanted. In furring walls they make a practically hollow wall or space between the outside wall and the plastering. They are sold at the average price of $7.00 per ton at the works; varying by the thousand according to size.

The recent terribly disastrous fires, involving great losses of life, have again aroused attention to the need of really fire-proof materials in the construction of our huge public structures, and porous brick or terra-cotta lumber and hollow brick answer the rapidly increasing demands for a first-class material. And these new works, with those of Henry Maurer, near Perth Amboy, on the Arthur Kill or Staten Island sound, are furnishing it. All of them are on tide-water and are conveniently located for getting their clays and other raw materials, and are near the largest market of the country. Their future is certainly very bright. And these additional uses for hitherto wasted clays is a matter of public importance.

5. SHORE CHANGES.

The changes which are taking place along the Atlantic shore, are receiving more attention from year to year, as the landed property becomes more valuable. In general, the shore is wearing away, and there is a considerable strip of land which has been lost since the first settlement of the country, and what was formerly dry ground, is now under the ocean. In some places, however, there is a gain of land upon the ocean. A comparison of the shore line of Long Beach, which extends from Barnegat Inlet to Little Egg Harbor, has been made upon the United States Coast Survey maps of 1839 to 1871, which shows a loss of land for almost the whole distance. The following table gives the breadth in yards which has worn away at every mile from Barnegat Inlet, southward.

Miles south of Barnegat Inlet.	Locality.	Yards worn away.	Yards gained.
1		220	......
2		190	......
3	Opposite Barnegat	80	......
4		130	......
5	Opposite Harvey Sedges	110	......
6		265	......
7		305	......
8	Hickey's House	310	......
9		290	......
10		210	......
11		70	......
12		0	......
13		0	......
14		......	70
15	Beach Haven	......	105
16		......	140
17		......	170
18	Long Beach House	......	25
18¼		......	0

Another comparison has also been made on the south end of the beach, between the United States Coast Survey of 1871, and a survey and map of Cox's patent, made by a New Jersey State Commissioner in 1818. The following is the result. The same confidence cannot be attached to this as to the preceding, as the points for comparison are not so accurately fixed:

SURVEY OF COX'S PATENT, 1818 TO 1871.

Miles.	Worn away.	Miles.	Worn away.
9	0	14	200
10	100	16	300
12	200	18	600

The sand of the beach has not, however, all been washed out to sea; a considerable portion of it has been blown in by the wind, and it is now found the beach does not lie upon sand, but that they have been carried over and deposited on the marsh, which was west of where the beaches formerly lay. This drifting inwards of the beach, the wearing away of the sand on the sea-side, and the drifting in of the sand beaches upon the salt meadows in the rear of them, has continued so long and extended so far inland, that the beaches are now, in some places, entirely upon the meadow sod, and the edge of it is to be seen projecting out seaward. During violent storms the sand of the front part of the beaches is washed out and spread out on the sea bottom for a considerable distance from the shore, and the strand is left very low and flat. At such times these meadow sods, trees, roots, or whatever may have been buried under the sand, are uncovered, and can be carefully examined. But during ordinary quiet weather, the waves gradually bring back this loose sand and bank it up in a flat-topped and more or less wide strip of sand, with its upper and nearly level surface about two or three feet above ordinary high water mark. As long as the quiet weather lasts this strip of sand continues to widen and the strand grows steeper on the border towards the sea till another storm comes and washes the loose sand into the sea and again lays bare the objects which had been hidden under this coating of sand.

It has been a common report that the meadow sods along the sea border, in some places which were uncovered by violent storms, were plainly marked with the tracks of horses, cattle and sheep. The unusually severe storm on Sept. 21st, 22d and 23d, 1882, cleared off the shifting sands on the beaches so as to expose a long surface of ancient meadow and swamp surface. Through the favor and intelligent assistance of Capt. I. S. Jennings, at the Harvey Cedars, on Long Beach, I was enabled to examine and verify this singular report. In company with Capt. Jennings we went south from the Harvey Cedars, on Long Beach, examining the shore for these marks. We found stumps of cedar trees which had been cut off with the axe, numerous fresh roots of trees and bushes, all apparently in their places of growth, but a little below ordinary high water mark; and numerous old and black sods that had been torn off by the waves and were scattered along the strand. These were about six miles below Barnegat inlet. At about the north line of Sonmans patent we found patches of these sods a rod or two in width, and perhaps 20 rods long, at the level of extreme low water. These had no appearance of having ever been moved out of their place, the outer edge was just in the water at low tide, and the inner edge ran in under the sand banks of the beach. No tracks were to be found at this place. A mile and a half farther south we found another portion of old meadow sod apparently in the spot where it formed. This was about three feet below ordinary high water mark, and extended lengthwise on the strand at least 100 yards. This was thickly marked with the tracks of horses and cattle. The horse tracks were of various but rather small hoofs, and without shoes, and the cattle tracks were also of all sizes. The sod was very firm and full of sand, from 6 to 8 inches thick, and lying upon a solid bed of sand into which the grass roots did not penetrate. The tracks were very numerous, perfectly distinct, and in one or two places they appeared to run into a well worn path. The sod and tracks extended back under the hillocks of beach sand.

The beach where these tracks are found, has very few, if any, domestic animals ranging about on it, and there are no houses for several miles along that part of it. But in 1690, it was settled by persons who came to engage in the whale fishery, and their descendants lived on the beach for several generations, and kept a stock of horses, cattle and sheep. The sand hills were then covered with cedar trees, and the intervals with deciduous trees such as grow in woods or swamps, and these afforded protection to the animals, while the borders on the side towards the salt marshes furnished them pasturage, and the marshes supplied the winter's hay. This condition of things still continues on Sandy Hook and on some of the beaches in Cape May. The edge next the marsh is always firm and solid, being made so by the sand from the beaches being blown westerly into the grass, and filling the spongy mass of roots, so that it is never a soft or miry mud, and tracks made in it retain their form and distinctness for a long time. These tracks were probably made when the ground on which they are, was at the west margin of the beach, and at a time when a heavy rain storm, or even shower, would wash enough sand over them to completely bury and preserve them.

The shore opposite where they are found has been worn inwards 310 yards since 1839. At this rate of wear the breadth lost since 1690 would be equal to the whole width of the beach at this place. And in fact the cedar trees are all gone, the Long swamp has been lost, the sand beaches have been drifted and driven landward by the storm winds; and what is left of the sand hillocks now lies upon the salt marsh on the west side of the site of the former trees and swamp and the old foot-marks; and the stumps and roots and these footprints are now on the shore of the ocean, or partly buried in the moving sand.

The surface upon which the tracks are found, in the judgment of Capt. Jennings and myself, is about three feet below ordinary high water. We found other portions of sod much lower than this, with no tracks upon them, and I infer that they were once a softer and deeper part of the marsh, and that they have been much compressed and solidified by the load of sand which has been piled upon them for so many years. The sod in which the tracks are is only a few inches thick, is full of sand, and does not appear to have suffered much change from its original form.

This fact furnishes another proof of the slow advance of the sea upon the land which is going on along the entire eastern sea coast of the United States, and a reason for the increased effect of the waves in wearing away the shore.

IV.

SEA-SIDE DEVELOPMENTS.

The advantages which New Jersey possesses in nearness to the great centers of population on each side have been often told. The accessibility to the best markets and the ready demand at remunerative prices for her products of soil and of mine, as well as for the innumerable varieties of manufacture, have been the subjects of many articles in reports and of the press. The advantages of our beautiful hills and mountains as sites for suburban homes have been frequently set forth. The New Jersey coast as a whole has not been referred to in any of the Survey reports, excepting some brief notes upon its climatic peculiarities. Each locality receives its share of local patronage, and has its enthusiastic admirers; and in this individual way all attract more or less public attention. There are, however, some general facts which belong to our coast and which merit the consideration of all seeking health and comfort at the sea side. And it is opportune to present them with the new edition of the State map, accompanying this report.

The trend of our coast, from Sandy Hook to Cape May, is in general, south-southwest and southwest. There are west-southwest courses for short distances, and at a few points only. The front is consequently to the east-southeast or southeast. The sea winds which blow from the east, or from the southeast, come from the ocean directly, and are laden with the tonic influences gathered through a sweep of thousands of miles. They are not the gentle currents arising from small bodies of water, as bays, sounds, &c. Again, with this direction of the shore, there is no reflection of the sun's rays landward from the water surface during the midday and afternoon hours. The ameliorating influences of proximity to the Gulf stream are felt very perceptibly in the southeasterly winds. And they are as refreshing in the warmer months as in the winter, or colder part of the year.

The coast of New Jersey is throughout its greater length a succession of sand beaches. Their open, porous soil and subsoil, and their slight elevation above the ocean level, are advantageous for healthy residence sites and for good sanitary conditions. There is a lack of good water, but by reference to the State map and the section thereon it can be seen that from the geological structure of this part of the State, it is reasonable to believe that an abundant supply of excellent water can be obtained in Artesian wells of moderate depth. The streams of the adjoining mainland, coming from the wooded interior, are capable of furnishing the best of water wherever a large town supply is needed. This subject is fully considered under the head of Water Supply, further on in this report.

The general absence of malarial diseases from the Atlantic slope of the State, south of Sandy Hook, is a strong point in favor of our sea-side resorts. This immunity from the depressing effects of malaria in all its forms, coupled with the general healthfulness of the coast, are positive advantages which ought to command the consideration of all who seek the benefits of a sea-side home or of a temporary sojourn there.

Nearly all of our sea-side towns and settlements are so situated that they have rivers, lakes, bays, or sounds to the west or northwest of them, or lying between the main land and the beaches. Sandy Hook bay, the Neversink, Shrewsbury, Shark and Manasquan rivers, Barnegat, Little and Great Egg Harbor bays are some of the larger sheets of water behind the coast towns. And the advantages of these smaller and more quiet waters for boating, fishing, &c., are too well known and appreciated to need any further notice here.

Another advantage belonging to our Jersey coast is in the many lines of communication, whereby access is rapid and at low rates from New York and Philadelphia, and our own large towns, to nearly all points along it. The Sea Shore and Long Branch, the New Jersey Southern and its branches to Port Monmouth, and Toms River and Waretown, the New York and Long Branch, all under the management of the Central Railroad of New Jersey; the lines of the Pennsylvania Railroad Company to Sea Girt and Long Branch, and its Pemberton and Sea Shore Railroad, the Tuckerton Railroad, the Camden and Atlantic and its branch to May's Landing; the Philadelphia and Atlantic City and branch to Somers' Point; the West Jersey Railroad Company's lines to Atlantic City and Cape May, and branches to Sea Isle City and Anglesea, reach nearly all the towns and larger settlements; and by connecting boat lines from their terminal points, the whole length of the beach is made accessible. With these means of communication there is not a point on the coast line more than ten miles, by navigable water routes, from a railroad station.

In view of these advantages of location, healthfulness and easy communication with the two largest centers of population on the continent, the development has been most rapid, and the great changes are apparent when the earlier maps of the Survey are compared with our last edition of the State map. The resident population along the shore is already large. In Monmouth and in Atlantic counties the shore belts are already the most populous parts of these counties. And the time is not far distant when the whole shore will be occupied, and there will be a nearly continuous line of settlements from Sandy Hook to Cape May Point. And it is not hazardous to predict that a line of railway on the beaches will yet connect them and make one of the grandest railway rides on the continent. The list of towns and settlements which are already in existence and attract attention, is here presented, accompanied by a short note as to the location of each one. The map exhibits them in their relative positions. Beginning at the northeast and on the Raritan bay shore there is the

Atlantic Highlands—A new settlement founded by an association.

Hilton Park—A new town site on the Neversink Highlands.

Highlands, P. O.—At the eastern base of the Highlands, and on the Neversink river.

Bellevue—On the Sandy Hook beach, opposite the mouth of Neversink river.

Sea Bright—On the beach, opposite Rumson neck, and five miles north of Long Branch.

Low Moor—On the beach, between Sea Bright and Monmouth Beach.

Monmouth Beach—On the beach near its junction with the mainland.

North Long Branch—Formerly Atlanticville, and essentially a part of Long Branch.

Long Branch—On the mainland, fronting on the ocean.

Branchport—On the south shore of Shrewsbury river.

Elberon—On the ocean front, just south of Long Branch.

Deal Beach—On the ocean, three miles south of Long Branch.

Asbury Park—On the ocean, five miles south of Long Branch.

Ocean Grove—On the ocean, five miles south of Long Branch.

Key East—Formerly Neptune City, and on the north bank of Shark river.

Ocean Beach—On the ocean, south of Shark river inlet.

Brighton—On the ocean, about half-way between Shark river and Manasquan river.

Spring Lake—On the ocean, and north side of Sea Girt inlet.

Sea Girt—On the ocean, opposite Spring Lake, on south shore of Sea Girt inlet.

Villa Park—A new town, between the two branches of Sea Girt inlet.

Manasquan—Formerly Squan village.

Brielle—On the ocean, north of Manasquan inlet.

Arnold City—In Ocean county, adjoining Point Pleasant City on the north.

Point Pleasant City—In Ocean county, south of Manasquan river.

Bay Head Junction—On the mainland, fronting the ocean, and near the head of Barnegat bay.

Cedar Croft—On the mainland, and north side of Metedeconk river.

Osbornsville—On Metedeconk Neck, and on south shore of the Metedeconk.

Mantoloking—On Squan Beach, opposite Metedeconk Neck.

Chadwick's—On Squan Beach.

Lavalette City—A newly laid out town on Squan Beach.

Berkeley—A new place on Squan Beach, near the old Cranberry inlet.

Island Heights—A camp ground association of the M. E. Church, on the north shore of the Toms river.

Sea Side Park—On Island Beach, south of the old Cranberry inlet, and the present terminus of railroad.

Barnegat City—On Long Beach, south of Barnegat inlet, and reached by boat.

Harvey Cedars—On Long Beach, six miles south of Barnegat inlet, and reached from Barnegat.

Rothesay—A prospective town on Long Beach.

Beach Haven—On Long Beach, opposite Tuckerton, and reached from Tuckerton.

Bond's—On the Long Beach, on line between Ocean and Burlington counties.

Sea Haven—A new town at south end of Long Beach, and opposite the inlet.

Island Beach—Another new town on the beach, south of Little Egg Harbor inlet.

Ocean Island—On Brigantine Beach.

North Atlantic—On the beach, north of Absecon inlet.

Atlantic City—On Absecon Beach.

South Atlantic City—On Absecon Beach, and four miles south of Atlantic City. Railroad from Atlantic City.

Longport—A new town on the south end of Absecon Beach.

Ocean City—A town founded by a religious association on the north end of Peck's Beach, Cape May county, and reached by boat from Somers' Point.

Sea Isle City—A new town on Ludlam's Beach, and reached by branch from the West Jersey Railroad.

Anglesea—A new town near the north end of Five-Mile Beach. A railroad is now building to connect it with the West Jersey line.

Holly Beach City—Another new place being laid out on Five-Mile Beach.

Sewell's Point—On Poverty Beach, two miles east of Cape May City.

Cape May City—On an upland island, fronting southeast on the ocean.

Cape May Point—At the point of the cape, three miles southwest of Cape May City.

V.

CLIMATIC PECULIARITIES.

The climate of the northern part of New Jersey, or of so much of it as lies north of a line drawn from Raritan bay to the Delaware, near Trenton, is of the continental type. The range of temperature between the extremes of summer and of winter is wide, and the changes in any given month or season are apt to be sudden. Lying between the continent to the west, and New York and New England on the east and northeast, it is not directly open to the ameliorating influences of the sea. Its climate is not, however, so severe as that of States in the same latitude to the west of it. The *extremely low* temperatures, frequent in the Ohio valley and the Upper Mississippi region, are not experienced in all their severity.

The southern part of the State, from its position, is more directly exposed to the modifying agency of the ocean and of Delaware bay. Looking at the map of the United States this peculiarity of situation is at once apparent. From Sandy Hook to Cape May, the coast line faces the open ocean. And from Cape May to Salem, the Delaware bay and Delaware river bound it on the southwest. The influences of this peninsular position are observed in its climatic peculiarities. This part of the State has a temperate climate. And that of the extreme southern end of the peninsula may be said to verge on the subtropical type. The range of temperature is not quite so excessive as further north, and the changes are less sudden. The seasons also differ. The winters are neither so cold, nor accompanied by so much snow as at the north. The summers are longer, and in the interior very hot. High temperatures are often recorded away from the sea shore. The influence of the ocean is felt most strongly in the shore belt, both in tempering the heat in summer and in mollifying the cold of winter. In consequence of this softening of the extremes, the seaside is becoming rapidly settled by the tide of people seeking pleasure and comfort in the summer. The growth of our coast towns and the list of settlements is given in preceding pages. The beaches, lying, as many of them do, between the ocean and bays or sounds, really have an insular position, and also in some degree an insular type of climate. The oceanic influences may be best shown in the isothermal or lines of equal heat for the several seasons, but particularly in spring and in autumn. These lines sweep around in long, concentric curves, corresponding nearly to the coast line in autumn, and in spring widening more to the east and west, parallel to Delaware bay and the coast. That is, the autumn is warmer on the coast, and the degree of heat diminishes in a west-northwest direction, or going inland from the ocean; in the spring the warmest belt is at the south and southwest, and the diminution is felt going north and northeast. Cape May, at the extreme south, shares in the warmth of both spring and autumn. The mean temperatures for the several divisions of the State are given in detail in last year's report. It may be stated here that the winter temperature of Cape May is 36°, corresponding to the mean or average for West Virginia and the western parts of North Carolina and Georgia. The climate of the coast belt is more even than that of these more southern States. And that of Cape May is remarkable for its evenness. The season for growing vegetation, or that between frosts, is from two weeks to a month longer in South Jersey than in the northern part of the State, or in the vicinity of New York. According to a record kept at Moorestown, by Thomas J. Beans, the average length of interval between the late frosts of spring and the early ones of autumn is about six months. In parts of Cumberland and Atlantic and in Cape May counties the average growing season is thought to be between six and seven months, while in the lower part of Cape May it is fully seven months, from April to November. It suffices to ripen cotton and the semi-tropical varieties of sorghum, as has been proven by the cultivation of both of these southern staple crops. The mildness of the winters in this county are shown by cattle wintering on the beaches without any attention or care in feeding or sheltering. The mild and equable climate in the southern part of the State has attracted the attention of visitors in pursuit of a retreat from the intense cold and sudden changes of more northern localities, and Lakewood and Vineland, in the interior, and Atlantic City on the coast, are known as winter health resorts. Their advantages as such are widely published, and their success is both gratifying to all interested in this part of the State, as well as encouraging to other places possessing a similar climate.

VI.

AGRICULTURAL DEVELOPMENT IN SOUTHERN NEW JERSEY.

The lands in Southern New Jersey have in some parts proved unattractive to settlers, and there is much good land there which is still in forest. This state of things cannot much longer continue. The parts formerly most remote from markets, are now easily reached by railroads. The New Jersey Southern, Manchester and Waretown, Pemberton and Sea Shore, New Lisbon and Sea Side Park, Tuckerton, Camden and Atlantic, Philadelphia and Atlantic City, West Jersey, with branches to Atlantic City, to Cape May City, Bridgeton and Salem; all cross portions of the State which have been slow in settlement. The thriving towns and villages along these roads, and the fine farms which have been cleared and put in cultivation since the railroads opened access to them, prove that the lands are desirable for agricultural use, as well as for supplying pleasant and healthy locations for those seeking country homes.

The soil is light and easily cleared and cultivated, and responds quickly and generously to fertilization. The crops grown upon it are somewhat different from those in the middle and northern parts of the State. Sweet potatoes, melons, grapes and small fruits grow finely, and are of a quality unknown in the cooler sun and heavier soils of the northern part of the State. This peculiarity in the quality of fruits and other products has been well and long known, but a more distinct statement of it can be made from some careful laboratory experiments made this year at the New Jersey Agricultural Experiment Station. The sugar cane grown at Rio Grande, Cape May county, has been largely and successfully grown there for the production of sugar. The cane has also been grown on the Agricultural College farm, and it grew well, and contained a good percentage of sugar. But the difference in quality of the two samples of juice is very decidedly marked. When the clarified juice from the Rio

Grand canes is evaporated down, the solid substance left contained from 81 to 92 per cent. of sugar, while that from the College farm only yielded from 65 to 77 per cent. of sugar, the remainder, in each case, consisting of salts and other substances, which in any case interfere with the crystallization of sugar, and if they are in too large percentage, render the extraction of sugar from them unprofitable. On this account, the sorghum juice grown on the warm sandy soils of Southern New Jersey, is preferable to that grown on heavier and richer soils.

What is thus proved to be true of the sugar cane, is equally true of the articles of produce. They excel in flavor and quality those grown on other soils, and are finding ready markets in all our large cities and towns. Vineland and Hammonton were the early settlements where the culture of these products of sandy soil was first started, and it is still carried on there, and the business has been extended to all the newer settlements. Egg Harbor City has been specially noted for its production of wines, of which large quantities are made, and which find a ready sale.

Ordinary staple crops are successfully grown, Indian corn, rye, wheat, oats, potatoes and sweet potatoes, clover and timothy are all produced in good crops. The soil needs fertilization to make it produce heavy crops, and those who apply fertilizers liberally get the best returns and the most profits.

There is a very large home market for fruits, vegetables, poultry, &c., as well as for staple products, at the great summer resorts which line the sea shore, all the way from Long Branch to Cape May. The thousands of summer visitors at these places consume all the fresh produce that can be grown on a large district of country, and the demand is increasing more rapidly than the supply.

To those skilled in the production of market garden vegetables, small fruits, and vineyard and orchard products, this country opens particularly fine opportunities. The remarkable and rich supply of natural products in the ocean and bays along the shores, have been detrimental to legitimate farming. The ease with which a living could be got from fishing or hunting, has created a divided interest in the minds of all classes, and whenever there was a choice to be made between the two, the farming and farm crops were always left to take care of themselves, while the farmer would be looking for oysters, clams, fish, game, or whatever else was the attraction. When the demand for shore property sprung up, there were scarcely any who lived by farming alone. But the rapid filling up of the sea-side resorts has brought enterprise, business and good markets through the whole length of the State from Sandy Hook to Cape May.

The increased value of land is bringing into market such as under low prices could not be cultivated to profit, but which, when prices are higher, come much nearer in their profits to high-priced farm lands. The lands of South Jersey, which are designated on the State map as oak lands, were, under our old system of farming, considered to be of but little value; but now, by the judicious use of fertilizers, they are made to produce paying crops, and the comparative ease with which they are cleared and cultivated, appears to compensate for the increased amount of fertilizers they require to make them produce good crops. Under the influence of good husbandry and a judicious use of manures, the value of staple crops is steadily increasing. The amount of stock kept is also greater than in former times.

The largest increase in agricultural products, however, is in sweet potatoes, market vegetables and fruit. Of the amount of these we have no means of getting accurate returns, the U. S. Census reports on these heads not being yet published. The older settlements of Hammonton, Egg Harbor City and Vineland, and the numerous later settlements along the lines of the West Jersey, Camden and Atlantic, and the N. J. Southern Railway are producing immense quantities of fruits, &c., for market. The annual report of the State Board of Agriculture for 1879, states that there were shipped from Hammonton that year 746,404 quarts of berries, 1,600 bushels of pears and 1,000 barrels of sweet potatoes. In the same report it is noted that from Egg Harbor City 132,000 pounds of grapes were sent to market, and about 100,000 gallons of wine were made. The amounts from Vineland are much greater than these.

These settlements are all new, the oldest one of them being only about twenty years old, and the grounds upon which they are located were all in forest until that time. The settlers are now getting to have comfortable homes, fruit trees in bearing, and gardens and fields well tilled and productive. The mild and healthful climate, and the warm and responsive soils are especially attractive to those who have suffered from the colder climate and soils of the Northern States; and they are adapting themselves to the changed condition which surround them.

As is natural to those on small farms, and making a specialty of garden and fruit culture, there has been too little attention paid to the keeping of stock, and to the cultivation of the staple crops which every farmer needs for his own use on the farm. Stock consume the coarser and waste products of the soil, and they help to supply the manures without which no good farming can be carried on.

In addition to the staple crops of corn, rye, wheat, potatoes, sweet potatoes, hay, &c., there are several other staple crops which are adapted to the soil and climate of Southern New Jersey, and which with the proper supply of labor may be profitably cultivated. The cow pea, which is the forage crop for warm climates and light soils, grows as well here as as it does in Virginia, and thrives where clover will not grow. For soiling and for a green crop to be turned under as manure, it is peculiarly well adapted.

Cotton grows as well in the southern counties as it does in North Carolina, and now that the value of its seed, as well as its lint, is getting to be understood, it gives promise of being well worthy of cultivation. The use of fertilizers, especially of superphosphates, has greatly increased the area on which cotton can be grown, and has given much more certainty to the production of paying crops.

Tobacco, particularly those varieties of it which have thin and strong leaves, has been found to be specially adapted to light, sandy soils, and there are districts in Virginia and North Carolina where the growing of "Yellow Tobacco" has entirely revolutionized the objects of farming. It has made the lands, formerly almost worthless, to be in greater demand than those which were heavy enough to grow wheat and grass, and comfort and thrift are now found where, a few years ago, a struggle was needed for a bare existence. This change is due to the moderate use of fertilizers, on which the growth of the plant really depends.

Sugar or molasses, or both, can be made from sorghum grown on our soils. And the juice of that grown on the light soils is remarkably free from gummy substance and easy to work. With the improvements in clarifying the juice, and in the apparatus for evaporating it, there is reason to hope that its manufacture into sugar or molasses, will become a regular and large branch of our farm industry.

Black grass, which grows on the tide marshes, along the shores of the ocean, bays and creeks, has been found to be of singular richness and nutritive value. It was not natural to our marshes, but has been introduced, and is taking the place of the salt meadow grass. It is propagated by seeds, or by transplanting small sods from which the roots and seeds spread rapidly, crowding out other grasses. The hay made from this grass is a satisfactory substitute for clover or timothy, and can be grown from year to year without cultivation or manuring. There is a very large area of marsh land which could be occupied by this grass, to the profit of the farmers, and the benefit of the State.

For much fuller information on all these new crops, the reader is referred to the annual report of the New Jersey Agricultural Experiment Station for 1882.

For the location of the unoccupied lands of Southern New Jersey, reference may be made to the geological map in this report. The oak lands and portions of the pine lands are open to settlement and improvement, and as is well shown there, numerous locations are to be found where roads and railroads are built, and churches and schools, with all their advantages, can be enjoyed from the outset.

VII.

DRAINAGE.

The drainage of the Great meadows, on the Pequest, is satisfactory. The deepened channel is sufficiently large to carry the whole of the water in all ordinary floods, without overflowing its banks. And in the extraordinary freshet of last October, there was very little overflow beyond the line of the stream. The crops grown on these reclaimed lands are remarkably fine, and when the whole body of drained land is cleared and improved, it will be the best and most desirable land in Warren county. The State Agricultural Society's State first premiums were awarded to William Vreeland, of Danville, for the largest crops of onions and of timothy hay. The crops were grown on these drained lands of the Great meadows. And Mr. Vreeland received the first State premium on corn for his crop grown on these lands in 1881.

VIII.

WATER SUPPLY.

The supply of good water for domestic use, and for general purposes, is becoming a matter of greater importance every year. The supply from wells, which was formerly the only resource, is insufficient to meet the demands of modern life; the labor of raising it in quantity is expensive, and in quality well-water is becoming more unwholesome, as the population increases in density. Diseases of a painful, malignant or fatal character, though not more common or severe than they always have been, are now traced back to their causes with much more directness and certainty than they were in former times. Some of the diseases which most affect our race, such as typhoid fever, cholera, and other disorders of the bowels have been traced to the use of impure water, and so much publicity is given to such cases that the public mind has become suspicious of danger from drinking water that has been exposed to pollution, and possibly to poisoning with the germs of malignant or fatal diseases. The great uneasiness expressed is, of course, in the majority of cases without any proper cause; but with the known exposure to pollution, the popular fears will continue, and justly so.

The polluting and dangerous materials come from sewers, drains, cesspools, privy vaults, and the filth and waste products which are thrown on the ground to be washed away or soaked into the earth. In this way streams of water are rendered unfit for use, and the underground water which supplies the open wells is gradually contaminated, and the well-water rendered unfit and unsafe for use.

This subject has furnished the material for much discussion among sanitarians, and many papers in the sanitary journals.

That open wells near dwellings or out-buildings are liable to be polluted by filth, and the water to become unwholesome, is too well known to require proof. Every physician can cite cases in which sickness and death have followed the use of impure water. Most of have proved the falsity of the assertion by carrying their daily allowance of water with them for some time, during which time they maintained perfect health, but becoming careless again resorted to the supply there, and were again attacked in the same way."

There was a very sudden and severe outbreak of typhoid fever at St. Mary's Hall, Burlington, in the beginning of the winter of 1874. The first case occurred on the 4th of December, and before the 20th of the month there were eighty cases. Sixty remained in the institution, and were all cured. Of the twenty who went away to their friends, five died very soon, and two others after lingering for six months. The cause of the disorder was a polluted water supply. A large well received its supply from the Delaware, and the water was pumped from this for the use of the establishment. Adjoining the well was a large cess-pool, lined with brick and cement, in which the cement had decayed, and allowed a leakage from the cess-pool to the well, by which the water was poisoned. As soon as the cause was known the proper remedies were applied, and the disease was stopped.

The disorder was entirely confined to the young ladies attending the school. Teachers and servants who drank tea and coffee only, escaped the sickness altogether.

The experience with water at the State Reform School, at Jamesburg, in 1878, is interesting. The former water supply was from wells and from springs which came out on the slope 15 or 20 feet below the level of the high ground on which the school is located. The spring water is evidently the drainage from the gravel and sandy loam which forms the top layer of the high ground, and of course the water, though soft and clear, must be polluted by the surface soil drainage, and this was made still worse by the defective sewerage from the buildings. The school had about 270 boys, and the teachers and other attendants made the whole number of persons there over 300. In August, 1878, there was an outbreak of typhoid fever of a mild form; before it ended, more than seventy boys were attacked, and two died. The use of water from these wells and springs was discontinued, and this, with perhaps other sanitary regulations, soon checked the advance of the disease, and no new cases occurred. In the summer of 1879, a case or two like those of the last season occurred, but the use of the chalybeate water from the board well put an end at once to the disease.*

*See third annual report of the New Jersey State Board of Health for more particulars.

these are not subjects of public description and comment, but a few well-known cases in New Jersey may be cited.

In the transactions of the New Jersey State Medical Society for 1863 is a report by Dr. Thomas F. Cullen, of Camden, on the "Kensington Diarrhœa." He says:

"Persons only were affected with this disorder who drank of the water supplied by the works, formerly owned by the district of Kensington, in the upper portion of the city of Philadelphia.

"The water supplying this reservoir is taken from the Delaware river, near where a creek and culvert empties into it, receiving the filth from numerous privies, sinks, culverts, &c., in a thickly settled and filthy manufacturing portion of the city. Of the residents so supplied with water very many were affected with diarrhœa, and many fatal cases occurred. The attention of the authorities of Philadelphia being called to this fact, this supply of water was cut off, and a supply from the Schuylkill substituted, during which time there was a subsidence of the disease—no new cases occurring and the majority of those sick recovering.

"On account of an accident to the Schuylkill works the Kensington works again opened, when a return of the disease followed.

"Many of the citizens of Camden are called by their business to that part of Philadelphia, where they remain all day, the mechanical nature of their business making large draughts of water necessary to their comfort. Among this class of our citizens we found many cases of the Kensington diarrhœa, the symptoms of which are diarrhœa, loss of appetite, great thirst, muscular debility; which symptoms, after continuing from a few days to a few weeks, become more severe, with a dry and cracked tongue, cool skin, contracted and leaden-hued, cramps in extremities and abdomen, discharges of a soap-suds character, or perfectly colorless, and very frequent. In fact, in a bad or neglected case all symptoms are present of Asiatic cholera, and the surprise to the practitioner, when called, is that the patients insist, in many instances, on their having been in nearly that condition for the past six, twelve, twenty-four or thirty-six hours, which, in fact, he cannot at first believe, and does not, until he finds them remaining in the same state for twelve or twenty-four hours longer, in spite of vigorous treatment. * * * Some few fatal cases have occurred in Camden.

"It has been denied by some persons that this disease was the result of the water used, but patients of mine who have suffered from it

At Princeton, in 1880, there was an alarming outbreak of fever, and during the months of April, May, June and July, there were forty cases of sickness and eight deaths. The gentlemen who investigated the disease in its outbreak and aftercourse, report that "the disease was typhoid fever, caused in the first instance by the use of water from a well, which was proved by chemical analysis to be impure, in which a dead cat was found, and having such relations to cess-pools, as shown by subsequent investigations, as to render its contamination by them extremely probable. We have been forced to this conclusion by the fact that the first cases of typhoid fever amongst the students during April, occurred in those boarding at the house using this well water, and because these students who became ill lived in different buildings. Moreover, it has since been ascertained, that a servant who worked at this house became ill at the same time, was removed to another house, and is considered by her physician to have had typhoid fever.

"The evacuations from the students who had become affected in this manner were thrown without disinfection into the sinks and water-closets in the dormitories, and gained access to the sewer system of the College, and to the cess-pools which formed a part of it. A subsequent outbreak of the fever occurring in May, was caused by the infection of the sewage of the College, contained in the aforementioned cess-pools and pipes. On this occasion, the disease was not limited as before, but followed the sewer distribution. The poison gained access through the sinks, water-closets, and the pipes connected with them." *

The unwholesome water in open wells in cities and towns has led to the abandonment of many of them, and the increased demand for abundant supplies of water for domestic purposes and for its various uses in the arts, have led to the construction of water-works, for the supply of more than half the population of the State at this time. A list of the cities and towns in New Jersey, which now have water-works, and the population supplied from them, with short notices of the several works, is given farther on.

It is claimed by some that in streams of water, the impurities which are discharged into them are gradually oxidized by the air and their injurious properties destroyed. Others, on the contrary, insist that no amount of exposure to the air will destroy or remove the poison germs from water which has been contaminated by them. The dense popu-

* Fourth annual report of the New Jersey State Board of Health, 1880.

lation of England, and the great need for a supply of pure and wholesome water for the inhabitants of their towns and cities, have caused the subject of water-supply to receive more careful attention and study there than it has received anywhere in our country. The conclusions and recommendations embodied in the "Report of the Rivers Pollution Commissioners on the Domestic Water Supply of Great Britain" are probably the best authority we have upon it. As their report is not generally accessible, we quote from it the parts which seem generally applicable.

"I. *As to the Chemical Quality of Water from Different Sources.*

"1. Of the various kinds of water used for dietetic and domestic purposes, *rain water*, when collected at a distance from towns, upon specially cleansed surfaces, and kept in clean receptacles, contains the smallest proportion of total solid impurity; but the organic contamination, even of such specially collected water, somewhat exceeds that of water from springs and deep wells.

"2. Rain water collected from the roofs of houses and stored in undergound tanks, is much more impure; it is often polluted to a dangerous extent by excrementitious matters, and is rarely of sufficiently good quality to be employed for dietetic purposes with safety.

"3. Water collected from the surface of uncultivated land, and either allowed to subside in lakes or reservoirs, or filtered through sand, constitutes *upland surface water*, of good quality for domestic, and of still better quality for manufacturing purposes. Numerous large towns, both in England and Scotland, are supplied with water of this description. If the gathering ground be non-calcareous, the water is soft and well adapted for washing, and for almost all manufacturing operations. It is nearly always wholesome, but sometimes suffers in palatability by containing an excessive quantity of peaty matter in solution.

"4. Water collected from the surface or the drains of cultivated lands is always more or less polluted with the organic matter of manure, even after subsidence in lakes or reservoirs. Such *polluted surface or drainage water* is not of good quality for domestic purposes, but it may be used with less risk to health than polluted shallow well water, if human excrementitious matters do not form part of the manure applied to the land.

"5. Surface water, which drains wholly or partially from cultivated land, should always be efficiently filtered before it is supplied for domestic use.

"6. *River water*, usually in England, but less generally in Scotland, consists chiefly of the drainage from land which is more or less cultivated. When it is further polluted by the drainage of towns and inhabited places, or by the foul discharges from manufactories, its use for drinking and cooking becomes fraught with great risk to health. A very large proportion of the running waters of Great Britain are either at present thus dangerous or are rapidly becoming so.

"7. Still more dangerous to health is *shallow well water*, when the wells are situated, as is usually the case, near privies, drains, or cesspools. Such water often consists largely of the leakage and soakage from receptacles for human excrements; but notwithstanding the presence of these disgusting and dangerous matters, it is generally bright, sparkling and palatable.

"8. Of the different varieties of potable water, the best for dietetic purposes are *spring* and *deep well waters*. They contain the smallest proportion of organic matter, and are almost always bright, sparkling, palatable and wholesome, while their uniformity of temperature throughout the year renders them cool and refreshing in summer, and prevents them from freezing readily in winter. Such waters are of inestimable value to communities, and their conservation and utilization are worthy of the greatest efforts of those who have the public health under their charge.

"9. The average composition of the four great classes of unpolluted water is given in the following table, which is condensed from the results yielded by the analyses of 589 samples:

AVERAGE COMPOSITION OF UNPOLLUTED WATER.

RESULTS OF ANALYSIS EXPRESSED IN PARTS PER 100,000.

DESCRIPTION.	DISSOLVED MATTERS.											Number of Samples Analyzed
	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Class I. Rain Water	2.95	.070	.015	.029	.003	.042	42	.822	.4	.5	.3	39
Class II. Upland Surface Water	9.67	.322	.032	.002	.009	.042	10	1.13	1.5	4.3	5.4	195
Class III. Deep Well Water	43.78	.061	.018	.012	.495	.522	4,743	5.11	15.8	9.2	25.0	157
Class IV. Spring Water	28.20	.056	.013	.001	.383	.396	3,559	2.49	11.0	7.5	18.5	198

"This concrete result of our analyses proves—Firstly. That in respect of freedom from that most objectionable of impurities, organic matter (organic carbon and organic nitrogen), these waters range themselves in the following order:

1. Spring water.
2. Deep well water.
3. Rain water.
4. Upland surface water.

The last being very much inferior to the first three. Secondly. That the evidence of previous sewage or animal contamination is strongest in the case of spring and deep well water; but this evidence may, in the case of these waters, be safely disregarded. And, thirdly, that as to hardness, rain water and upland surface water are on the average very much softer than spring and deep well water.

"10. In respect of wholesomeness, palatability and general fitness for drinking and cooking, our researches lead us to the following classification of waters in the order of their excellence, and founded upon their respective sources:

Wholesome.	1. Spring water.	Very Palatable.
	2. Deep well water.	
	3. Upland surface water.	Moderately Palatable.
Suspicious.	4. Stored rain water.	
	5. Surface water from cultivated land.	Palatable.
Dangerous.	6. River water to which sewage gains access.	
	7. Shallow well water.	

"11. A large proportion of the water supplied for domestic purposes is used for washing, and in many towns considerable volumes are used in manufactories. For these purposes it is of the utmost importance that the waters should be soft—a quality which is not always associated with wholesomeness and palatability. Classified according to softness, waters from the various sources fall into the following order:

1. Rain water.
2. Upland surface water.
3. Surface water from cultivated land.
4. Polluted river water.
5. Spring water.
6. Deep well water.
7. Shallow well water.

"The interests of the manufacturer and the laundress are thus opposed to those of the householder, inasmuch as they lead to a preference for moderately palatable water, or even unwholesome water, over that which is very palatable and wholesome. Most of the waters from springs and deep wells can be easily and cheaply softened on the large scale by Clark's process, and thus the sanitary authorities of towns have at their disposal a method of rendering hard water from springs and deep wells available for washing and manufacturing purposes, without diminishing either its palatability or its wholesomeness.

"12. The chemical qualities of water are profoundly influenced by the character of the geological formations from which the water is derived. Rocks and soils which impart to water salts other than those of potash and soda, render it more or less hard; and as such hardening salts are almost invariably compounds of lime and magnesia, with carbonic and sulphuric acids, it follows that chalk, limestone, dolomite and rocks containing the carbonates of lime and magnesia, or sulphate of lime, are those which are almost exclusively instrumental in communicating hardness to water. The following formations yield, as a rule, soft water:

Igneous,
Metamorphic,
Cambrian,
Silurian (non-calcareous),
Devonian (non-calcareous),
Millstone grit.
Coal measures (non-calcareous),
Lower green sand,
London and Oxford clay,
Bagshot beds,
Non-calcareous gravel.

On the other hand, the following geological formations almost invariably yield hard water:

Silurian (calcareous),
Devonian (calcareous),
Mountain limestone,
Coal measures (calcareous),
New red sandstone,
Conglomerate sandstone,
Lias,
Oolites,
Upper green sand,
Chalk.

"13. The influence of geological formation upon the palatability and wholesomeness of *surface water* is often inconsiderable, owing to the deposit of peaty matters upon the surfaces of the rocks or soils. Unpolluted surface waters from the most widely different geological formations differ but little in the proportions of organic matter which they contain; but where the water percolates or soaks through great thicknesses of rock, its quality, when it subsequently appears as *spring* or *deep well water*, depends greatly upon the chemical character of the material through which it has passed. When the formation contains much soluble saline matter, the water becomes loaded with mineral impurities, as is frequently the case when it percolates through certain of the Carboniferous rocks, the Lias and the Saliferous marls. When the rock is much fissured or permeated by caverns or passages, like the mountain limestone, for instance, the effuent water differs but little from surface drainage, and retains most of the organic impurities with which it was originally charged. But when it is uniformly porous, like the chalk, oolite, green sand or new red sandstone, the organic matter at first present in the water is gradually oxidized and transformed into innocuous mineral compounds. In effecting this most desirable transformation, and thus rendering the waters sparkling, colorless, palatable and wholesome, the following are the most efficient water-bearing strata: chalk, oolite, green sand, new red and conglomerate sandstone.

"14. Surface water and river water which contains in 100,000 parts more than 0.2 part of organic carbon, or .03 part of organic nitrogen, is not desirable for domestic supply, and ought, whenever practicable, to be rejected.

"15. Spring and deep well water ought not to contain in 100,000 parts more than 0.1 part of organic carbon or .03 part of organic nitrogen. If the organic carbon reaches 0.15 part in 100,000 parts, the water ought to be used only when a better supply is not obtainable.

"In all cases in which spring and deep well water of good quality are available, we recommend that they should be employed in preference to surface or river water for domestic supply.

"II. *As to the Possibility of Rendering Polluted Water again Wholesome.*

"1. When the sewage of towns or other polluting organic matter is discharged into running water, the suspended matters may be more or less perfectly removed by subsidence and filtration, but the foul organic matters in solution are very persistent. They oxidize very slowly, and they are removed only to a slight extent by sand filtration. There is no river in the United Kingdom long enough to secure the oxidation and destruction of any sewage which may be discharged into it, even at its source.

"2. Of all the processes which have been proposed for the purification of sewage, or of water polluted by excrementitious matters, there is not one which is sufficiently effective to warrant the use for dietetic purposes, of water which has been so contaminated.

"3. In our opinion, therefore, rivers which have received sewage, even if that sewage has been purified before its discharge, are not safe sources of potable water.

"III. *As to the Propagation of Epidemic Diseases by Potable Water.*

"1. The existence of specific poisons, capable of producing cholera and typhoid fever, is attested by evidence so abundant and strong as to be practically irresistible. These poisons are contained in the discharges from the bowels of persons suffering from these diseases.

"2. The admixture of even a small quantity of these infected discharges with a large volume of drinking water is sufficient for the propagation of those diseases among persons using such water.

"3. The most efficient artificial filtration leaves, in water, much invisible matter *in suspension*, and constitutes no effective safeguard against the propagation of these epidemics by polluted water. Boiling the infected water for half an hour is a probable means of destroying its power of communicating these diseases.

"4. Other epidemics, such as dysentery and diarrhœa, are also probably propagated by drinking water, but the evidence is here neither so abundant nor conclusive as it is in the case of cholera and typhoid fever.

"IV. *As to the Alleged Influence of the Hardness of Potable Water upon Health.*

"1. While waters of excessive hardness may be productive of calculus, and perhaps other diseases, soft and not excessively hard waters, if equally free from deleterious organic substances, are equally wholesome.

"2. In towns where the chief sanitary conditions prevail with tolerable uniformity, the rate of mortality is uninfluenced by the softness or hardness of the water supplied to the inhabitants.

"V. *As to the Superiority of Soft over Hard Water for Washing, Cooking and Manufacturing Operations.*

"1. The washing of linen can only be performed with soft water. If the available water be hard, it must be artificially softened, an operation which, on the domestic scale, must be performed at great expense, by the aid of either fuel, soda or soap. In personal ablution, also, the use of soft water is much more pleasant and efficient. It is also more economical; but, by the general use of a very small quantity of water, the waste of softening material is here much less than in a laundry.

"2. In cooking, the extraction of the soluble parts of such materials as are submitted to boiling, or to digestion at a high temperature, is more completely and economically effected by soft than by hard water.

"3. In manufacturing operations involving the use of water, soft water is, almost without exception, preferable to hard. Dangerous encrustations in steam boilers are prevented by the use of soft water.

"VI. *As to the Softening of Hard Water.*

"1. All hard water can be softened, either by distillation or by the addition of a sufficient quantity of soap or carbonate of soda. Water, the hardness of which is due to the *carbonates** of lime and magnesia (temporary hardness), may be softened, either by boiling for half an hour, or by the addition of a proper quantity of slaked lime. Except the last, all these processes are expensive, and inapplicable on the large scale.

"2. Water, the hardness of which is wholly or chiefly of the temporary kind, may be easily, cheaply and efficiently softened, on the large scale, by the proper use of lime, and the wholesomeness and palatability of such water are sometimes increased, and never diminished, by the process.

"3. The lime method of softening may be applied with ease and great economy to the whole supply of even the largest towns, provided the hardness of the water be wholly or chiefly of a temporary kind.

"VII. *As to the Improvement of Water by Filtration.*

"1. Sand filtration, as carried out in water works, not only clarifies the water by removing suspended impurities, but also diminishes the proportion of organic matter in solution, to an extent dependent upon the thickness of the filtering medium, and the rate at which the water passes through that medium.

"2. Domestic filtration, as usually practiced, is of little or no use, but, properly performed, it is much more efficient than sand filtration on the large scale, in improving the quality of water polluted by organic matters. The best materials for domestic filters are spongy iron and animal charcoal.†

* Water which is hard from sulphates cannot be so well purified by the use of lime. Most of our New Jersey hard waters contain sulphates.—G. H. C.

† Long experience has convinced me that spongy iron possesses many advantages over animal charcoal for domestic filtration.

"3. Although the improvement of excrementally-polluted water by filtration may reasonably be considered, on theoretical grounds, to afford some feeble protection against the propagation of epidemic diseases by water, no trustworthy evidence can be adduced in support of such a view.*

"VIII. *As to the Deterioration of Water during its Transmission through Mains and Service Pipes.*

"1. Potable water can be transmitted through mains of even great length, if they be properly laid, without any appreciable deterioration of quality; but if the joints are caulked with hemp, or other similar organic material, the water is often seriously polluted for months, or even years, after the laying of the mains.

"2. The experience of Glasgow, Manchester, and other towns, proves conclusively that leaden service pipes can be safely used for the delivery even of water which acts violently upon lead, if the pipes be kept constantly charged with water."

Hard water, is water which does not readily form a lather or suds with soap, but when soap is put in it a curdy precipitate forms. This precipitate is produced by the combination of the acids of the soap with the lime and magnesia in the water. And much soap is always wasted in attempting to wash with such water.

Rain water and *some* river waters are generally free from salts of lime and magnesia, and are said to be *soft*, while many well and spring waters are *hard*. The hardness of water varies with the quality, as well as the amount of mineral matter in it. But it is common to speak of water containing ten grains or more of solid matter to the gallon, as *hard*, and that with less than that quantity as *soft*.

Soft water is necessary for washing, for making steam, and for most purposes in the arts. Hard water, though unfit for these uses, is not unwholesome nor unpalatable, and persons drinking water which contains 50 or 60 grains of mineral matter to the gallon, enjoy as good health as those who drink soft water.

The injurious effects of drinking-water are due to the organic matter in it.

*Bischof has recently shown that filtration through spongy iron destroys bacterial life, and that water so filtered is incapable of inducing putrefaction in animal matters.

In our country there is a much larger portion of land in forest, or in a low state of cultivation, than in England, and surface water from the country has not been found as much contaminated with impurities here as it is there. Water of unexceptionable quality from surface streams is used for the supply of most of the cities here.

Deep well-water has not been so uniformly good in quality as that obtained in the deep wells about London, as will be seen in several cases mentioned farther on.

In 1876 the mayors of several of the cities in this State requested the Survey to collect and furnish information in regard to the sources from which satisfactory supplies of pure and wholesome water could be obtained for the use of those living in densely populated districts. In accordance with this, a report was prepared and widely circulated, but it is now out of print. Much other information upon the subject has also been since obtained, and published in the successive annual reports which have been issued since that time. The importance of the subject, and the awakened interest in it, are sufficient reasons for bringing this material together in the present report.

The original source of all water supply is from rain and snow. This is true, whether it is collected directly in cisterns or ponds; or soaks into the earth to remain until drawn out from wells or other openings into it; or until it escapes in springs; or drains off from the surface as brooks or rivers. The amount of rain and melted snow which falls, then, is the first element for determining the supply which can be depended upon in any cases.

The amount of rain water which falls is calculated from its measured depth, and the latter is usually recorded in inches and hundredths of an inch. Thus, if the rain-fall is one inch in depth, the amount fallen on a square foot is 144 cubic inches, or about 2½ quarts; and on 1,000 square feet, which is not more than the surface covered by an average-sized house or barn, the rain water from one inch depth fallen on it is 2,500 quarts, or more than 20 barrels.

The following written and tabular statements furnish a full account of the rain and melted snow which has fallen in several places in the State for a number of years past, including some which have been very dry, and others which have been remarkably wet.

The mean yearly rain-fall does not vary greatly in the several natural divisions of the State. The average at eight stations taken to represent the central part of the State is 43.8 inches. The records, which have been kept for periods of five years or more, show that, in general, there is an increase in the total amount of moisture precipitated, from north to south and from northwest to southeast. The average at Lake Hopatcong in the Highlands, from a record for twenty-four years, is 42.54 inches. That for thirty-nine years and eight months, at Newark, 46.48 inches. At New Brunswick, the mean quantity for twenty-nine years is 45.42 inches. And at Philadelphia, the average of fifty-six years is 43.69 inches. The following table of the mean amount of precipitation in rain and melted snow, gives the averages for the months, the seasons, also the year.

TABLE OF MEAN AMOUNT OF PRECIPITATION IN RAIN AND MELTED SNOW.

DEPTH IN INCHES AND HUNDREDTHS OF INCHES.

Station Number.	Location.	Height above tide in feet.	January.	February.	March.	April.	May.	June	July.	August.	September.	October.	November.	December.	Spring.	Summer.	Autumn.	Winter.	Year.	Time of Beginning Record.	Time of End of Record.	Length of Period of Record. Yrs.	Length of Period of Record. Mos.	Station Number.
			Months.												Seasons.									
1	Lake Hopatcong, Morris Co.	914	2.37	2.44	2.79	3.47	4 67	3 66	3 95	4.31	3.98	3.77	3 67	3 46	10.93	11.93	11 42	8.26	42.54	Jan., 1846	Dec., 1869	24	0	1
2	Easton, Pa.	310	2.97	2 58	3.27	3.48	5.57	3.91	3.96	3.98	3.74	3.09	4.66	4.35	12.32	11.85	11.49	9.90	45.56	Apr., 1846	Dec., 1859	5	1	2
3	Paterson, Passaic Co.	60	4.46	4.43	7.54	3.05	5.16	5.91	6.15	4.63	7.32	2 89	3.63	5.52	15.75	16.69	13.84	14 41	60.69	Jan., 1878	Dec., 1882	5	0	3
4	Newark, Essex Co.	35	3.59	3 43	3 87	3.73	3.99	3.49	4.29	5.23	3 87	3.56	3.66	3.77	11.59	13.01	11.09	10.79	46.48	May, 1843	Dec., 1882	39	8	4
5	New Germantown, Hunterdon Co	320	3.08	2.78	3.76	3.24	3.29	4.03	4.71	4.95	3.13	5 01	3.67	2 44	10.29	13.69	11.81	8.30	44.09	Nov., 1868	Aug , 1876	7	10	5
6	New Brunswick, Middlesex Co.	90	3.43	3.18	3.55	3.75	3.87	3 92	4.72	4.78	3.74	3.30	3.69	3.49	11.17	13.42	10.73	10.10	45.42	Jan., 1854	Dec , 1882	29	0	6
7	Lambertville, Hunterdon Co.	96	3 22	3.12	3 22	3.19	4.29	3.38	4.07	4.94	3.90	3.41	3 21	3.87	10.70	12.39	10 52	10.21	43.82	July, 1843	Aug., 1860	17	2	7
8	Trenton, Mercer Co.	60	3.25	2.59	3.87	3 86	3.10	4.01	5.61	5.39	3.61	3.67	4.43	3.11	10.83	15 01	11.71	8.95	47.55	Jan., 1866	Dec., 1880	15	0	8
9	Freehold, Monmouth Co	190	3.96	3.51	5.38	3.35	2 63	3 58	4.06	5 30	4.40	2.76	3.69	3.77	11.36	12.94	10.85	11.24	46.39	Apr., 1874	Dec., 1882	8	9	9
10	Sandy Hook, Monmouth Co.	30	4.13	3 30	5.94	4.57	3.89	4.25	4.38	4.79	5.22	3.12	4.41	3.99	14.40	13.42	12.75	11.42	51.99	Jan., 1874	Dec., 1882	9	0	10
11	Barnegat, Ocean Co.	20	5.07	3.74	5.56	4.10	4 02	3.90	4.25	5.15	5.51	3.31	4.75	4.48	13.68	13.30	13.57	13.29	53.84	Jan., 1874	Dec., 1882	9	0	11
12	Atlantic City, Atlantic Co.	14	3.46	2.82	4.06	3.51	2.41	3.30	3.01	5.45	3.65	2.42	3.33	4.19	9.98	11.76	9.40	10.47	41.61	Jan., 1874	Dec., 1882	9	0	12
13	Moorestown, Burlington Co.	104	3.33	3.07	3.53	3.00	3.70	3.82	4.21	4.58	3.98	3.20	3.34	3.24	10.23	12.61	10.52	9 64	43 00	May, 1863	Dec., 1882	19	8	13
14	Vineland, Cumberland Co.	119	4.18	3.67	4.64	3.16	3.92	3.81	4 35	5.45	4.98	3.14	3.86	3.84	11.72	13.61	11 98	11.69	49.00	Jan., 1866	Dec., 1882	17	0	14
15	Greenwich, Cumberland Co.	30	2 97	3.86	4 28	2 51	4.74	3.17	2.81	4.29	4.06	2 95	3.25	2.64	11.53	10.29	10.26	9.47	41.53	Mar., 1864	Feb., 1873	9	0	15
16	Cape May, Cape May Co.	28	4.15	3.40	5.19	3.21	2.75	3.57	3.22	6.32	4.45	3.11	3.76	4.17	11.15	13.11	11.32	11.72	47.30	Sept., 1871	Dec., 1882	11	4	16

The distribution among the months is by no means uniform. In the northern and central parts of the State, August is the wettest month, and next to it is May. The amounts are least in February, June and October—that is, these latter are the dryer months. By seasons, the greater mean fall is in the summer, and the least in the winter. The autumn is dryer than the spring. The curve for the annual fluctuation at localities in the southern part of the State differs from the more northern in its maximum coming in August and in March, while the dryer months are May, October and then February, in order.

Although the average for the summer is the highest of the calendar seasons, there is probably more variation or a wider range, owing to the droughts and the heavy rain-falls accompanying summer thunder storms. The latter are generally of limited extent, and give rise to great differences within short distances. A low ridge or chain of hills often determines their course, and separates a well-watered from a parched district. The longer storms of the other seasons are wide-spread, and cover the whole State in their sweep.

In the study of rain-fall statistics, it is necessary to have the extremes as well as the averages, since our calculations for collecting must be based upon the least amounts, or those of the driest seasons, while the extraordinary heavy falls are instructive in giving notes of warning against accidents from floods. The tables below give the monthly extremes, and also those for the year.

TABLE OF EXTREME MONTHLY PRECIPITATION.

DEPTHS IN INCHES AND HUNDREDTHS.

	JANUARY.		FEBRU'RY.		MARCH.		APRIL.		MAY.		JUNE.	
	Greatest.	Least.	Greatest.	Least.	Greatest.	Least.	Greatest.	Least.	Greatest.	Least.	Greatest.	Least.
Lake Hopatcong.......	5.15	0.48	5.84	0.40	7.54	0.40	7.35	0.25	7.69	1.89	7.64	0.93
Newark....................	6.52	0.61	6.07	0.82	10.00	0.98	11.36	0.39	8.74	0.85	9.74	1.04
New Brunswick........	7.35	0.64	6.01	0.46	7.51	0.80	9.22	0.55	7.57	0.65	10.90	0.24
Moorestown.............	5.82	1.13	5.96	0.56	5.78	1.42	8.40	0.67	7.88	0.47	7.56	1.61
Vineland..................	6.81	1.30	6.25	1.73	6.84	1.22	8.32	1.30	8.45	0.77	5.59	0.60

	JULY.		AUGUST.		SEPTEMBER		OCTOBER.		NOVEMB'R.		DECEMBER	
	Greatest.	Least.	Greatest.	Least.	Greatest.	Least.	Greatest.	Least.	Greatest.	Least.	Greatest.	Least.
Lake Hopatcong.......	7.91	0.90	10.70	0.50	11.44	0.85	9.82	1.04	8.46	1.61	7.30	0.60
Newark....................	8.94	1.12	22.48	0.95	17.66	0.55	7.73	0.32	8.74	0.87	7.54	0.92
New Brunswick........	10.42	1.26	11.52	0.70	15.52	0.34	8.53	0.27	8.77	0.00	5.95	1.13
Moorestown.............	6.97	1.40	9.44	0.81	11.71	0.67	6.83	0.47	6.30	1.52	5.77	0.90
Vineland..................	9.82	1.85	10.64	0.65	12.35	0.69	6.75	1.03	7.24	0.99	7.52	1.88

EXTREME ANNUAL RAINFALL.

	GREATEST	YEAR	LEAST.	YEAR	LENGTH OF PERIOD.		GREATEST	YEAR	LEAST.	YEAR	LENGTH OF PERIOD.
Fort Columbus, N. Y. Harbor.........	65.51	1837	27.57	1836	24 years.	Lambertville.............................	57.36	1841	32.32	1856	27 years.
Lake Hopatcong...........................	54.61	1850	30.06	1866	24 years.	Moorestown..............................	52.72	18—	36.03	18—	19 years.
Newark.....................................	57.05	1859	34.07	1856	39 years.	Vineland...................................	56.53	18—	40.73	18—	17 years.
New Brunswick............................	59.95	1873	30.33	1876	29 years.	*Paterson.................................	85.42	1882	....	18—	— years.

*In 1882 the fall in September amounted to 25.98 inches.

We note in this table that the monthly range is from *none* up to 22.48 inches, and the annual variation is from 30.06 inches to 59.95 inches. The longer records show that any given month may pass with little or no rain, although this deficiency is more likely to occur in the summer and autumn months, than in the winter or spring. Taking the least monthly falls at Newark for the four consecutive months, viz., July, August, September and October, their sum is 2.94 inches. A coincidence of this nature is quite improbable, but it is possible. A few examples of droughts are instructive in this connection. The Morris Canal Company's record kept at Lake Hopatcong, mentions a drought in 1856, continuing from January 6th to April 19th—105 days—with 2.66 inches of rain and melted snow. Two others, which occurred in 1867 and 1868, or from August 29th, 1867, to April 4th, 1868, the total precipitated moisture amounted to 9.5 inches. Another extraordinary drought was that of 1881, felt more or less severely throughout the State. At Newark, it was unprecedented, and the total rain-fall for four months, from June to November, was 5.22 inches only, or but little more than one-third of the average for the same months. At New Brunswick the precipitation was still less, and the amount for 123 days was 2.94 inches. The summer rains at Vineland amounted to 6.04 inches, whereas the average is 14.17 inches. Fortunately the areas of such severe droughts are not so large as to cover the water-sheds of the longer streams which afford supplies to our cities. Wherever dependence is upon small streams, however, they would be very likely to feel the effects of the deficiency in all its force. The size of the stream and the area whence the supply is drawn, become vital questions in this relation. Generally dry seasons are not consecutive, though several dry years *may* occur in succession. But the same season may run below the average for two or three years in succession. Thus, the autumns for 1878, '79, '80 and '81, were all drier than the average.

STORAGE OF RAIN WATER.

Satisfactory supplies of rain water can be collected from the roofs of houses, barns, and other buildings. Nearly all the rain which falls on roofs can be saved. In the case of a house 30 by 40 feet on the ground, with the annual rain-fall of the driest years, 30 inches, the whole quantity of rain which falls on that roof in the whole year, is

58,500 gallons, or 160 gallons a day. This is about five barrels per day and ordinary families do not use nearly as much as that. A barn 40 by 60 feet would supply double the amount mentioned above, which would be more than enough for all the animals that could be properly kept in such a building. As a matter of fact, stored rain water does not fail in amount when the cisterns to hold it are sufficiently capacious. On account of drouths, it is necessary to have cisterns, or tanks, sufficiently large to hold a supply for three months; and for this purpose one 8 feet square and 12 feet deep, or a circular one 10 feet in diameter and 12 feet deep, would be ample for the house, and two of that size for the barn. Deep cisterns are better than shallow ones, on account of their keeping the water much cooler than the shallow ones do. Cisterns, in most places, have got in disrepute from being made of wood, and also from being imperfectly covered, so that surface water and filth may leak into them. With the present abundant supply of hydraulic cement, brick or stone cisterns can be made and tightly covered so as to be entirely secure from such pollution.

The purity of rain water is popularly supposed to be complete. It is, of course, free from all mineral matter, but it contains a little organic matter which it has taken up from the air, and sometimes a trace of smoke is perceptible in it. These impurities are greater in amount in the rain water in towns than in that of the country. The taste of the water is not quite so pleasant as that of good well or spring water, but it is wholesome, and for culinary and laundry purposes it is better than any other.

That collected from slate or metal roofs is better than that from those of shingles, and in all cases the roofs should be protected from defilement by pigeons gathering on them, and from accumulations of dust and leaves. And the rain water may be improved in cleanliness by allowing that which first falls to run to waste, and only saving that which falls later in the shower or storm.

The capabilities of stored rain for water-supply have been much underrated, and there are many cases in which it is the most available and economical of any satisfactory source of supply.

WATER-SUPPLY FROM STREAMS AND LAKES.

For cities and towns experience has proved that the most satisfactory supply of water is obtained from the streams and lakes which are in the most mountainous and uncultivated parts of the country. This would naturally be the case, for the soil is the poorest, and so furnishes the smallest amount of soluble matter to the water, and the uncultivated surface is the freest from the polluting elements which gather on improved grounds and thickly settled districts.

There are a number of streams in the State which are capable of supplying pure and wholesome water to all its inhabitants, even if they should increase to five, or even ten times their present number.

The amount of water which any stream can supply depends upon the annual rain-fall and the area of the country which the stream drains. This area may be called the *water-shed* of the stream. The rain-fall in different parts of the State has been given in the tables on pages 110 and 112 of this report. The whole of this water cannot, however, be collected for use, as there is a large percentage wasted by evaporation, the leaves of trees and plants exhale great quantities, some soaks into the earth and escapes by courses which cannot be controlled, and some gets away in leaks of various kinds. In hilly and rocky countries, where the water runs off quickly, a larger percentage can be collected in reservoirs than there can be in more level districts. Some engineers have estimated the percentage of loss at fifty per cent. of the whole rain-fall, but more cautious calculators have thought it safer to allow sixty per cent. for loss. As the rain-fall in the driest years is all that can be depended upon, the minimum rain-fall of 30 inches must be taken. Forty per cent. of this is 12 inches, and this it will be safe to use in our calculations. Though it will probably be found that a much larger percentage is really saved. A proof that more than this can be saved may be found in the experience of the Morris Canal Company with their reservoirs, Lake Hopatcong and Greenwood lake.

Lake Hopatcong originally covered 1,500 acres, and by means of a dam at its outlet its surface was raised 10 feet, and it covered 2,800 acres. This gives an average of 2,150 acres, which is 3½ square miles. The whole *drainage* area for the lake is 27 square miles, which is 7 7-10 times the area of the lake. A rain-fall of 1 foot on the whole water-shed would only raise the lake 7 7-10 feet. But it is generally drawn down more than this below high-water mark for the uses of the canal during the season of navigation, and yet the lake has sometimes been filled between the close of navigation—about December 1st—and February 1st; generally, it is filled by the 1st of March, though in some cases it has not been filled till the middle of May. These times cover only half the year or less, and the inference is conclusive that more than a foot of rain-fall can be stored from this water-shed. The Stanhope mill has rights to the original water power on the outlet, and an opening of 10 x 36 inches is kept for this use. A large draught is made upon the water of the lake for the mill, even during the time when it fills so rapidly. It is a common observation, that the lake rises about twice as much as the rain-fall in the two days following a rain.

The surface of Greenwood lake has been raised 13 feet by means of a dam. Its drainage area is 32 square miles, and its surface is 4 square miles. It has never been largely drawn upon for the uses of the canal, seldom being lowered more than 2 feet; but it furnishes water power to Hewitt furnace, and there is a gate drawn constantly of 5 x 36 inches. This draws out a large quantity. The lake, however much drawn down in the autumn, is expected to be full before spring. The water has been known to rise 3 feet by a single storm. It is sometimes raised so as to be 2 or 3 feet higher than the the dam.

Assuming then that 12 inches in depth can be saved, a cubic foot can be saved on every square foot of surface, and from an acre which is 43,560 square feet of surface, 43,560 cubic feet or 326,700 gallons of water can be collected in a year. And from a square mile there can be collected 27,878,400 cubic feet or 209,088,000 gallons in a year, which is equivalent to a daily supply of nearly 900 gallons per acre or 572,844 gallons per square mile.

The drainage areas of the more important water-sheds and of some of those of lesser streams, which supply cities or towns with water, have been computed in the large State geological map, scale two miles to an inch, by using tracing-cloth and weighing the areas traced on the same, and then weighing the area of the tracing-cloth, which represents a square mile, and computing the area sought by proportion. The best tracing-cloth is of very uniform weight in its different parts, so that we were satisfied the error from any variation in it could not be more than two per cent., which is as accurate as the map we used, and the traces of the lines we drew to show the borders and divides of different water-sheds. The weighing has to be done with the most sensitive of our laboratory balances.

The map of Northern New Jersey, published in 1881, and the


GEOLOGICAL SURVEY OF NEW JERSEY
MAP
OF
NEW JERSEY
SHOWING WATER-SHEDS
1882.
Scale
FLAT BROOK
WALL KILL
PAULIN'S KILL
PEQUEST RIVER
MUSCONETCONG RIVER
POHATCONG CREEK
RAMAPO
WANAQUE
PEQUANNOCK
SADDLE RIVER
HACKENSACK
PASSAIC
ROCKAWAY
WHIPPANY
UPPER PASSAIC
RAHWAY
ELIZABETH
RARITAN
LAMINGTON RIVER
NORTH BRANCH OF RARITAN
SOUTH BRANCH OF RARITAN
LOWER RARITAN
MILLSTONE RIVER
LAWRENCE BROOK
SOUTH RIVER
NAKINOKAKE
NISHISAKAWICK
LOCKATONG
WICKICHEOCKE
ASSANPINK CREEK
SWIMMING RIVER
MANASQUAN RIVER
WRECK POND
METEDECONK RIVER
CROSSWICKS CREEK
TOMS RIVER
ASSISCUNK CREEK
NORTH BRANCH RANCOCAS
SOUTH BRANCH RANCOCAS
PENSAUKEN CREEK
COOPER'S CREEK
CEDAR CREEK
FORKED R.
WADING RIVER
OSWEGO RIVER
LITTLE EGG HARBOR RIVER
GREAT EGG HARBOR RIVER
MANTUA CREEK
RACCOON
OLDMAN'S
SALEM
MAURICE RIVER
ALLOWAYS
COHANSEY CREEK
MANANTICO
MANUMUSKIN
TUCKAHOE
BABCOCK'S CREEK
ABSECUM CR.
EASTON
PHILADELPHIA
TRENTON
Camden
Burlington
Mount Holly
Salem
Bridgeton
Vineland
Atlantic City
Long Branch
Cape May City
Port Jervis
RARITAN BAY
DELAWARE BAY
ATLANTIC OCEAN
DELAWARE RIVER
75°30'
75°
74°30'
74°
41°
40°30'
40°
39°30'
39°
Julius Bien & Co. lith

more recent surveys in the Highlands, have been the basis for ascertaining a few of the smaller areas, as those of Morristown, Dover, Hackettstown, &c.

The drainage areas, estimated, are shown on the small map of New Jersey, which is here inserted for this purpose.

Names.		Areas. Square Miles.
Wallkill		203
Flat Brook		61
Paulinskill		163
Pequest		168
Pohatcong		58
Musconetcong		162
Hakihokake creek		14
Nishisakawick creek		15
Lockatông creek		23
Wickcheoche creek		28
Alexsauken creek		14
Jacobs creek		14
Assanpink creek		94
Crosswicks creek		151
Assiscunk creek, to tide water		38
Rancocas, north branch, to Mount Holly		157
Rancocas, south branch, to Lumberton		133
Pensauken creek, to tide		28
Cooper's creek, to Cooperstown		29
Big Timber creek, north branch, to Chew's Landing		14
Big Timber creek, south branch, to Blackwoodtown		21
Mantua creek, to Carpenter's Landing		29
Raccoon creek, to Swedesboro		30
Oldman's creek, to Sculltown		27
Salem creek, to Sharptown		26
Alloways creek, to Hancock's Bridge		53
Cohansey creek, to Bridgeton		41
Maurice river, to Vineland (Landis avenue)		109
Maurice river, to Millville		230
Hackensack river, in New York	74	
Hackensack river, to New Milford	57	
		131
Saddle river, in New York	10	
Saddle river, to Lodi	48	
		58
Ramapo river, in New York	125	
Ramapo river, in New Jersey	47	
		172

Names.		Areas. Square Miles.
Wanaque, in New York	35	
Wanaque, in New Jersey	89	
		124
Pequannock		95
Pompton river, including all tributaries		423
Rockaway river, above Lower Montville		138
Whippany, above Hanover		50
Passaic river, above Millington		60
Passaic river, above Chatham bridge		113
Passaic river, above Little Falls		854
Passaic river, above Paterson		877
Passaic river, above Newark		974
Elizabeth river, to Parker's road bridge		19
Rahway river		63.7
Peckman's river, above Verona		2.6
Peckman's river, above Cedar Grove		6.5
Lawrence brook, Weston mills		46
Raritan river, New Brunswick		892
North Branch of Raritan, including Lamington		188
South Branch of Raritan		281
Millstone		280
Lamington		101
Stony brook, above Bruere's		45
South river, old bridge		100
Swimming river, to tide in Neversink		47
Whale Pond creek, to tide		8
Hockhockson brook, to Tinton Falls		11
Little Silver creek, to tide		2.3
Wreck Pond brook, to tide		12
Shark river, to tide		11
Manasquan river, to tide		68
Metedeconk, to Burrsville		70
Toms River, to tide (Toms River)		157
Cedar creek, Cedar Creek village		59
Forked river, north branch, to tide		16
Oyster creek, to tide		
Manahawken creek, to Manahawken		20
West creek, to tide		22
West creek, to Tuckerton		10
Oswego river, Harrisville		58
West branch Wading river, Harrisville		81
Bass river		14
Mullicas, or Little Egg Harbor river, to Batsto		217

Names.	Areas. Square Miles.
Doughty's, Absecon creek, Absecon	16
Patconk creek, at Bargaintown	20
Great Egg Harbor river, at May's Landing	199
Babcock's creek, at May's Landing	37
Tuckahoe, at Etna furnace	32
Manumuskin creek, Manumuskin Manor	25
Manantico creek, to tide	34
Morristown, Reservoir pond	0.5
Streams on mountain to pond near Englewood	2.6
Dover, Richard's pond, Wallace brook	0.6
Hackettstown, springs and water works reservoir	1.1
Plainfield, Stony brook to gap	5.3
Plainfield, Green brook, at Scotch Plains gap	7.6
Perth Amboy, Five Oak springs	2.8
Bridgeton, reservoir	6.6

The Hackensack river rises in Rockland county, New York, and runs through Bergen county to Newark bay. Its drainage area above New Milford, at head of tide, is 131 square miles.

Saddle river also rises in Rockland county and thence through Bergen county and empties into the Passaic. The area drained by this stream down to Lodi amounts to 58 square miles.

The area of the Passaic drainage basin above Little Falls is 854 square miles. It is made up from that of its branches, the Ramapo, Wanaque, Pequannock, Rockaway, Whippany and the Upper Passaic.

The Ramapo rises in Orange and Rockland counties, New York, and runs through Bergen county to Pompton river. Its drainage area amounts to 172 square miles.

The Wanaque rises in Orange county, New York. It receives the waters of Ringwood creek and also of Greenwood lake. The area drained by its waters is 124 square miles.

The Pequannock* rises in Morris, Passaic and Sussex counties, in New Jersey, and is the boundary between the two first named. It has a drainage area of 28 square miles above Oak Hill, and in all of 95 square miles.

The Rockaway river has its whole course in Morris county. Its drainage area above Lower Montville is 138 square miles.

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* The Ramapo, Wanaque and Pequannock rivers unite at Pompton, and form Pompton river, which runs into the Passaic at Two Bridges.

The Whippany rises near Morristown, has an area above Hanover of 49 square miles.

The Passaic, which rises near Mendham, Morris county, and retains its name down to Newark bay, has an area of drainage above Millington of 60 square miles; at Chatham bridge of 112 square miles, and at Little Falls of 854 square miles. At Paterson the area is 877 square miles. This area is capable of yielding a daily supply of 502,384,000 gallons of water, if a depth of 12 inches of rain-fall can be collected, and the experience at Lake Hopatcong and Greenwood lake proves that it can be done. This would give a daily supply of 100 gallons each to five million people.

The Passaic water is used for water-power at Little Falls, Paterson, and at Dundee, and for supplying the Morris canal, east of Stanhope. The water supply of Paterson is also taken directly from that stream above the Falls. The water supply of Passaic is taken from the same stream at Dundee. The supply of Newark is obtained from it about a mile above Belleville, and that for Jersey City is taken from it opposite that place. The Passaic is enlarged beyond its size at Little Falls, by Peckman's river and Oldham creek, above Paterson, and Saddle river, above Dundee.

The Passaic river, from Two Bridges up to Chatham, runs through a very flat country, and with but little fall. The channel is deep for the whole distance, but in times of heavy rain the river overflows its banks, and covers with water the flat lands on its borders. In summer, when the meadows are covered with standing grass or other vegetation, the freshets subside very slowly, and great damage is done to health and property. The overflow is caused by the slackness of the current of the river. The obstructions to the flow are:

1. A bar of earth and boulders across the stream just above the mouth of the Pompton, at Two Bridges.

2. A ledge or reef of trap-rock across the stream at the head of Little Falls, which is of about the same height with the bar at Two Bridges.

3. A strong stone dam built just below the reef, which is about a foot and half higher than either the reef or the bar.

These effectually obstruct the free flow of water in the stream. The lowering of the obstructions seven feet is, from the depth of the channel above, feasible, and comparatively inexpensive; and when done would lower the water surface to almost the same extent. By this change the water could be kept within the banks of the stream after ordinary rains; and in times of heavy rain the overflow of water would soon drain off. The plan for this improvement has been matured, but its execution is delayed on account of the expense to be incurred before work can be begun. It is greatly needed for its sanitary and economical benefits, and it would improve the quality of the water in that portion of the Passaic.

Surveys of valleys were made on the Rockaway, Pequannock, Ringwood and Ramapo in 1876, in which deep, capacious and unpolluted reservoirs can be made, which would hold a daily supply of more than 100,000,000 gallons.

The supply from natural ponds is least expensive, most quickly obtained, and with less change in the arrangements of property. To get more definite information regarding some of the ponds from which supplies could be drawn, George W. Howell, C.E., was instructed to examine a number of them and report the result, which he did as follows:

"In accordance with your instructions I have made an examination of various lakes or ponds in Passaic, Morris and Sussex counties, especially with the view of ascertaining the extent of surface which is or may be flowed, the capacity for storage of water, and also their respective drainage areas, together with such other items of information as may be of service in defining their utility in supplying and storing water, a report whereof is hereto annexed.

"For convenience of reference I have arranged the lakes in the order of their outlets, classifying together those respectively that flow (I.) into the Ramapo river, (II.) the Wanaque river, (III.) the Pequannock river, and (IV.) the Rockaway river.

"I. THE RAMAPO RIVER.

"1. *Franklin lake* lies about three miles directly east of Pompton Furnace. It covers an area of 94 acres and drains about 1,000 acres, the drainage area being about equally divided between mountain slopes and gravelly farming land. There are numerous small ponds in the vicinity, some of them having no visible inlet or outlet, and all of them nearly, if not altogether, of the same level. Crooked lake, a pond of inconsiderable depth, but some 30 or 40 acres in extent, is said to rise and fall with Franklin lake, the residents of the vicinity maintaining that there is some subterranean connection between the two. About half a mile west of Crooked lake is Crystal spring, which discharges large volumes of water, supposed to be derived from the lakes, which, collectively, are known as 'The Ponds.' Singack brook, rising in a ravine a little to the south of Franklin lake, is supposed to have a similar origin. A few years ago one of the ponds was observed to rise to a much higher elevation than ordinary, and from no known cause, so much so, that it became necessary to change the location of a public road, which had been submerged. After remaining thus for a year or two, the pond subsided to its former level, which it has since retained.

"The outlet of Franklin lake, which is smaller than the inlet, runs for about 500 feet through a level meadow, when, with about 7 feet head, it drives a small water-wheel. The head has been obtained rather by lowering the tail-race than by a dam.

"Lowering the surface of the lake 5 feet would diminish its size perhaps one-third.

"Raising a dam of 5 feet at the outlet would overflow 75 to 80 acres more, the greater part of the addition being a cedar swamp at the head of the lake. Such a dam would be 300 feet long. A higher dam would be over 1,000 feet long, and it is quite doubtful whether the first mentioned rise of 5 feet in the surface could be maintained, owing to the porous, gravelly nature of the soil, and the probability that some connection exists between the various ponds in the locality.

"2. *Rotten pond* takes its drainage wholly from the mountains, and lies one and a half miles southeasterly from Wynokie. The original surface was about 80 acres, which has been reduced to 20 acres by lowering the outlet some 6 feet. Should the present surface be raised 10 feet by a dam 4 feet high, fully 100 acres would be covered. The drainage area is about 1,200 acres.

"3. *Negro pond*, a long narrow pond between the mountains, a little east of Shepherd's pond, lies partly in New Jersey and partly in New York, about one-quarter of a mile east of the 19th milestone. It covers an area of about 100 acres, and drains about 900 acres, wholly mountainous. The ordinary surface can be lowered several feet without uncovering much land, and the dam can also be raised 4 or 5 feet, and would flow 25 to 30 acres more.

"II. THE WANAQUE RIVER.

"1. *Mud pond* lies one and half miles north of Bloomingdale, and has its outlet in a small stream which crosses the New York and Greenwood Lake Railroad, near the first public road north of Pompton Junction. Its area is 50 acres and drains 1,600 acres, chiefly mountainous. It is surrounded by a cranberry bog and other low lands, which would be covered to the extent of 70 acres by raising the present surface 10 feet. The outlet has been lowered 4 feet through the rock. A dam 6 feet high would be 800 feet long. The present outlet runs through the marsh for 300 feet and then falls rapidly, and could be lowered without great expense.

"2. *Tice's pond* is a natural lake one mile east of Boardville. Its water surface is 40 acres, but before the outlet was lowered 5 feet for a distance of several hundred feet, the area was nearly or quite 100 acres. An area of 125 acres would be covered by raising the original surface 3 to 5 feet. The dam required would be 400 feet long. The drainage area is about 800 acres. Mountainous.

"3. *Shepherd's pond* has had its natural surface drawn down 4 feet. It covers about 90 acres, and owing to its steep shores but little more land would be covered by raising it 10 feet. A dam of 150 feet would be sufficient. The pond lies wholly in New Jersey, near the New York line, about half a mile west of Negro pond, and drains 1,000 acres, chiefly of mountain forest land, but with a small area of rough clearing. The water is said to be of considerable depth.

"The outlets of Shepherd's and Tice's ponds unite near Boardville and enter the Ringwood river, along which, between Boardville and Wanaque, have been several large furnace and forge ponds, but whose dams have been more or less broken away.

"4. *Greenwood lake,* the head of Wanaque creek, which flows into Ringood river, has an area of a little more than 4 square miles, and has a water-shed of 32 square miles. It is used as storage for the Morris canal. The surface of the lake is 13 feet above its original level.

"III. THE PEQUANNOCK.

"1. *Macopin pond, or Echo lake* is situate two miles northeast of Newfoundland. Its area is 363 acres, and by raising the surface 5 feet an area of 412 acres can be obtained. The depth is 40 to 50 feet. The pond can now be drawn down 4 feet by means of a flume. The surface, also, can be raised 5 feet by a dam 250 feet long. A greater rise than 5 feet would flow a tract of several hundred acres, called the 'Pine Hammock,' lying at the head of the lake. The drainage of Macopin pond is 1,700 acres. An additional drainage of 1,500 acres can easily be procured, at little expense, by turning a stream to the east into the pond. The drainage is divided between mountain forests and rough farm land, about in the proportion of one to two.

"2. *Hank's pond*, two miles north of Newfoundland, covers about 80 acres. It is a natural lake and has been lowered 4 feet, and can be still more drawn down by cutting a channel 500 feet long. The surface can also be raised above its original height by a dam 300 feet long, thus affording large available storage capacity. By raising the dam 120 acres would be flowed. The drainage area is 4 square miles, wholly mountainous.

"3. *Cedar pond*, one and one-half miles northeast of Hank's pond, draining entirely from mountain slopes, has had a natural surface of 125 to 140 acres, but has been reduced to about 96 acres by lowering the outlet. Its vertical capacity is 7 feet, and drains an area of 800 acres.

"4. *Buck Mountain pond*, four miles north of Newfoundland, has an area of 75 acres, but can flow 120 acres by means of a dam 250 feet long, and can be used with 10 to 12 feet head. It drains two and one-half square miles of mountain slopes. The outlets of Hank's, Cedar and Buck Mountain ponds unite and form Cedar brook, which flows through Clinton, giving opportunities for artificial reservoirs on that stream.

"5. *Dunker pond* lies one and one-half miles north of Stockholm, and has a present surface of 25 acres. The outlet has been lowered through rock at considerable expense, thereby reclaiming a large tract of rich soil, similar in character to the Bog and Fly in Morris county. A dam 100 feet long and 10 feet high would make a lake two to two and one-half miles long and half a mile wide. The drainage area is about five square miles, principally rough and mountain lands.

"6. *Canistear pond* is an artificial pond three miles north of Dunker pond, and covers, when full, 70 acres. By raising the dam 600 feet long and 5 feet higher, 120 acres may be flowed, and 20 feet head may be obtained. Drainage area about 2,000 acres, one-third farming land and the remainder forest and mountain.

"7. *Pine Hammock*, at the head of Canistear brook, flows about 100 acres, and is an artificial pond used as storage for Canistear pond. Drainage area probably two to three square miles.

"8. *Timber Brook pond*, which lies two miles southwest of Charlotteburg, has an area of 72 acres and can draw down 5 feet. Raising 3 feet higher, thus giving 8 feet head, would flow 25 to 30 acres more. Raising the surface of the pond would make it necessary to lift several hundred feet of the track of the Green Pond Railroad, it being within 2 to 3 feet of the surface of the water. This pond has a drainage area of about 800 acres, one-half forest and one-half rough farm land.

"9. *Stickle's pond*, lying about two miles east of Timber Brook pond, has its outlet through Stone House brook into the Pequannock river, at Bloomingdale. Its area is 101 acres and can be drawn 10 feet. A dam 5 feet higher than the present dam, and 800 feet long, would flow but little more land. The drainage is about 1,800 acres, wholly in forest and mountain.

"IV. THE ROCKAWAY.

"1. *Split Rock pond*, five miles northwest of Boonton, has an area of 237 acres, and drains six and one-quarter square miles, almost wholly mountainous and forest. 20 feet available head can be obtained by raising the dam 2 feet, the length of the dam being 200 feet.

"2. *Durham pond*, near the head of Split Rock brook, and used as a storage for Split Rock pond, covers an area of about 65 acres and drains about 1,000 acres, one-half woods and one-half rough farming land. The present dam is 900 to 1,000 feet long, and, if raised, would flow 30 to 40 acres more. The pond could be drawn down 4 feet.

"3. *Green pond, or Green lake*, a noted resort four miles southwest of Newfoundland, contains 560 acres and drains two and one-half to three square miles. It has great depth, no inlets and a small outlet.

"4. *Denmark pond*, on Burnt Meadow brook, a tributary of Green pond outlet, drains two and one-half to three square miles, and has an area of about 175 acres. It receives its waters from forest and rough farm land.

"5. *Middle Forge pond*, on Green pond brook, receives the waters of Green pond and Denmark pond, and contains about 70 acres.

"6. *Dixon's Forge pond*, on a tributary of the Rockaway river, about two miles south of Split Rock pond, covers an area of 60 to 75 acres, and has a drainage area of one and one-half to two square miles, mostly rough land.

"7. *Shongum pond*, five miles northwest of Morristown, and at the head of Den brook, drains two and one-half to three square miles of rough land, and embraces an area of 125 acres. Increasing the height of the dam 5 feet, thus giving 10 feet head, would cover an area of 165 acres.

"In addition to the above ponds, which are already in existence, a large number of artificial reservoirs can doubtless be constructed, affording valuable additional storage, and utilizing the rain-fall over a wide extent of mountain lands. A few of these are herewith given:

"1. On the outlet of Mud Pond, one-quarter of a mile above the Montclair and Greenwood Lake Railway, a dam 250 feet long can be erected, which, if 15 feet high, would flow 100 to 125 acres, and would receive the drainage of four or five square miles.

"2. Along the Ringwood river, between Boardville and Wanaque, as before mentioned, are several forge and furnace sites, the dams of which have been broken away, but which, by being rebuilt, would afford very large storage facilities.

"3. One mile west of Hewitt Furnace, on a stream flowing easterly, a reservoir of 75 to 80 acres could be made by a dam 150 feet long and 15 feet high, and would drain about two square miles.

"4. About three miles due west of Boardville is a tract of land which has been drained, at some expense, but which it is said could be converted into a reservoir of 140 or 150 acres with little difficulty. A large drainage of several square miles finds its outlet through the locality.

"5. On the outlet to Stickle's pond, a dam 15 feet high and 350 feet long, at the old forge site below the pond, would flow 80 to 100 acres, chiefly meadow, and would drain $1\frac{1}{2}$ to 2 square miles, independent of the drainage of Stickle's pond.

"6. At Mount Pleasant, on Green Pond brook, a reservoir of 800 acres, and capable of drawing 10 to 12 feet, may be constructed by means of a dam, at a moderate expense, and afford storage for the drainage of 12 to 15 square miles of mountain lands.

"7. At Berkshire valley a dam could be built across the Rockaway, by which a reservoir could be made, covering 1,200 acres, 20 or 30 feet deep, and capable of storing the drainage of 30 square miles.

"Annexed is a table showing the capacity and supply of the ponds here described, and the approximate cost of making them available by dam or otherwise.

"TABLE.

NAME OF POND.	Drainage area in acres.	Area in acres.	Head, or working depth, in feet.	Storage capacity in gallons.	Minimum supply in gallons.	Approximate cost of dam, &c.
Franklin lake	1,000	91	5	161,000,000	327,000,000	$750
Rotten pond	1,200	100	10	294,000,000	392,000,000	1,500
Negro pond	900	100	9	294,000,000	294,000,000	2,000
Mud pond	1,600	120	15	441,000,000	523,000,000	6,200
Tice's pond	800	125	8	261,000,000	262,000,000	1,175
Shepherd's pond	1,000	90	10	294,000,000	327,000,000	1,150
Greenwood lake	20,480	2,560	13	10,040,000	....	....
Macopin pond	3,200	362	9	1,117,000,000	1,046,000,000	950
Hank's pond	2,500	120	11	431,000,000	817,000,000	1,310
Cedar pond	800	140	7	274,000,000	262,000,000	860
Buck Mountain pond	1,600	120	12	353,000 000	523,000,000	2 600
Dunker pond	3,200	800	10	1,960,000,000	1,046,000,000	1,400
Canistear pond	2,000	120	20	588,000,000	653,000,000	2,100
Timber Brook pond	800	100	8	196,000,000	262,000,000	3,000
Stickle's pond	1,800	101	15	392,000,000	589,000,000	2,700
Split Rock pond	4,000	237	20	1,307,000,000	1,308,000,000	1,800
Durham pond	1,200	110	10	327,000,000	392,000,000	4,000
Green pond	1,920	....	3	551,000,000	627,000,000	600
Denmark pond	1,800	300	8	462,000,000	589,000,000	1,000
Middle Forge pond	4,000	100	15	490,000,000	1,308,000,000	750
Dixon's pond	1,200	75	10	245,000,000	392,000,000	1,300
Shongum pond	1,800	165	10	473,000,000	589,000,000	1,200

"The following table shows the approximate capacity of the artificial reservoirs which have been referred to:

"TABLE.

LOCATION OF RESERVOIRS.	Drainage area in acres.	Area in acres.	Head, or working depth, in feet.	Storage capacity in gallons.	Minimum supply in gallons.	Approximate cost of dams, &c.
Outlet of Mud pond	3,000	125	10	290,000,000	981,000,000	$800
On Ringwood river	55,680	570	20	3,650.000,000	18,200,000 000	22,200
Near Hewitt Furnace	1,300	80	10	245,000,000	425 000,000	600
West of Boardville	1,000	150	10	320,000,000	327,000,000	1,000
Outlet of Stickle's pond	3,000	100	8	261,000,000	981,000,000	500
Mount Pleasant	8,320	800	10	1,831,000,000	2,718,000,000	25,000
Pompton Furnace	94,720	292	6	573,000,000	31,000,000,000	5,000

"Very large and capacious reservoirs can also be made in the valley of the Pequannock at Oak Hill, at Newfoundland, at Bloomingdale, and at some other points, altogether sufficient to store the whole of the freshet waters of that stream.

"A very large reservoir can also be made on the Ringwood at Wanaque, by raising the old Furnace dam; or still better, by erecting a dam where the stream crosses into the eastern valley, for which an estimate is put into the table.

"The Furnace pond on the Ramapo, at Pompton, now covers 275 acres, and averages probably as much as 20 feet in depth; can be raised 6 feet more, and thus be made to store the surplus water from 148 or more square miles on that stream.

"There are many other ponds known, and many other promising locations for storage reservoirs, in high and sequestered localities."

The quality of the water in the Passaic above Paterson is good. After it receives the sewage of that city, of Passaic and the smaller towns along its banks, and the filth, impurities and waste from the numerous manufacturing establishments in those places, it cannot but be polluted and rendered disgustingly undesirable for use. In addition to this, the whole of the sewage of Newark, a city of 136,500 inhabitants, is poured into the river, and some of it is carried by the flood-tide up the stream and directly in front of the pumping stations of Jersey City and Newark. Much uneasiness has been expressed in regard to the quality of the water supplied to these cities, and careful analyses of it have been made at various times.

Prof. Henry Wurtz analyzed it, and his report, which was made to the Jersey City Water Board, was published in March, 1873.

Prof. Albert R. Leeds also analyzed it, and his report, which was made to the Jersey City Water Board, was published in March, 1873.

In 1876, analyses were made in the Geological Survey Laboratory of the water taken at various places along the river from Newark up to the smaller branches, and these are given in the following table:

	SOURCES.	SOLID MATTER.			Chlorine.	Sulphuric Acid.	Lime.	Magnesia.	Date of Collection.
		Dried at 212° Fah.	Ash after burning	Volatile and Organic Matter.					
1	Jersey City pump works, high water	15 89	12 21	3.58	5.35	1.03	1.24	0 79	1876. Aug 31.
2	" " low water	6.52	4.52	2.00	0.58	0 48	1.24	0.54	Aug. 31.
3	" " hydrant	13.04	10.02	3 02	4.10	0.40	1.19	1.03	Aug. 25.
4	Newark pump works, high water	9.37	7.36	2 01	3.60	0.83	1.17	0 90	Aug. 31.
5	" " low water	5.85	4 35	1.50	0 25	0 46	1.17	0 51	Aug. 31.
6	" " hydrant	7.52	6.35	1.27	1.46	0.40	1.19	0 72	Aug. 25.
7	Passaic river, at D. L. & W. R. R. bridge, Lyndhurst	....	4.18	......	0.29	0.40	1.15	0.70	Aug. 31.
8	" above Two Bridges	4.52	3.34	1.18	0 16	0 20	0.98	0 72	July 20.
9	" at Hanover bridge	4.22	2 92	1.30	0.17	0 57	......	......	Aug. 16.
10	" above mouth of Rockaway	8 53	6 02	2 51	.....	0.28	1.22	0.69	July 20.
11	Rockaway river, below Dover	5 02	4.70	0 32	0.13	0 57	1.04	0 71	Aug 16.
12	" at Lower Longwood	3.76	....	......	0.09	0 11	0 75	0.54	Aug. 16.
13	Ramapo river, Pompton Furnace pond	2.63	2 05	0 58	0 10	0 23	0 65	0 42	Aug. 23.
14	Ringwood river, near Pompton	2.34	1 67	0.67	0.12	0 23	0 51	0.36	Aug. 23.
15	Pequannock river, near Pompton	3.51	2.68	0 83	0.12	0.23	0 65	0.48	Aug. 23.
16	Morris canal, head of Bloomfield plane	3 18	2.09	1.09	0 09	0 23	0 58	0.30	Aug. 25.

The interpretation of these results of analysis might be made at length, but it is sufficient to say, that from the amount of chlorine, which is the largest constituent of salt, in the waters from the Newark and Jersey City works it is conclusive that salt water from the ocean comes up with the tide and is mixed with the river water at the pumping station, or else there is an enormous amount of that substance from filth and waste animal matters poured into the stream at Newark. It will be seen that the amount is greater at high water than it is at low water, so that it must in considerable part come up the stream with the tide.

The unusually large amount of volatile and organic matter in the solid substance connected from these waters, together with the knowledge of the sources from whence it is derived, is also strongly against its character and desirability for domestic and household use.

In the table of analyses, the water from the Passaic above the mouth of the Rockaway, was taken because it was in a portion of the stream in which there was very little current, and where there were great numbers of pond lilies growing. There was no other source of impurity apparent, and yet the amount of organic matter was very large. But it was not harmful It is a good example of the necessity for knowing something of the history of water, and of the sources for pollution to which it has been exposed.

Besides the survey and report of the water-supply from the Passaic river, in the Geological Report for 1876, a very careful and detailed examination and survey of the Passaic as a source of water supply was made for the city of Newark by Messrs. Croes & Howell, civil engineers, in 1878-9.

A large number of samples of water from the Passaic at different places from Newark up the stream to Little Falls, were taken by Prof. A. R. Leeds, of the Stevens Institute, in the autumn of 1881, and were carefully analyzed. His report is published in the Annual Reports, for 1881, of the Newark and the Jersey City Water Works.

His conclusions are, that much of the filth received into the stream at Paterson is oxidized and rendered harmless by the oxygen of the air, as the water is flowing from that place to Newark, and that the pollution of the water used for the supply of Jersey City and Newark was derived mainly from the sewage of Newark, which was carried up the stream with the salt water at every flood tide, and carried directly in front of the pumping works of both cities.

During the present year a full and exhaustive report on "the determination of organic matter in potable water" has been published in successive numbers of the *Chemical News*. It was prepared by Prof. J. W. Mallet, of the University of Virginia, at the request of the National Board of Health. He examines the different methods of analysis which have been proposed and advocated by different chemists, demonstrates their merits and defects, and in his conclusion says: "(1) It is not possible to decide absolutely upon the wholesomeness or unwholesomeness of a drinking water by the mere use of any of the processes examined for the estimation of *organic matter*, or its constituents. (2) I would even go further, and say that, in judging the sanitary character of a water, not only must such processes be used in connection with the investigation of other evidence of a more general sort, as to the source and history of the water, but should even be deemed of secondary importance in weighing the reasons for accepting or rejecting a water not manifestly unfit for drinking on other grounds. (3) There are no sound grounds on which to establish such general standards of purity as have been proposed, looking to exact amounts of organic carbon or nitrogen, 'albuminoid ammonia,' oxygen of permanganate consumed, &c., as permissible or not. Distinctions drawn by the application of such standards are arbitrary, and may be misleading."

The difficulties in the way of reliable analyses of drinking water are owing to the very small quantities of the dangerous constituents. The amount of organic nitrogen in polluted and dangerous water may not be more than three parts in 10,000,000 of water, which is about one grain in a hogshead. That errors should be made in working upon such small quantities, is not to be wondered at. Neither is it surprising that many persons consider such results to be of doubtful value. The knowledge that matters certainly polluting, and possibly poisonous, have been in water, is some evidence that it is still dangerous.

The following waters have been analyzed in the laboratory of the survey. They may be taken as fair representatives of the water supplied by public water-works:

Sources.	Solid Matter. Dried at 212° Fah.	Ash after burning.	Volatile and Organic Matter.	Chlorine.	Sulphuric Acid.	Lime.	Magnesia.	Date of Collection.
1 Elizabeth, hydrant	7.86	6.02	1.84	0 33	0 63	1 68	0 54	....
2 Rahway, hydrant	10.20	9 02	1.18	0 25	1 86	2.82	0.72	....
3 New Brunswick, hydrant	1.61	0.84	0 77	0.08	0 23	0.22	0 16	....
4 Camden, hydrant	4.52	3.34	1.18	0 38	......	......	......	....
5 Mount Holly water works (1)	......	......	......	0 17	0 18	0 83	0 18	....
6 " " (2)	2.37	2 09	0 28	0.12	0.23	0 17	0 24	....
7 Hackettstown, hydrant	1.25	......	......	0 08	0.34	0.32	0.18	....
8 Delaware river, Lambertville	6.50	3.50	3.00	0.35	......	......	......	....
9 Alexsauken creek, near Lambertville	8.50	5 75	2.75	0 15	......	......	......	....
10 Morristown, hydrant	3.10	2 51	0 59	0 41	......	......	......	....

SPRINGS.

Springs of water have always been esteemed as the best sources of supply. The water from them is clear and sparkling, cool and agreeable to the taste, and usually wholesome. The water may be hard or soft, as is the case in different springs, but its clearness gives the idea of purity, and this satisfies those who are so fortunate as to get their supplies from them. There are springs of sufficient size to yield water enough for single dwellings in all parts of the State, and many of them are used for that purpose. There are a number of very large ones in the valleys in Sussex and Warren counties, the streams from some of which are large enough to run a mill.

The water supply of Morristown is entirely from springs. The new water-works of Dover are to be fed from springs also; and the water-works of New Brunswick and of Hackettstown also get part of their supplies from spring-water; and in all these cases the water is pure, soft, and free from albuminoid ammonia.

The temperature of good spring water is very nearly that of the mean annual temperature of the year, which varies from 48° in the northern part of the State to 53° in the southern.

It should be said, also, that since springs derive their water from the rain, they are liable, like wells, to grow impure as sources of pollution increase with the agricultural enrichment of the soil, the increase of population, and the establishment of manufactories throughout the country. And the purity, as well as the value of springs, is likely to diminish in the future, and they cannot usually be looked to for any large supplies of water.

OPEN WELLS.

Where springs or streams of water could not readily be resorted to for water, holes have been dug in wet ground, and the water allowed to settle into them from the surrounding earth. To keep the earth from tumbling in and filling up the hole, it has been usual to hold it back by old headless barrels, or other wooden supports, or when deeper by walls of brick or stone laid up without mortar. In this way the water nearest the surface would first run in and fill the well, and the supply would be taken from that which was most contaminated by impurities from the surface and surrounding earth. As the necessity for wells increased, they were dug in drier ground and to greater depths, in some cases a hundred feet or more, and they were still lined with brick or stone, laid without mortar. Such wells are to be found in the country everywhere, and many are still in use in towns and cities. But every year is diminishing their number, in the thick-settled districts. Cases of sickness and death are traced directly to the use of water from such wells, and they have to be given up. The water is clear and cool, and those who are accustomed to its use cannot but think it better than any other, until some sad experience teaches them its dangerous character.

Wells which are lined with brick or stone laid in cement mortar so as to keep out all water except that which enters at the bottom, are much safer. If they are sunk down several feet below the surface level of the water in the ground, the supply will be drawn from beneath, and not be near so likely to be contaminated by surface filth or impurities.

The following account of some of the primitive wells, such as were in use at that time on some of the sea-side sand beaches, was published in our annual report for 1875:

"Wells, as they call them, are made by sinking a barrel or hogshead, from which the heads have been taken out, into the sand to the depth of from two to six feet, and removing the sand from the inside of the cask. The water rises in the inside of the cask to within a foot or two of the top, and the well is complete. It needs no bucket or pump, and is usually without cover or curb, so that the water can be dipped out with a pail. Wells of this kind, situated so that water from the sloughs, or from the sea could not readily soak into them, were considered to be good enough when but few people lived on the beaches, but, as population increased, and waste matter, refuse and filth of every sort accumulated upon the surface, the products of their decay would naturally be carried into the sand with the rain, and so find their way into the wells. The necessary consequence of drinking water poisoned in this way was soon seen in the increased sickness and mortality among those who used it, especially in summer and autumn.

"Water from one of the best of these surface wells, on being analyzed, was found to contain 15.74 grains of solid matter in a gallon. It contained less of carbonates, and more of sulphates, and a trace of nitric acid. The water was slightly yellow, and the solid matter, when burned, gave off a strong, but not unpleasant odor."

The following descriptions of two large open wells of the best construction will give a correct idea of what may be done with open wells:

"At the State Prison, in Trenton, a large amount of water is needed, and a well was dug to help out their supply.

"The prison is located on flat ground, not far from the Delaware and south of the city. The surface of the ground is 45 feet above low water in the river. The material on the surface is a modified drift, consisting of bowlders, cobblestones, gravel, sand and loam mixed, but it was presumed that the granitic rock of the vicinity would be found at the depth of 30 or 40 feet. The well was dug of a clear inside diameter of 12 feet 8 inches, besides the brick lining, 9 inches thick, and the heavy plank curb outside the bricks.

"The materials passed through were—

(1) Gravel, &c.	33 feet.
(2) Yellow clay (decomposed gneiss)	5 "
(3) Blue clay (rotten gneiss)	7 "
(4) Partially rotten rock	7 "
(5) Solid gneiss rock.	

"Water was first met in the gravel at 21 feet down, in large quantity but somewhat hard. The quantity did not increase much until the clay was passed and the rock reached. There was then a considerable addition, apparently about as much as there was in the gravel, and the water quite soft.

"An analysis of the water from the gravel showed it to contain about 50 grains of solid matter to the gallon, most of which was sulphates of lime and magnesia, and only a trace of chlorine, and no organic matter.

"Analysis showed the water from the rock to contain less than two grains of solid matter, mostly carbonate of lime, to the gallon, and a very little carbonate of iron.

"Several holes, of two and three inches diameter, and from four to seven feet deep, were bored in the rock at the bottom of the well, and much of the rock water comes from these holes.

"The temperature of the water from the gravel on the 4th of October was 59° Fahrenheit, and that of the water taken directly from the rock was 56° Fahrenheit.

"To ascertain the quantity of water the well would supply, all the water was pumped out, and then the time of filling up of each foot was recorded.

1st was filled at beginning.	16th was filled in.........22 minutes.
2d was filled in......... 9 minutes.	17th " " .... 23 "
3d " " ....11 "	18th " " .... 23 "
4th " " ....15 "	19th " " ....29 "
5th " " ....17 "	20th " " .... 32 "
6th " " .... 18 "	21st " " .... 35 "
7th " " ....18 "	22d " " .... 43 "
8th " " ....17 "	23d " " ....48 "
9th " " ....20 "	24th " " ....58 "
10th " " ....20 "	25th " " ....76 "
11th " " ....20 "	26th " " ....104 "
12th " " .... 20 "	27th " " ....182 "
13th " " ....20 "	28th " " ....251 "
14th " " ....20 "	28¾ stopped rising.
15th " " .... 21 "	

"One foot in depth of water in the well is 943 gallons. Now if we take the time of filling this to be 20 minutes, which is the time required when about half the water is out, the well will supply 68,000 gallons in 24 hours, or if it is pumped down till the water is only two and a half feet deep, and kept at that, it will supply 135,000 gallons a day.

"It is probable that the amount from the gravel is all a well of this size can furnish; but it may be that a much larger quantity can be got from the rock, by sinking the well deeper into it. The rock is gneiss, stratified, not very solid, nor uniform in quality, but open and with the strata almost perpendicular, so that a deepening of the well, in rock which would need no lining, would expose a much greater surface of rock and length of seams from which water could escape.'

"There is a slight taste to the water which is unpleasant; it probably comes from the wood of the curb, as it is well known such wood used in water pails gives a disagreeable flavor to the water, and continues to do so for a long time; and in this well all the water from the gravel comes down behind the wood in contact with it."

There is a large open well at the Rio Grande sugar house, in Cape May county. It is dug on ground the surface of which is 10 or 15 feet above tide level. And it is sunk through the sand, gravel and clay there to the depth of 32 feet. It is lined with 4 wooden curbs, each 8 feet long, and inside this with a brick wall 9 inches thick. The wall is laid in good cement mortar. The well is 18½ feet in diameter in the clear, and the water rises to within 9 feet of the surface. The well yielded about 200 gallons a minute for 20 hours a day during the 10 weeks the mill was running. This was 240,000 gallons. There was not less than 8 feet of water in the well at any time while the works were in operation.

While digging the well they had a pulsometer which was rated at 400 gallons a minute, in operation, but it would not keep the well free when near the bottom, and they were obliged to get one which was much larger. They secured one rated at 1,100 gallons a minute, and with this they had no difficulty in keeping the well free of water quite to the bottom. When first dug the well filled about 6 feet in an hour, but some time afterwards it seemed to rise more rapidly.

The water was clear, soft, and of good quality for all purposes.

There are large open wells at Long Branch, Princeton, Cape May City, and other places in the State, which are used to supply water to towns. Notices of these are to be found under the respective heads in the section on water supply of cities and towns.

DRIVEN WELLS.

Driven wells are such as are made by driving an iron tube into the earth until it meets a water-bearing stratum of sand or gravel, and then attaching a pump to the open end of the tube. Water is readily raised in such wells where the sand or gravel is sufficiently coarse and open so as to allow the water to move freely to the lower end of the tube. They have the advantage over open wells, in that they do not draw from the top of the underground stores of water, and so from that which is most likely to have the surface impurities in it; but they draw from beneath this surface, and in that way they get water less liable to pollution, and usually a little harder than that in open wells.

These wells can be used wherever the geological structure of the surface materials will allow. They cannot be driven in rock, or in earth filled with bowlders, but they can be driven wherever there are deep beds of sand and gravel; they can be put down within a few hours, and they supply water that is usually much superior to that in open wells. A large number of these wells are in use in Plainfield, Union county, in a bed of sand which underlies the town. The ordinary open wells there have the water standing in them with its surface from 15 to 18 feet below the surface of the ground. The driven wells are put down from 30 to 40 feet, so that they draw the water from 15 to 22 feet below the surface of the underground store of water, and they are reported to furnish a satisfactory supply of good water. O. B. Leonard, Esq., of Plainfield, has been very efficient in furnishing information in regard to the water supply of that place, and from him we obtained average samples of the water from the driven wells and the bored wells of that city.

The water from the driven well of Mason W. Taylor, which is 40 feet deep, contains

Solid matter, per gallon, in grains	8.864
Chlorine	.846
Hardness, calcium carbonate	4 024
Free ammonia, parts per million,	.027
Albuminoid ammonia	None.

This is a good and wholesome water.

Driven wells were also tried by the Newark Aqueduct Board, near their pumping station above Belleville, in the alluvial sand and gravel on the west bank of the Passaic. A large number of them, about 40, were driven to depths varying from 40 to 48 feet, and they yielded to steady pumping nearly 100,000 gallons each per 24 hours. The tubes reached between 30 and 40 feet below tide level, and the water in them rose and fell with the rise and fall of the tide, though not to the same extent.

The water was probably Passaic river water that had filtered through the sand and gravel. It was clear and much more satisfactory to the eye than the unfiltered river water, and was no doubt much safer for domestic use. A very large amount of water could be obtained there by such wells, when driven down so far below the tide level.

Driven wells have also been extensively used at Asbury Park, and other towns along the sea-shore, and generally, but not always, with success.

In many other places they have also been found to furnish a ready means of getting a supply of water.

ARTESIAN, OR BORED WELLS.

At various places in the State a number of deep wells have been bored, with the hope of reaching water which would rise to the surface and flow over, forming true artesian wells. Very few have been successful in that respect, but a large number have been bored in which the water has risen nearly to the surface, and which have yielded a very satisfactory supply. Public attention is strongly and favorably drawn to them; and the following classified account of them is here given:

Beginning at the northeast and north, the only wells in the gneissic and other crystalline rocks, are in Jersey City.

"At Mattheissen & Wiecher's sugar refinery, on the south side of the Morris canal in Jersey City, a boring was begun in 1867, which was discontinued in 1872, at a total depth of 1,000 feet; inclusive of 20 feet of surface earth, the diameter of which, in the upper 180 feet of the rock, was eight inches, and in the lower 800 feet, four inches. The rocks penetrated are chiefly gneiss and quartz with white sandstone and thin bands of slate, occurring below 800 feet. Several veins of water were met with between 600 and 900 feet, of which the most important were at a depth of 720 feet. The yield was found to be 50 gallons per minute, when tested by pumping. The level in the well being 12 feet below tide, and the temperature of the water 52° Fah.

The brackish quality of the water obtained has prevented its use and the well is closed."

A well bored at the Central Stock Yards, and some 500 feet back from the shore line of the Hudson, passed through 70 feet of mud and earth full of bowlders; then through red sand rock to a depth of 215 feet, where a mica rock (gneiss) was struck. The boring was continued to a depth of 455 feet. The water which was obtained was brackish. The well is tubed with an 8-inch pipe down to the rock, and from that down the bore is 6½ inches.

"In the marsh, and near the south end of Grand street, in Hoboken, a boring was made in 1828, which is mentioned in Mather's "*Geology of New York*," as 400 feet in depth, reaching rock at 40 feet, and has penetrated serpentine, sandstone, and supposed white marble. This boring, probably, did not come upon water, and the work was abandoned. Mr. Theodore Van Tassell recollects to have seen the boring apparatus remaining in position some years later."

The attempts to get water by boring wells in the red sandstone have been more numerous, and have met with success in obtaining sufficient quantities of water, although in most cases of inferior quality. In Jersey City the borings have been made on the flat and also on the hill.

"A boring of small diameter was made about 1842 by Mr. Andrew Clerke, in the marsh at the corner of Montgomery and Henderson streets, in Jersey City. Here, the red sandstone was met with 15 feet below the surface, and was penetrated to a depth of 200 feet, when a stratum of very hard rock of whitish appearance was encountered, and the work abandoned. A liberal supply of clear, bright water, but strongly impregnated with magnesia and common salt, was found at the depth of 150 feet, which overflowed at the surface. The temperature was not noted.

"In the same marsh, and about 1,000 feet northeast of the last, an unsuccessful boring was made a few years later, respecting which details have not been obtained.

"At Cox's brewery, on Grove street, between Seventh and Eighth streets, in Jersey City, the underlying sandstone is covered by about 70 feet of bowlder clay and earth. A small boring of 100 feet in depth, was first made nearly thirty years ago, and was enlarged to 5 inches in diameter and carried down to a depth of 400 feet in 1872 and 1873. Small veins of water were met with in the rock at all depths. The water, though so hard as to form a heavy scale in a steam boiler, was of satisfactory quality for brewing purposes. Its temperature was 54° Fah. The well easily afforded 300 barrels of water per day, the water rising in the excavated well to the level of the tide, thence passing away through the earth to the street sewers. The boring intersected a number of seams in the sandstone, which contained fine earthy matter, and limited the capacity of the well to deliver clear water.

"At Limbeck & Betz's brewery, on Ninth, between Grove and Henderson streets, in Jersey City, and 800 feet northeast of Cox's brewery, the sandstone is covered by 40 feet of bowlder clay, with 30 feet of surface sand. A boring 8 inches in diameter was made here in 1875, penetrating the red sandstone rock 776½ feet to reach water, which was found at the bottom in a stratum of white or light-colored stone. At its completion, the well, when tested by pumping, yielded 33 gallons per minute continuously for 24 hours. The water is sufficiently soft and sweet for brewing, but it is ordinarily used only for cooling purposes, its temperature being 52½° Fah. The well affords 1,000 barrels of water per day without difficulty, the level of the well being 10 feet below tide, or 25 feet below the surface of the ground.

"Borings made to rock at the Pavonia ferry, distant, viz., 2,300 feet, 2,850 feet, and 3,300 feet nearly east from the last, came upon serpentine at 63 feet, 120 feet, and 179 feet below tide, respectively.

"At the Palisade brewery, at the summit of the main ridge of Bergen hill, and corner of Hudson avenue and Weehawken street, in the Town of Union, a boring 7 inches in diameter was carried down in 1877 and 1878, through trap, to a depth of 297 feet from the surface, water being found in quantity, increasing with the progress of the work. The well is pumped from the bottom, and yields 250 barrels per day of very pure, soft water, of a temperature of 51° Fah. When not pumped it discharges a much smaller quantity, at a level of 161 feet above tide, into the bottom of an excavated well, 28 feet under ground and 12 feet below the surface of the rock.

"In the marshes west of the Hackensack river are a number of wells which have been bored through alluvium and bowlder clay. Four of them, which were sunk in 1871, derive their supply from a sheet of water-bearing gravel, at a depth of nearly 200 feet, the water rising to the surface and flowing off in moderate quantity. The water, while it is palatable, has a noticeable taste, said to be of sulphur. The wells now mentioned are upon the line of the Newark plank road; an equal number of wells are to be found on the line of the old Newark turnpike; these are now disused and their origin and depth are unknown.

"At *Hackensack* there are several bored wells now in operation. T. T. Crane, Esq., of that place, has courteously contributed the information in relation to them. He says there were put down some 5 to 7 years ago, wells for Wm. De Wolfe, Garret Ackerson, Jacob Hopper and Huyler & Rutan.

"The well of Huyler & Rutan is located on their dock, about 75 feet from the water front, and is 105½ feet deep. It went through 10 to 12 feet of meadow mud; then through blue clay and thin seams of red clay to a depth of 104 feet. At the depth of 104 feet red shale 6 inches thick was struck. When the drill passed through this layer it dropped suddenly 6 inches, and then struck a second layer of shale 7 inches thick. After passing through the latter, water commenced to flow, and has flowed ever since, except when the tide in the Hackensack is out (low water) the flow ceases altogether. And when the tide is up it commences again. The river bed is 15 to 20 feet deep.

"Mr. R. P. Terhune on the opposite side of the river, and some 650 feet or more from Huyler & Rutan's, has bored down 135 feet without getting a flow of water as yet."

At the Secaucus iron works a well was bored to the depth of 600 feet. The strata passed through, as reported by I. P. Pardee, Superintendent, were—

From the surface to shale rock	18 feet.
Red shale to	370 "
Shaly sandstone to	395 "
Red shaly sandstone from	400 to 600 "

The quantity of water was largest between 200 and 250 feet down. The water yielded on evaporation 68.64 grains of solid matter to the gallon. It probably gets a little salt water in it from the Hackensack river, near which it is bored. The diameter of the bore is 6 inches. It yields a steady supply of 8 gallons per minute.

In Newark the large consumption of water by the extensive manufacturing establishments of the city, has stimulated the search for cheap and abundant supplies in the underlying red sandstone strata, and several wells have been put down which are successful in affording the needed quantities. We reprint, from the annual report of 1879, some notes of these wells:

"The well of Messrs. E. Balbach & Son's smelting and refining establishment, in Newark, is located near the Morris canal, and only a few feet above tide-level. It is 500 feet deep, of which about 100 feet were in sand and gravel, and the rest in red sandstone rock. It is tubed down to the rock, is 8 inches in diameter, and the water rises in it to a little above tide-level. The water is very clear, a little hard, and has a temperature of 55¼°. It yields 500 gallons a minute, and when pumped at that rate the water surface in the well is lowered 6 or 8 feet. The ground around the well is dug away so as to allow the pump to be set within about 2 feet of the surface of the water.

"The water is used for all purposes about the establishment, but is specially valued for its low temperature and its usefulness in cooling the heating furnaces.

"The well of Messrs. P. Ballantine & Sons is at their brewery, on Freeman street, Newark, and not far from the well just mentioned, though the ground is perhaps 10 feet higher. It is an 8-inch bore, and is tubed through 90 feet of earth and 10 feet into the rock; the remaining 350 feet is without tube, being all in red sandstone. The water rises to within 24 feet of the surface. It has been tried for water, but is not yet in regular use. The quality of the water is good, being clear and cool. With the pump considerably above the surface of the water, it has yielded 200 gallons a minute, and is expected to yield more than twice that when the pump is properly set near the surface of the water.

"The well of the celluloid works, in Newark, is 250 feet deep, and yields a satisfactory quantity of water. This water was analyzed by Messrs. Ballantine, and found to contain in a gallon—

Chloride of sodium (common salt)	0.6	grains.
Sulphate of soda (Glauber salts)	11.7	"
Sulphate of lime (gypsum)	85.1	"
Sulphate of magnesia (Epsom salts)	18.7	"
Carbonate of magnesia	6.1	"
Silicic acid	2.0	"
Grains of solid matter	124.2	

"Messrs. Lister Brothers have recently bored a deep well at their works, on the banks of the Passaic, in Newark. It is 8 inches in diameter and 615 feet in depth. It was sunk 110 feet in earth and 505 feet in rock. The surface is but a few feet above tide, and the water rises to within 2 feet of the surface. It is in constant use, and is yielding at the rate of 800,000 gallons a day. The water is clear and cold, its temperature being 55½°. An analysis of the water shows it to contain 152.34 grains of solid matter to the gallon. The mineral matter in it is composed of the following substances:

"ANALYSIS.

Sulphate of soda	15.94	grains.
Sulphate of magnesia	23.87	"
Sulphate of lime	108.98	"
Carbonate of magnesia	1.55	"
Chloride of sodium (salt)	2.47	"
	152.81	"

"A second analysis of the water from this well, after about six weeks' pumping, shows 145 grains of solid matter and 88.1 grains of sulphuric acid in a gallon, instead of 152.8 grains of solid matter and 89.1 grains of sulphuric acid in the first analysis."

This water was again analyzed at the end of 1882, when it was found to contain 151.79 grains of solid matter to the gallon. After three years' steady pumping it has not changed in quality.

"Sulphate of lime makes a hard scale in steam boilers, and the large amount of it in this water shows it to be unfit for use in steam boilers, or in any apparatus liable to be affected by an accumulation of scale or sediment. Such water is too hard for laundry purposes, and not to be recommended for drinking or household use. In these large manufacturing establishments it is, however, of great value on account of its being always clear and cold, so that it can be used for condensing or cooling hot substances, and for the ordinary washing and rinsing operations where neither heat nor soap is needed. The amount of sulphate of lime in the water from all these deep-bored wells which are in the red sandstone is too much to make it desirable for steam boilers. The amount appears to be greatest in that from the deepest wells.

"The deepest boring in the State is the well of the Passaic Rolling Mill Co., at Paterson. Its depth is 2,100 feet; and, excepting six feet of earth at the top, was all in shale and sandstone to a depth of 1,120 feet, where a layer of quicksand was met which caused much trouble. There was some water found in the well at various depths down to the quicksand. It rose in the bore to within seventeen feet of the surface. Of this water in the well no examination was made at that time, but when the boring was down about 1,700 feet some of it was drawn up and tested. It was found to contain 340 grains of solid matter to the gallon, and most of this was sulphate of lime, so that it was quite unfit for drinking or for making steam. From the trials since made it is presumed that the water examined came from the layer of quicksand, which is 1,120 feet down.

"No attempt was made to pump the water from it at that time, as it was hoped to find a supply that would rise above the surface and make a flowing well.

"In order to shut off the quicksand the well was tubed down to 1,120 feet. This effectually shut it out, and the water also, and the rock was found to be entirely without water from that down to 2,050 feet. From 2,020 to 2,050 feet the red rock was more granular and worked up into sand by the action of the boring tools. Water that was strongly saline was met at 2,050 feet, and the usual red shale and red sandstone continued on 50 feet further, at which depth the boring was stopped. The salt water rose in the well to within 30 feet of the surface. No attempt was made to learn how much the well would yield by pumping.

"The analysis of this salt water was as follows, per gallon: Of

Chloride of sodium	408 46	grains.
Chloride of potassium	5 54	"
Chloride of calcium	278.32	"
Chloride of magnesium	109.44	"
Sulphate of lime	120.70	"
Chlorides of iron, alumina, &c.	7 00	"
Traces of bromine and iodine	....	
Total weight of solid matter per gallon	929.46	"

"This is not more than one-half as salt as sea water, and the chlorides of potassium, calcium and magnesium are in much larger quantity than they are in the water of the ocean.

"The well was begun with an eight-inch bore, and was cased with a six-inch tube down to 1,120 feet, and the bore from that down to 2,100 feet was four and one-half inches.

"At this depth the attempt to bore through the red sandstone was abandoned, the water being altogether unfit for ordinary use, and the character and amount of the saline impurities giving little hope of success by going deeper. The question as to the thickness of the red sandstone has not been settled, though it is shown to be more than 2,100 feet thick at Paterson. And the questions suggested by finding the salt water must also remain unanswered for the present, though the fact that the rock salt of England, and of some of the other salt mines in Europe is found in rocks of the same age as this, raises the question whether it may not also be found here.

"About the end of December the tubing was drawn out of the well and the bore was stopped by a seed-bag below 900 feet. The water now rises to within seventeen feet of the top. By putting down a pump forty feet into the well it has been made to yield 100 gallons of water a minute for five hours, without lowering the surface materially. This water has been analyzed, and found to be slightly alkaline, agreeable to the taste, and to contain 13.54 grains of mineral matter to the gallon, and this mostly carbonates of lime and magnesia.

"The analysis showed in a gallon (or 58,318 grains):

2.15 grains of magnesia,
3 71 grains of lime,
1.15 grains of soda, with very little potash,
1.08 grains of chlorine,
.55 grains of sulphuric acid,
Not weighed, carbonic acid.

"It may be assumed that these constituents are combined and exist in the water as:

4.51	grains of carbonate of magnesia,
5.95	grains of carbonate of lime,
1.78	grains of common salt,
.37	grains of carbonate of soda,
.93	grains of sulphate of lime.
13.54	

"These constituents are not such as to make the water unwholesome for drinking or for household uses, and they will probably deposit in boilers as a sandy or muddy sediment, and the water can be used for supplying steam-boilers without danger or inconvenience."

A second well has been bored 900 feet deep near this one to serve as a supply in case of any accident or interruption in pumping from the first one. A letter from Watts Cooke, Esq., of December 11th, 1882, says: "The wells are in constant use. We get a discharge of about 250 gallons per minute, which is more than we require. We think that for drinking it is the best water in this section. We have used it in our boilers for over a year and find no trouble. In fact, it leaves less sediment than the Passaic river water. What it does leave is, as you stated, a muddy deposit."

Analysis of water from well of the Burton Brewing Company, Paterson:

Sodium chloride, per gallon	2.33	grains.
Potassium sulphate, per gallon	0.29	"
Calcium sulphate, per gallon	1.11	"
Calcium carbonate, per gallon	4.66	"
Calcium chloride, per gallon	0.47	"
Magnesium carbonate, per gallon	1.17	"
Alumina, per gallon	0.58	"
Oxide of iron, per gallon	trace.	
Silica, per gallon	0.93	"
	11.54	"

In a second sample the total solids per gallon amounted to 17.1 grains. Hardness equivalent to calcium carbonate, 6.1 grains.

The well of the Burton Brewing Company, in Paterson, is 200 feet deep and five-inch bore. The depth to rock is 18 feet. Then the boring passes 18 feet through a red, soft sandstone. The remaining depth is through a conglomeratic sandstone (said to be "a kind of Scotch granite").

The water contains about 12 grains of solid matter per gallon. We have no definite information as to the amount of water which the well supplies.

In *Plainfield* and vicinity, Mr. O. B. Leonard reports 20 bored wells "located from Scotch Plains to Dunellen and Bound Brook. They have always given a satisfactory supply. My inquiry has not given me information of any flowing wells. As far as I can ascertain, the water in the different tubes does not rise above the general average level of the underground supply in the sand and gravel." These wells penetrate the shale from 10 to 59 feet. The supply is satisfactory in quantity and, like that of the overlying sand and gravel, of excellent quality. Two samples were analyzed. One from the well of L. V. F. Randolph, 21 feet in the shale, was found to contain:

Total solids, per gallon	5.950	grains.
Chlorine	0.612	"
Hardness (grains of calcium carbonate)	2.974	"
Free ammonia, parts per 1,000,000	0.040	"
Albuminoid ammonia, parts per 1,000,000	none.	

The second sample came from the well of John B. Brown, also in Plainfield, and 59 feet in the shale. It contains:

Total solids, per gallon	5.365	grains.
Chlorine	0.525	"
Hardness (grains of calcium carbonate)	2 859	"
Free ammonia, parts per 1,000,000	0.027	"
Albuminoid ammonia, parts per 1,000,000	none.	

At *New Brunswick* a number of wells were bored, 30 to 60 years since; those on grounds not much above tide level are flowing wells, while in those on higher ground the water does not rise to the surface.

"One bored in the old paper mill at Raritan Landing, 303 feet deep, and on ground some 12 or 15 feet above tide, delivered 40,000 gallons a day, some 10 feet or more above the surface. It still continues to flow; the bore was not more than 4 inches in diameter. The water was clear and answered for paper-making, though it was very hard. Sulphate of lime was the chief mineral constituent. Two other flowing wells—one at the residence of Richard Johnson, Esq., the other in a field formerly belonging to Dr. H. Pool, and near Mile Run—which were bored many years ago, are still to be seen. They were probably not so deep as the later wells, and the quantity of water they supply is not large.

"The well bored by the late David Bishop, Esq., at his residence in New Brunswick, is 455 feet deep, all in red shale. It is on a hill 90 feet above tide and the water rises to within 10 feet of the surface. The water is clear but so charged with sulphate of lime as to be unfit for use. The quantity of water to be obtained from the well is inconsiderable.

"Some other wells have been bored in the rock about New Brunswick for the supply of private dwellings. They are at depths of from 30 to 60 feet, and for the moderate quantity of water needed in a household have mostly been satisfactory. In some instances, however, they have failed to yield a supply."

At *Perth Amboy* a well was sunk at the terminus of the Easton and Amboy Railroad to a depth of 130 feet, through successive beds of sand and clay. An account of the strata passed through is given in the Report on Clays, p. 183. But no water was obtained from the bored portion of the well. There was an abundant flow in the coarse gravel, about 20 feet down, in the excavated portion of the well.

Jamesburg.—A well was bored at the Reform School, near this place, in 1879 and 1880. Its bore at the top and down to near 300 feet was eight inches in diameter. From that depth to 481 feet it was six inches. The strata passed through were clays and sands of Cretaceous age. A list of them was given in the last annual report. On account of the failure to get a flowing well it was abandoned, although about 110 feet down water-bearing sands were encountered, and found to be 23 feet thick. The water is soft, but contains a small quantity of iron and is chalybeate. It is not used, as a full supply of spring water collected on the premises is preferred for laundry purposes and also for drinking.

At *Columbus*, Burlington county, a well on the Rancocas Stock Farm of P. Lorillard, is 356 feet deep. It affords a fair supply of good water; rises to within 45 feet of the surface of the ground. The materials passed through were irregularly alternating beds of sandy clay and sand of Cretaceous age. An artesian well 156 feet deep, on the same farm, flows at the rate of ten gallons per minute. The water is slightly tinctured with sulphate of iron.

"A well at the residence of Charles S. Taylor, Esq., near Burlington, was sunk 200 feet, most of the distance in the dark clays of the lower part of the marl formation and the upper part of the clays. It ended in light-colored clay, but no good supply of water was met. The tube was 8 inches in diameter.

"At the residence of Dr. Van Buren, at Shrewsbury, Monmouth county, a well was bored through several strata of the marl formation to the depth of 200 feet, but water was not found.

"In the Great swamp, Passaic township, Morris county, Dr. Van Wagenen had a 2½-inch tube sunk at his farm-house near Myersville, to the depth of 64 feet. It is in clay with very little sand, and enters the red sandstone rock 8 feet. It is a flowing well, and yields a sufficient supply of water for his farm stock.

"The late Hon. F. S. Lathrop, on his farm in the Great swamp, near Madison, sunk a 2½-inch pipe through strata of sandy clay, sand and fine sediment, to the depth of 165 feet. No water was found, and the rock was not reached. The material appears to be too close for water to filter through it. The basin in which it is located is surrounded by a rocky rim, which in its lowest part is not 10 feet below the surface at the well, and there is no outlet for water below that level. If the material were sufficiently open for water to run through, it should rise in the tube up to very near the surface.

"*An artesian well was bored at Winslow for the late Hon. A. K. Hay*, thirty years ago, for water-supply for a steam engine at the Winslow Glass Works. The elevation of the surface is about 115 feet above mean tide. The well was bored 335 feet, which carries it 220 feet below the level of the sea. The following strata were passed through:

Surface earth	5	feet.
Blue and black clay	15	"
Glass sand, described as quicksand	95	"
Miocene clay, described as hard, black clay	35	"
Micaceous sand, described as quicksand	107	"
Brown clay, described as black, hard clay	43	"
A gum log, one foot in diameter, found here.		
Greensand marl and white shells, teeth, &c	20	"
Pure greensand—no fossils	15	"
	335	

"Water rose from the bottom of the greensand.

The geological relations of these beds are described on pp. 291 and 292 of the "*Geology of New Jersey*."

"The analysis of the water of this well, as made for the report in 1868, is here given.

1000 parts of water gave:

Silica	.0140
Chlorine	.0002
Sulphuric acid	.0027
Carbonic acid	.0520
Peroxide of iron	.0030
Lime	.0202
Magnesia	.0079
Potash	.0100
Soda	.0554
Solid matter in 1,000 parts of water	.1654

"This well-water has much excess of carbonic acid, keeping in solution the alkaline earths as bicarbonates.

"The well was bored 343 feet deep to get a supply of water which would not corrode a steam boiler. The experiment was entirely successful. Sufficient water was obtained, and the boiler has not corroded since.

"The sediment deposited is a soft and sandy one, and without any tendency to incrust, and the water in the boiler finally becomes very strongly alkaline from the abundance of carbonates of potash and soda accumulated in it.

Well at Harrisville, Burlington county.—This was a well intended to supply pure water for the paper mill there. Mr. R. C. Harris says: "In 1866, I had an artesian well sunk at Harrisville, to obtain a supply of pure water, free from iron, from which ingredient we had a great deal of trouble, causing our wrought-iron boiler to rust out rapidly. The well was sunk to the depth of 306 feet, and lined with six-inch tubing. Gravel, blue and gray clay were passed through, until a depth of 180 feet was reached; mud, sand, and what appeared to be decayed wood, were also encountered. Further on, a gravelly bed was found, and water suddenly spouted up, reaching the top of the tubing, eight feet above the ground. Water continued to flow quite freely, and it seemed to be pure and free from iron. The party doing the work, thinking to do better, persuaded me to let him go on; and, after a great deal of labor, he reached the above depth of 306 feet. The result was, no water of any volume; and that which overflowed was impregnated with iron very strongly, which was the very thing I wished to avoid. At this I concluded to abandon the project, and declined to bore any further."

"At *Atlantic City*, a well was bored in 1858 by the late Manasseh McClees, 185 feet deep, at Cottage Retreat, near the lighthouse and between Atlantic and Pacific avenues. The ground was about six feet above the high-water mark. The materials passed through were:

Beach sand	50 feet.
Blue clay, like marsh mud	5 "
Beach sand	30 "
Very tough blue clay and salt water	5 "
Sand, more or less coarse; water salt	90 "
Clay, yellow and blue, in streaks; water salt	5 "
Beach sand and salt water	

"The boring was lined with an iron tube eight and a half inches in diameter. The whole cost of this well was $1,000.

"In 1874, the Atlantic City Gas and Water Company sunk two artesian wells on the middle of the beach, at the south end of the city, and in ground eight feet above high-water. One of these, ninety feet deep, passed through:

Beach sand	60 feet.
Mud and sand	15 "
Beach gravel, and fresh water	15 "

"The materials passed through in the second well were:

Beach sand	56 feet.
Beach mud and sand	5 "
Beach sand, gravel and fresh water	57 "
Total depth	118 "

"These wells were tubed with 12-inch pipe, and the water rose in them to within 10 feet of the surface. A steam pump was applied and water drawn steadily for 24 hours without lowering it more than three feet in the tube. A gallon of the artesian well-water left, on evaporation, 24.20 grains of solid matter. This was mostly in the form of mineral carbonates. No nitrates or ammonia were found in it. The water was clear and without smell when examined, though persons present when the pumping was going on, say that it then had a disagreeable smell, which was perceptible at a distance of 60 feet.

"Water from the well of J. Adams, which is one of the best surface wells in the city, on being analyzed, was found to contain 15.74 grains of solid matter in a gallon. It contained less of carbonates and more of sulphates, and a trace of nitric acid. The water was slightly yellow, and the solid matter when burned, gave off a strong but not unpleasant odor.

"The rain water was, of course, unexceptionable.

"The water from the surface wells there is contaminated with organic matter, and it is unsafe to use it. That from the artesian wells is palatable and contains no poisonous organic matter. I think there would be risk in depending upon it for a full supply; for it is apparent from the three borings that the material of the beach is the same from the surface to the bottom of the tubes, and if the wells are drawn hard the water from the sea is likely to be drawn in and spoil them, as it evidently did in the McClees well."

Of the *Cape May* bored wells, R. B. Swain, C.E., furnished the following notes for the report of 1879:

"There have been seven 8-inch artesian wells made, at depths varying from 87 to 92 feet, according to the elevation of the land at the point where the well may be made, within a period of about 24 years; developing a stratum bearing fine fresh water, yielding about 75 gallons per minute. Two of said wells, however, were spoiled by the ignorance, carelessness, or cupidity of the party who had the contract for making them, by driving them too far, or below the water-bearing stratum.

"The drive wells are 1¼-inch tubes driven from 25 to 30 feet, as may be required from the variable surface of the ground. They will yield from 7 to 10 gallons per minute.

"Water, in all deep wells, will rise to the point at which water will stand in an open or surface well.

"If a tube is driven to either the 2d or 3d stratum and opened, in a surface well, at any point below the point at which water will naturally stand, the water will continuously flow into the surface well, with a force in proportion to the distance at which the opening in the tube may be made below the surface of the water in the open well.

"This town is supplied from one artesian well of 8-inch diameter, settled 84 feet to contact with a cedar log 3 feet in diameter. The 8-inch pipe coming in direct contact with the log, it was necessary to drill inside of the pipe, which curtailed the hole through the log to 6 inches, making the well 87 feet deep. Also from one surface well 20 feet diameter and 19 feet and 4 inches deep, with three sub-wells in the bottom of it, each 3 feet diameter and 6 feet deep. From which sources of supply are distributed, during the summer, about 120,000 gallons daily.

"That you may more thoroughly understand the geological formation, I send you, per express, my specimens, or what is left of them, taken from the *first* well made at the Columbia House (excepting the two bottles marked 2d well.) Also a specimen from the drilling of the log under the well at the city water works. Use whatever portion of specimens may suit you. You will find specimens from the surface to 224 feet depth. The exploration to this depth is due to the man employed to sink the well. I had the work suspended at the proper point, and a better well I never saw; but in my absence he drove it through the stratum, expecting to meet other strata; and, as it could not be remedied, the owner of the property concluded to make an experiment of it to the depth indicated, where he struck salt water."

The sand beaches along the sea-shore possess very valuable and attractive features for visitors in search of change of air, health or recreation. They are deficient in supplies of good water. There have been no deep borings yet made to ascertain the practicability of getting good water from deep wells, but the geological structure of the country is such as to encourage efforts to obtain a full supply of pure and wholesome water in that way. And on the geological map which accompanies this report, we have drawn a section to show the position and inclination of the strata which have their outcrop in a belt of country crossing the State from near Long Branch to Salem. These strata all dip towards the southeast, with a descent of not more than 20 feet to the mile, and probably less; and it is fair to presume that they continue on out, in somewhat the same way, beneath the ocean. And if so, these successive strata can be met by boring down on the beaches to the proper depths. Some of these strata are close and compact, so that water will not filter from the surface down through them, while others are made up of sand, more or less fine, but open, so that water passes along them freely. As these strata come to the surface at a long distance from the ocean, and yet where the rain can fall upon and follow down the open sandy ones, they are likely to be full of clean, fresh water, and if they were penetrated by boring tools and tubes, water would rise from them near, to and possibly above the surface, at the sea-shore.

Wells in the same geological formation and under almost the same circumstances have been bored at Charleston, S. C., and they yield an abundant supply of good water. And at Winslow, in the eastern part of Camden county, a well was bored by the late Hon. A. K. Hay, until it penetrated one of these sandy strata, which, at that place, was perhaps 150 feet below the ocean level. The well gave a satisfactory supply of good water, and it has now been in use for more than thirty years. *See page* 149.

As the outcrop of the strata is not parallel to the shore, but oblique to it, getting farther and farther from the shore as it goes towards the southwest, it follows that the strata carrying the fresh water will be deeper on the more southerly beaches, and comparatively shallow on those more northerly. The section is drawn from Camden to Atlantic City, and the depths at which the water-bearing strata may be expected can be seen on it.

From these sections it appears probable that water-bearing strata will be met with at various places along the beaches between Asbury Park and Cape May, at depths varying from 200 to 1,000 or more feet. It must, however, be considered that it is not by any means certain that such wells will be successful. They may fail from strata not being present, or from being too compact for the water to get through them easily, or from allowing sea water to get in them, or the quality of water may not be good. But, if successful, they will be much less expensive than any supply which can be brought from streams or wells on the main land. And a careful examination of the ground and surroundings should be made in every case before deciding which, upon the whole, is most desirable: the less expensive but, as yet, uncertain plan by boring, or the more costly but certain one of bringing it in pipes from the main land. Borings to test this hypothesis would be interesting to science, and a valuable contribution to our geological knowledge of the shore and the beaches, and might prove the best source of water-supply. It is to be hoped that some enterprising land owner will solve this interesting problem, and benefit himself by putting down a deep well on some of the beaches. One good well of this kind would do much to settle the doubts in regard to them.

The section on the map is drawn from Philadelphia, through Camden to Atlantic City, and runs near the line of the Camden and Atlantic railroad. The horizontal scale is the same as that of the map, one inch equivalent to six miles, but the vertical scale is one inch to one thousand feet. This section line varies slightly from the line of dip, as determined by the strike of the greensand marl formation. The latter has the true bearing of south 55° west. And it is represented upon the map by the line designated as *register line.* On this line the *bottom* of the red sand bed is at tide-level at Red Bank and along the Highlands, and on the western side of the State, in Salem county. In consequence of a slight curve in the formation near the line between Monmouth and Burlington counties, the red sand bed may not, at all points on this line, be at the ocean level.

The dip of the greensand marl beds is, in general, at the rate of 30 feet to the mile to the southeast, or at right angles to the line of strike or *register line* of the map. The rate at the northeast, in Monmouth county, appears to be a little greater than it is in West Jersey. And it decreases in the higher or newer beds to the southeast. The elevation of the lower marl bed (bottom) near Morganville, in Monmouth county, is 188 feet. At Red Bank the bottom of the same bed is about 30 feet below tide level, or a difference of 218 feet in a distance of 5½ miles, measured on the line of dip, equivalent to a descent of 39 feet per mile. At Mount Holly the middle marl bed is 115 feet high; at Gaskill's pits, near Pemberton, it is 26 feet. The two places are 3½ miles apart on the line of dip, showing a descent of 25 feet in a mile. In the artesian well bored at Winslow the marl was struck at the depth of 300 feet. As the place is 12¼ miles southeast of Clementon, where the same upper marl bed is worked, there is a descent here at the rate of 25 feet to the mile. Allowing for the thickness of the intervening sand beds, and computing from known elevations of the middle and upper marl beds, we find that in the eastern part of Monmouth county the dip is between 25 and 29 feet to the mile. It appears, therefore, safe to conclude that in the newer beds which lie to the southeast of the marl belt, the dip or descent is not more than 25 feet to the mile. But from the steeper dips in the clay beds northwest of the marl, it is probable that there is a flattening of all the strata from northwest to southeast, and that the dip or descent grows less in the overlying sand and gravelly beds. The gentler slope of the surface, as well as the very gradual descent of the sea bottom off our coast, also indicate the same lessening dip. In conformity with this generalization, the strata have been drawn with a gentle upward curve, going southeast, so that any given bed is not as deep at Atlantic City, for example, as its angle of dip at the northwest outcrop would make it. Then, again, the sand beds between the lower marl bed and the upper marl bed may thin out towards the southwest, and so lessen the depth below the surface. Lines have been drawn parallel to the register line at varying distances from it. And they are designated by the depths at which the bottom of the red sand bed is computed to be below the level of tide water. This horizon has been chosen as the bottom; below this the marly and clayey strata so predominate that the chances of obtaining water of good quality are not so good as they are in the higher and more sandy beds.

The several lines and their locations are as follows:

The 250-foot line is drawn from the ocean, at Asbury Park to the Delaware river, in Lower Alloways Creek township, passing near Shark river, Lakewood, Atco and Clayton. The probable depth of this horizon at any point on or near this line, is equal to the sum of the height of the land above the ocean level and 250 feet. Since the highest ground near it is about 170 feet above the ocean, the distance to the lower marl bed ought not to exceed 420 feet. The variation from this extreme depth would be determined by the distance of any place either to the northwest or southeast of this line, and would be at the rate of 25 feet greater for each mile going southeast from this 250-foot line. Wells or borings for good water ought therefore to reach water-bearing beds at depths not exceeding 420 feet. The upper marl bed on this line is probably between 30 and 200 feet deep, according to the elevation of the surface.

The next line on the map going southeast, is marked as the 400-foot line. It runs from Manasquan inlet to a point on Delaware bay, near the mouth of Stow creek. It is five and a half miles southeast of the last line. It passes near Manchester, Whitings station, Atsion, Winslow and Malaga. At the average dip of 25 feet to the mile, the depth below tide level to the lower marl bed is about 400 feet. Allowing 185 feet for differences of elevation of the surface, the total depth varies from 400 to 585 feet. At Winslow, the upper marl bed was reached at a depth of 300 feet. And good supplies of water can no doubt be obtained in the sand beds which lie above the marls, and are nowhere more than 350 feet deep. Spring Lake, Sea Girt and Manasquan are near this line.

The 630-foot line starts from Sea Side Park, on Island Beach, and runs to Cedar Creek, in Cumberland county. Cedar Creek and Cedar Bridge, in Ocean county, are near it. It passes across West Plains, near Oswego, Batsto, Elwood and South Vineland. The villages of Toms River, Hammonton and Vineland, are between it and the 400-foot line. Bridgeton is 6 miles northwest of it; Millville is one mile southeast of it. The greatest elevation of the surface along it is not 170 feet above tide, so that it is safe to put the bottom of the red sand bed at a maximum depth of 800 feet. The upper marl bed ought to be found at about 400–500 feet. And wells in the belt between this line and that next northwest should not go below 500 feet to strike water of good quality, and in abundance. The Harrisville well is one mile south of it. Its depth was 306 feet.

Going southeast our next line is 33 miles from the register line, and is designated as the 840-foot line, that being the depth of the lower marl bed below tide level. Its course, parallel to the others, is from Barnegat inlet, thence near Mannahawken, West Creek, New Gretna, Mays Landing, Port Elizabeth and Port Norris to False Egg Island Point on the Delaware bay. Egg Harbor City is about equidistant between it and the last described line. The highest ground on or near this line is not more than 60 feet high, making 900 feet as the probable extreme depth to the lower marl bed, or 675 feet to the upper marl bed. The glass-sand beds and other sandy beds between that depth and the surface ought to be largely water-bearing and easily penetrated.

Our sixth line is that running from Beach Haven to Absecon, Tuckahoe, Woodbine, and so to the Delaware bay. The depth on it to the horizon of the lower marl bed is 1,040 feet, or 810 feet to the upper marl bed, assuming, as heretofore, that the strata of the greensand marl series are uniformly thick, and that the dip is constant.

The most southern line of our map is that running lengthwise of Absecon beach from Atlantic City to Peck's beach, and thence to the mainland of Cape May county. If the uniform conditions of dip and thickness continue to this distance, as there is reason to believe that they do, the lower marl bed is here 1,170 feet deep, and the top of the upper bed 845 feet. The projected towns of Sea Haven, Island Beach, North Atlantic City, Longport and Ocean City are all near this line. At all of them it is safe to put the depth of the greensand marl at not more than 850 feet. It may be somewhat less. In the absence of any deep borings, it is not possible to indicate the subordinate members of the more recent formation which overlies the marl, excepting as we know that the outcrops on the mainland to the west, between this line and the marl belt, are sands and sandy clays with some beds of quartzose, pebbly gravel. It ought not to be necessary to bore down to the marl, or into that series of beds, to find an abundance of good water, as the overlying, sandy strata are very probably full of it.

The section is drawn to a scale and, hence, can be used to ascertain the depth of any given bed at any point on it. The figures at the sides show the successive 100-foot levels below tide. From it we see that the distance to the crystalline rocks under Atlantic City, or, in other words, the thickness of the sedimentary strata there is put at about 1,500 feet. Good water would be expected in the gneissic rocks, but a large supply can be found at much less depths in the sands and sandy and gravelly beds above the greensand marls. Where a large supply, adequate to the wants of a village or town, is needed, it is doubtful if it would not be economy in the end to bore to the rock, and so be sure of both quantity and of good quality, rather than stop in the higher beds of sands. The original outlay would be greater. For smaller supplies, more shallow wells and borings may answer all the needs.

PUBLIC WATER WORKS.

The following is a tabular exhibit of the cities and towns of New Jersey, and the number of inhabitants, which have a public water supply, with the source from which it is derived, and the names of gentlemen furnishing information:

CITIES AND TOWNS HAVING PUBLIC WATER-SUPPLY, WITH THEIR POPULATIONS, SOURCES OF SUPPLY, AND NAMES OF THOSE FURNISHING INFORMATION.

CITIES AND TOWNS.	POPULATION.	SOURCE OF SUPPLY.	NAMES OF INFORMANTS.
Paterson	51,031	Passaic river	William Ryle, Superintendent.
Passaic City	6,532	"	W. Paulison, Secretary and Superintendent.
Newark	186,508	Passaic river, at Belleville	G. R. Gray, Superintendent.
Jersey City	120,728	" "	W. W. C. Sites, Chief Engineer.
Bayonne City	9,372	" "	
Hackensack	4,248	Hackensack river, at New Milford	Chas. B. Brush, C.E.
Hoboken	30,999	" "	" "
West Hoboken and Town of Union	11,290	" "	" "
Orange	13,206	West branch of Rahway river	W. B. Rider, Engineer and Contractor.
East Orange	8,349	Bored wells	Geo. P. Olcott, Sanitary Engineer.
Elizabeth	28,229	Elizabeth river	L. B. Battin, Manager.
Rahway	6,455	Rahway river	H. B. Bunn, Superintendent.
New Brunswick	17,167	Lawrence brook	A. J. Jones, Superintendent.
Perth Amboy	4,808	Five Oak springs	
Morristown	5,418	Springs, near town	H. C. Pitney, President.
Dover	2,958	Springs, near town	Fred'k A. Canfield, C.E.
Hackettstown	2,502	Springs, on Schooley's mountain	W. L. Johnson.
Washington	2,142	Stream near Brass Castle	Daniel Vliet, Secretary.

CITIES AND TOWNS HAVING PUBLIC WATER-SUPPLY, WITH THEIR POPULATIONS, SOURCES OF SUPPLY, AND NAMES OF THOSE FURNISHING INFORMATION—*Continued.*

CITIES AND TOWNS.	POPULATION.	SOURCE OF SUPPLY.	NAMES OF INFORMANTS.
Flemington	1,751	South branch	John C. Hopewell, Superintendent.
Somerville	5,151	Raritan river	
Princeton	4,348	Large wells	William Libbey, Jr., Secretary.
Belvidere	1,773	Delaware river	A. McCammon, Secretary.
Phillipsburg	7,180	"	J. H. Griffith, Mayor.
Lambertville	4,183	"	Martin Coryell, Superintendent.
Trenton, including Chambersburg	35,347	"	John B. Quigley, Superintendent.
Bordentown	4,258	"	John M. Steele, Superintendent.
Burlington	6,090	"	H. S. Haines, Superintendent.
Camden	41,658	"	Henry Steter, Superintendent.
Mount Holly	4,630	Rancocas river, north branch	Marmaduke S. Pancoast, President.
Long Branch	3,833	Whale Pond creek	Thos. W. Cooper, Agent.
Atlantic City	5,477	Well and small stream	E. Graves, Superintendent.
Cape May City	1,699	Bored wells	H. C. Thompson, Recorder.
Woodbury	2,298	Bored wells	G. G. Green, Proprietor.
Salem	5,057	Stream and wells	Chas. S. Lawson, Mayor.
Bridgeton	8,729	East Lake creek	Timothy Woodruff, Superintendent.
Millville	7,660	Maurice river	
	613,064		

The information contained in these tables, so far as business and engineering particulars are concerned, has been obtained by correspondence. It is sufficient for the purposes of this report, but it would require careful inquiry on the spots—much more labor and time than we can bestow upon it—to make it a satisfactory exhibit of the working, economy and special adaptations of the several works to local wants. The following table gives the results of inquiries, as far as we have been able to tabulate them, of cost, annual expenses, number of water takers and daily consumption:

TABLE.

	CITIES AND TOWNS.	COST.	ANNUAL EXPENSES. Expenses. Repairs.	WATER TAKERS.	DAILY CONSUMPTION. Gallons.
2	Atlantic City	$300,000		125	300,000 to 900,000
2	Belvidere	16,600	$1,500	104	2,800
2	Bordentown			300	250,000
1	Bridgeton	81,000	$1,300 + $400	650	150,000
1	Burlington	64,000	2,200 + 300	1,100	150,000
1	Camden	200,000	15,000 + 13,000	7,170	4,500,000
1	Cape May City	40,000	$1,500	212	50,000 to 400,000
...	Dover	40,000			
...	East Orange			70	
2	Elizabeth	600,000	$5,000 + $500	2,300	2,000,000
2	Flemington	25,000		99	7,000
...	Hackensack				50,000 to 75,000
2	Hackettstown	54,000		266	200,000
...	Hoboken				4,000,000
1	Jersey City	4,918,493	$96,383		15,921,742
2	Lambertville	35,000		150	
2	Long Branch	100,000		250	300,000 to 1,000,000
2	Morristown	132,000	$800 (?) + $1,000	700	120,000 to 300,000
2	Mount Holly	(Capital) 7,500	2,100 + 450	375	200,000 to 250,000
1	Newark	3,300,000	42,471 + 13,365	12,000	10,000,000
1	New Brunswick	440,000	12,446 + 2,598	1,300	1,000,000
2	Passaic	100,000			500,000
2	Paterson	1,415,007		3,200	6,000,000
2	Perth Amboy	100,000			51,000
2	Princeton	50,000			
1	Rahway	(Capital) 185,000	$3,200 + $800	400	651,136
1	Salem	(Capital) 75,000		80	67,113
...	Somerville	54,000		180	
1	Trenton	322,106	$9,774 + (Const.) $4,893	5,338	1,275,585
2	Washington	32,000		60	
2	Woodbury	9,500	$700 + $100		60,000

1 Public—Owned by town or city.

2 Private—Owned by a company.

Further particulars in regard to the water-supply, such as could not well be tabulated, are here presented, taking up the several places in alphabetical order:

Atlantic City.—The subject of a water-supply at Atlantic City, after much discussion of various sources, including artesian wells, has been decided by the introduction of water from a large well on the mainland, near Absecon, and from the Absecon stream. The well is about half a mile back from the tide meadows. It is 20 feet deep and 25 feet in diameter, and is reported to have a capacity of yielding 500,000 gallons of water daily. The balance of the supply needed is drawn from the stream. The water is carried through six miles of 12-inch pipe across the meadows, and is then distributed through ten miles of smaller size pipes. The quality of the water is good, as it comes from a wooded district. The works are owned and managed by the Atlantic City Water Works, a private corporation. The works have been completed and in operation only a few months.

Bayonne City.—Water is being introduced into Bayonne City by the city authorities, under the management of a board of councilmen. Five miles of 20-inch cast iron pipe have been laid, connecting with the Jersey City reservoir, and the source of supply will be the same, viz., Passaic river, at Belleville.

Belvidere.—Belvidere is supplied with water from the Delaware river by the Belvidere Water Company. The water is pumped by steam pump into a stand-pipe 160 feet high and 6 feet in diameter. The distribution is through 4, 6 and 8-inch cast iron pipes. The water is of excellent quality.

Bordentown.—Bordentown is supplied with water from the Delaware river by the Bordentown Reservoir and Water Company.

Bridgeton.—The city of Bridgeton is supplied with water from East lake, a natural reservoir a short distance east of the city, whose water-shed or drainage area is at least six square miles. The works are owned by the city and managed by a committee of the city council and a superintendent. They were built by the city, and consist of a retaining reservoir, having a capacity of 3,000,000 gallons, and a distributing reservoir of 1,500,000 gallons. The water is pumped into the latter by a compound duplex Worthington engine of a capacity of 1,000,000 gallons a day. There are 12.5 miles of cast-iron distributing pipes, 4 to 16 inches in diameter. The water supplied from East lake is very soft; it comes, mainly, from cedar swamps along the streams flowing into the lake. And such water is well liked by all persons familiar with it, and is sweet and wholesome.

Burlington.—Burlington gets its water-supply from the Delaware river. The works are owned by the city and managed by a board of water commissioners. The water is pumped by a Worthington steam pump into an iron reservoir, whence it is distributed through 7¾ miles of cast-iron pipes. The water is good.

Camden.—Camden obtains its supply of water from the Delaware river. The city owns the works, and they are under the control of a commission of the city council. One Blake compound duplex pump, with a capacity of 5,000,000 gallons, and a Corliss pump, with a capacity of 3,000,000 gallons, raise the water from the in-take in a stand-pipe, from which it flows to the reservoir. It is distributed through cast-iron 4, 6, 8, 12 and 16-inch pipes. It should be stated here that this point is the lowest on the Delaware where that stream affords any public water-supply. The works are situated about one mile up stream from the city.

Cape May City.—The water works of the city of Cape May are owned and controlled by the city. The supply is obtained from two large surface wells and one artesian or bored well. The former are each 20 feet in diameter and 30 feet deep—sunk in the sandy and gravelly strata. The surface water is kept out by cement. The bored well is 96 feet deep. Four small steam pumps are in use, and pump the water into large, cylindrical cedar tanks, whose capacity is 100,000 gallons each. For additional notes on these wells and water, see pages 151 and 152. There are five miles of 10 and 12-inch mains for distributing the water.

Dover.—Water is about to be introduced into Dover by the Dover Aqueduct Company. It is proposed to take the water from springs forming the head of Wallace brook, and carry the same through porous tile to a reservoir on this stream one mile southwest of the town. This storage reservoir is to have a capacity of 11,000,000 gallons. Thence the water is to be conducted 7,250 feet in an 8-inch cast iron main to a service reservoir, 157 feet above Blackwell street. The distribution is to be through 4, 6 and 8-inch cast iron pipes. The area of the water-shed which will drain into the storage reservoir is about half a square mile. It is all cleared and in farms. The gneissic rock substratum ought to yield good, soft water.

East Orange is provided with means for a water-supply from three bored wells, located on Grove street, about 1¼ miles north from Main street. The wells are 6 inches diameter, bored about 10 feet in earth and the remaining depth in red sandstone. Well No. 1 is 86 feet deep; No. 2 is 92 feet, and No. 3 is 112 feet deep. The distances between them are 125 and 200 feet; the water rises to within 4 feet of the surface in No. 1, within 4½ feet in No. 2, and 7½ in No. 3. The works are not yet in full operation, but 118,000 gallons were pumped from No. 1 in 12 hours without materially lowering the water in the well. About 11 miles of pipe are laid, 100 fire hydrants are set, and water pipes are being put in the houses. It is too soon to give particulars of cost, sales, or consumers.

Elizabeth.—The Elizabeth Town Water Company supplies water to the people of Elizabeth. The Elizabeth river is dammed at Parker road, whereby a receiving reservoir with a capacity of 150,000,000 gallons is made. It is known as Lake Ursino. The water is carried in a 24-inch main one mile, and is then distributed through 40 miles of wrought iron, cement-lined pipes, 4 to 16 inches in diameter, to 2,300 water-takers. The consumption averages 2,000,000 gallons each 24 hours. The Elizabeth water-shed is red shale and red-shale drift surface. It is quite thickly settled, and a large part of it is cleared and in farms. An analysis made at the survey laboratory in 1876, yielded 7.86 grains of solid matters in a gallon, and of this amount 1.84 grains were volatile and organic. The chlorine amounted to 0.33 grains. For comparison with waters from other places see table on page 132.

Flemington.—Flemington has a private water company which gets its supply from the South branch, about three miles east of the town, and near Barleysheaf. The water power of the stream is used to force the water to the distributing reservoir. The pipes are of cast iron and aggregate 1.5 miles in length. The average daily consumption is 7,000 gallons and there are 99 water-takers. The South branch is a rapid stream and flows out of the Highlands, and then through the red shale territory for a few miles, in which it receives a few tributaries. The water ought to be well aerated. As a part of the area is limestone, the water may contain some lime.

Hackensack.—The Hackensack Water Company has been re-organized, and the new works are not yet completed. This company is to supply both Hoboken and Hackensack.

The present supply of Hackensack is obtained from the Hackensack river, at Cherry hill, 2½ miles north of the town. The water is pumped from the river into a 12-inch main and delivered to the Cherry hill reservoir, one-third of a mile distant, and 110 feet above tide level. The distributing pipes are of cast iron and have a total length of 4 miles. It is intended in the future to supply the Hackensack reservoir with water from New Milford, 5 miles north of the town.

Hackettstown.—Hackettstown is supplied with water from springs on the Schooley's mountain range, one mile east of the place. The water-shed whence the supply is drawn has an area of one square mile. It is partly wooded and partly in farm lands. The elevation of the reservoir is 100 feet above the lower part of the town. The water flows by gravity through a 10-inch main, and is distributed through 3-inch cast iron pipes. The water is soft and of excellent quality, coming as it does from a gneissic rock soil and not polluted by thickly settled population. The aqueduct company is under the government of a board of six commissioners appointed by the town council. For analysis of water, see page 132. These figures show an exceptionally pure water.

Hoboken.—Hoboken obtained its water-supply from Jersey City, until recently. During the year the newly re-organized Hackensack Water Company has assumed the work of supplying Hoboken from the Hackensack river, at New Milford. And extensions are being made to supply West Hoboken and the Town of Union also. The pump works of this company are located at New Milford. They have two Worthington duplex engines. The force main is 14 miles long and 20 inches in diameter. The reservoir has an elevation of 180 feet, and a capacity of 15,000,000 gallons. The consumption amounts to 4,000,000 gallons daily.

The Hackensack water-shed is nearly all on red sandstone, more or less covered by drift. There is a narrow margin on the northeast and north, of trap-rock. The greater part of the whole water-shed is cleared and in farms. The trap-rock surface is wooded. In Rockland county the streams are rapid, but in Bergen county there is considerable swamp along the Hackensack and Pascack. Inasmuch as the population is not dense and there are no large manufacturing towns in this territory drained by the Hackensack, there is no immediate danger from sewage or contamination likely to arise from other polluting material.

Jersey City.—The Jersey City water works are owned by the city, and managed by the six commissioners of the Board of Public Works. These commissioners serve for two years, and are elected by the people at their charter elections.

The Passaic river at Belleville furnishes the supply. The water is pumped into a settling reservoir on the ridge east of Belleville, and 157 feet above tide level. It flows thence, by gravity, through one 20-inch and two 36-inch conduits to the distributing reservoir in Jersey City. The low service district is supplied direct, by gravity, while the high service district receives its supply by pumping. There are 815,940 lineal feet of distributing pipe, varying from 3 inches to 36 inches in diameter. Both cast iron and wrought iron and cement-lined pipe are in use. Two Worthington pumps, with a capacity of 8,000,000 gallons each; one Cornish, of 8,000,000 gallons; two Cornish pumps, of 7,000,000 gallons; one Worthington, 3,000,000 gallons, and one Knowles, 1,000,000 gallons, are at the works.

For quality of water, see page 129.

Lambertville.—Lambertville receives its water from small streams on the Goat Hill range, southeast of the town. The drainage area is estimated at 1,000 acres. The soil is clayey, and rests upon trap-rock. The reservoirs are above the town, and the water is distributed by gravity. During the severe drought of 1881, the supply was insufficient, and recourse was had to pumping from Island creek, an arm of the Delaware river. The construction of a second reservoir, capable of holding 6,000,000 gallons, will probably afford storage sufficient to supply the town, and do away with pumping from the river. The water is soft. The number of water-takers is 150. The works are owned and managed by a private corporation, known as the Lambertville Water Company.

Long Branch.—The Long Branch Water Company supplies water to Long Branch. The supply is taken from Whale Pond creek near where it empties into Green's pond and south-southwest of the village. A well 30 feet in diameter and 15 feet deep is also used. The drainage area of the creek is about eight square miles. It is partly cultivated and partly in wood. The water is raised by two high-pressure pumps into a stand-pipe 75 feet high. There are eight miles of cast iron distributing pipes, 4 inches to 16 inches in diameter. The well yields about 70,000 gallons a day. The water is good, coming from the sandy outcrop of the yellow sand bed and drift gravels.

Morristown.—The "Proprietors of the Morris Aqueduct" were incorporated in 1799. The supply is obtained from two groups of springs in the hillsides west of the town. The areas from which they gather the water are small; that nearest the place not exceeding a half a square mile; and the other, to the west of the former, is but little larger. These springs flow out of gneissic and granitic rocks. While only a small part of the drainage area is in forest, another and larger part is under the control of the water works, and is kept in pasture. The quality of the water is not affected by any tillage or by any of the polluting matters incident to manufacturing establishments, or to a densely populated district. It is soft and excellent. See analysis on page 132. The distributing pipes aggregate 25 miles in length. They are of cast iron, and from 3 to 6 inches in diameter.

Mount Holly.—Mount Holly gets its water from the North branch of the Rancocas creek. The water is soft and of excellent quality, coming largely from the sandy, pine-covered district of eastern Burlington and western Ocean counties, and from cedar swamps bordering the head-waters of the Rancocas. The latter give it a deep brownish tinge, and impart to it a sweetish taste, pleasant to all accustomed to its use, and special health-giving properties are popularly attributed to it. The water is pumped up by means of steam pumps. The pipes are of cast iron, and from 3 inches to 6 inches in diameter.

Newark.—The city of Newark is supplied with Passaic river water, taken near Belleville, where the water works are located. The in-take is above the village and above the Jersey City works. The water is raised by means of steam pumps and forced into the reservoirs in the city, whence it is distributed through 135 miles of cast iron pipe, 4 inches to 24 inches in diameter. The works are owned by the city, and are under the management of commissioners elected by the people. For quality of water, &c., see page 129.

New Brunswick.—The water-supply of New Brunswick is obtained from Lawrence brook. It is taken at the head of tide, at Weston mills, south of the city. Thence it is forced 130 feet upwards into the distributing reservoirs in the city. The pumping is done by water power of the Lawrence brook, supplemented by steam in dry times. The distributing pipes are cement-lined, wrought iron. The water-shed of the Lawrence brook has an area of 46 square miles. It is partly in wood and partly cleared and in farms. The water is very soft, and of excellent quality. For analysis see page 132.

Orange Water Works.—These are just in course of construction. The supply of water is to be obtained from the West branch of Rahway river. The water is collected in the narrow valley between the First and Second mountains, and consists of the rain which falls upon five square miles at the head of that stream. The dam across the valley by which the water is collected into a reservoir, is located just where the boundaries of Livingston, West Orange and Millburn meet in that valley. The reservoir when full covers 60 acres of ground, and will hold between 250,000,000 and 300,000,000 gallons of water. The elevation of the reservoir is such that it will deliver water by gravity at the height of 142 feet above the surface at the Orange depot. The present plan is to convey the water from the reservoir to Orange through a 16-inch, cast iron main.

The water is soft and pure, and the supply ample for a population much greater than the city now contains. The construction of these works had come to be urgent necessity; the only previous supply being from open wells, and many cases of sickness being directly traceable to the use of water from them.

Passaic City.—The Acquackanonck Water Company supplies water to Passaic City from the Passaic river. The water is taken from the river near the town, and is raised to a reservoir by means of water and steam power. The distribution is through 6, 8 and 12-inch pipes of wrought iron, cement-lined. The daily consumption averages 500,000 gallons. Of the quality of Passaic river water, see page 129.

Paterson.—Paterson gets its supply of water from the Passaic river a short distance above the Passaic falls, and within the city limits. There are four horizontal piston pumps, each having a daily capacity of 3,000,000 gallons, and one Worthington duplex pump of a capacity of 4,000,000 gallons a day. There are 50 miles of distributing pipes. Both cast iron and cement-lined pipes are in use, from 6 to 20 inches in diameter. The works are owned by the Passaic Water Company. The area of the Passaic water-shed above Passaic falls, or Paterson, is 877 square miles. The nature of this water-shed is greatly varied in its different parts. The head-waters are in the Highlands, and the streams are rapid and have a great fall, whereas the middle Passaic and the lower part of the Rockaway and the Pompton rivers are sluggish, and flow through the flat, wet lands of the Passaic valley. Overflows are consequently common whenever there are freshets and high water. Organic matter of vegetable origin is sometimes present in large quantities, as shown by analysis No. 10 of table, on page 129. But the low percentage of chlorine shows that it is not contaminated, as the waters of the lower Passaic, by sewage. And the organic matter, from vegetable origin, cannot be considered as especially injurious or objectionable.

Perth Amboy.—Water has lately been introduced into Perth Amboy by the Perth Amboy Water Company. The supply comes from the Five Oak Springs stream, one mile west of the city. The area of water-shed above the works is nearly three square miles. Its surface is red shale drift covering clay beds, and is partly wooded. The water is reported as excellent. Steam pumps raise the water into a stand-pipe, or, in case of need, they pump direct into the mains. The distributing pipes are of cast iron, and from 4 to 12 inches in diameter.

Princeton.—Water has lately been introduced into Princeton by the Princeton Water Company, a private corporation. A large well, 25 feet in diameter and 25 feet deep, was dug in the meadows south of the town and about 600 feet from the Delaware and Raritan canal, and 2,000 feet south of the basin. The ground at this point is below the level of the canal. The water comes from sand and gravel beds, 6 to 10 feet in depth, and protected by a clay stratum, 8 to 10 feet in depth. A steam pump, with a capacity of 40,000 gallons per hour, forces the water to a stand-pipe, $1\frac{1}{8}$ miles distant, whence the distribution is through cast iron pipes, 4 inches to 10 inches in diameter. The supply is considered ample, as the test wells gave over 35 gallons per minute. The water is good, but a little hard. Analysis shows it to contain in one gallon, 0.35 grains of chlorine and 2.3 grains of calcium carbonate. The advantages of the well over any other source of supply found near the town are said to be "greater purity of the water, and freedom from possible future contamination."

Rahway.—Rahway owns its water works, and their management belongs to the common council of the city. The Rahway river is dammed about a mile north of the town, and the water is raised by pumps directly into the mains, supplying the distributing pipes. Cement-lined pipes are employed in distributing. The area drained by the Rahway to the reservoir is 38 square miles. It is a red shale and trap-rock country, but largely drift covered, so that the surface is of a somewhat mixed character. The larger part of this area is cultivated and in farms. The trap-rock ridges are mostly wooded. The quality of the water is fairly good. It contains, according to an analysis made for the report of 1876, 10.20 grains of solid matter per gallon, of which 1.18 grains is volatile and organic. The chlorine amounts to 0.25 grains in a gallon.

Salem.—Salem has its water-works owned by the city and under the direction of its common council. The supply comes from a well and from a small stream east of the city. The Holly system is in use. There are 15,958 feet of 12-inch supply pipe and 24,988 feet of cast iron distributing pipes. The drainage area of the reservoir is about 1,000 acres; that of the pond reservoir, 25 acres. The water is soft.

Trenton.—The city of Trenton and the adjacent borough of Chambersburg are supplied with public water from the Delaware river. The works are within the city limits, and the in-take is above the tide line. There are four large pumps, one of which is worked by water power and three by steam. Their combined capacity is 4,000,000 gallons daily. The distributing pipes are of cast iron, and their aggregate length is 40 miles. The Delaware river water is of the best quality. An exhaustive analysis by Dr. Henry Wurtz, made in 1855, showed that it had only 3.5 grains of solid matter in one gallon, of which the organic matter was 0.6 grains. The river is deep and rapid, having many riffles, so that its waters are well aerated. Its water-shed, above Trenton, of 7,500 square miles, is largely in its original *forested* condition, and the tributaries are like the river itself, generally rapid. It is a region of mountains and valleys. And there are few, if any, large streams whose water is purer or more wholesome. Besides, there are no large manufacturing establishments on its banks to contaminate its water by poisonous or filthy waste products. Comparatively speaking, the larger portion of this water-shed is thinly populated.

Washington.—Washington, in Warren county, is supplied with water from the Brasscastle creek, on the eastern slope of Scott's mountain. The water is taken at a considerable elevation, and flows by gravity direct to the town, about three miles distant. About half of the area of two square miles is in woods; the rest is in farm lands. It is a gneiss rock surface, and the water is of good quality. The works are owned and managed by the Washington Water Company.

Woodbury.—Woodbury has no public water-supply, but several of its hotels, its railroad, glass works and Green's chemical factory are supplied by the works of G. G. Green, Esq. The water is obtained from a lake east of the town, whence it is raised by a steam pump into a reservoir holding 100,000 gallons and 98 feet high. The main pipe is two miles in length.

IX.

STATISTICS OF ORES, CLAYS, CLAY PRODUCTS AND LIME.

IRON ORE.

According to returns of ore tonnage received from the Delaware, Lackawanna and Western, the Central of New Jersey, the Lehigh Valley Railroad and the Morris Canal Companies, the aggregate amount of iron ore carried by these companies over their lines in 1882, from stations in the iron ore district of the State, was........	897,183	tons.
The total amount received direct by teams at the furnaces at Franklin, Chester and Oxford Furnace, was...	35,579	"
Total	932,762	
In 1881 the aggregate over these lines and received at the furnaces by teams, amounted to....................	737,052	"
An increase in 1882 of..................................	195,710	

ZINC ORE.

The product of the zinc mines of Sussex county, as ascertained from the returns of the several companies which carry these zinc ores to the furnaces using them, amounted in 1882 to 40,138 tons. These ores are used at Newark, Jersey City, and at Bethlehem, Pa.

CLAYS.

The product of the clay banks, fire-sand *feldspar* and *kaolin* pits of the State exceeds that for the year 1881. The reports which have been received are not complete, and are, in part, estimated. The total output of clays, *feldspar, kaolin, fire-sand,* and other materials of a refractory nature, in 1882, amounted in Middlesex county to 300,000 tons.

In this total are included stoneware clay, 15,000 tons.*

There were 15,000 tons of moulding sand in addition to the above, which would make the total 315,000 tons.

John D. Hylton, Palmyra, reports the shipment from his banks on Pensauken creek, in Camden county, clays for fire-brick, retorts and foundry uses .... 14,000 tons.

Kaolin	6,700	"
Fire-sand	3,400	"
Foundry gravel	8,000	"
	32,100	"
Additional from neighboring pits on the Delaware....	6,000	"
Total	38,100	"

BRICKS.

The statistics of red brick made in 1882 at the several large centers of this manufacture in this State, are reported by our correspondents conversant with the business, as follows:

Hackensack river yards	25,000,000
Raritan and South river yards	64,000,000
Raritan bay and Matawan creek yards	15,225,000
Trenton and Kinkora yards, including 8,000,000 of pressed bricks	24,000,000
Delaware river, (Pea Shore), Fish House	7,000,000
Total	135,225,000

If to this sum there be added 15,000,000, as an estimate for the scattering yards, which do a more local business, the sum total amounts to 150,000,000—an increase of 34,000,000 over that of last year.†

LIMESTONE.

The adaptation of the pure white, crystalline limestones of Sussex and Warren counties to the manufacture of pure lime for the best purposes to which lime is applied, has been referred to repeatedly in

* Reported by Otto Ernst, South Amboy.

† The Hackensack yards were omitted in the statistics for 1881. Hence the increase is perhaps too high.

the reports of the Survey. In the "*Geology of New Jersey,*" 1868, pp. 400–404 and 524–525, localities and analyses were given, with brief notices of earlier trials of this stone near Hamburg, in Sussex county, and near Oxford, in Warren county. The attention of capitalists was directed to the subject as promising of rapid development. In the annual report for 1873, the beginnings of the lime manufacture near McAfee valley were mentioned, and the prospects in connection with the opening of the New Jersey Midland Railway (now, New York, Susquehanna and Western Railroad). It is pleasant to have our attention now called to the present condition of this new industry in the territory thus referred to in previous reports. From Samuel Higbie, of the firm of Marcus Sayre & Company, of Newark, we learn that the production of that firm, of fine, barreled lime is at the rate of 1,800 barrels per week; that of the two firms of Beardslee and Sheldon amounts to about 230 barrels daily, or 1,400 barrels weekly. The aggregate product of these three firms is, therefore, 3,200 barrels weekly, or 150,000 barrels a year. The superior quality of this lime, and its nearness to the great markets of the country, give it important advantages both for the manufacturer and the consumer, and it is fast taking the place of more costly kinds of the same quality.

X.

PUBLICATIONS OF THE SURVEY.

The ANNUAL REPORTS OF THE STATE GEOLOGIST are printed as part of the legislative documents of the State. And they are largely distributed by the members of the Legislature. Extra copies printed are distributed by the members of the Board of Managers, and the State Geologist also distributes copies to libraries, institutions of learning, and to persons interested in such work. A list is kept of those to whom distribution is made regularly. Several of the reports of preceding years are all distributed, and of others but few copies are left.

There are still a few copies left of the GEOLOGY OF NEW JERSEY, the octavo volume and maps printed in 1868.

The REPORT OF THE FIRE AND POTTERS' CLAYS OF NEW JERSEY, with a map of the clay district of Middlesex county, published in 1878, has been very widely distributed. There are copies still on hand for distribution.

The copies of the LARGE GEOLOGICAL MAP of the State are nearly all distributed.

A PRELIMINARY CATALOGUE OF THE FLORA OF NEW JERSEY, prepared by N. L. Britton, Ph.D., was printed in 1881, and distributed to botanists for their remarks, corrections and additions. A great many of the plants have been noticed in only a single place in the State. By the circulation of this catalogue among botanists, it is hoped that many new localities of rare plants will be discovered, and the list thoroughly revised. The catalogues are to be returned after two or more seasons, and the notes in them used in making out a more perfect catalogue, for general circulation throughout the State. Only 600 copies were printed, and these have already been placed in the hands of working botanists, and much work has been accomplished in its revision. The work commends itself to all lovers of botanical science, and we are promised their hearty co-operation in completing the revised edition.

A TOPOGRAPHICAL MAP OF A PART OF NORTHERN NEW JERSEY, on a scale of one mile to an inch. In addition to the delineation of boundaries, streams, roads and geographical matter, it has on it contour lines of level, so that the elevations of the surface above mean tide are accurately marked on all parts of it. This map has been very generally approved, and is in demand for laying out drains, ditches, water-works, roads and railroads, and for selection of building sites, and as a study for drives, bicycle excursions, &c.

GEOLOGICAL MAP OF NEW JERSEY.—Scale six miles to an inch. The improvements going forward in the State, call for a revision of our map very often. The one which has been printed with the annual report for several years, is corrected up to the date of this report, and again reprinted. A few corrections will be found in railroads—some minor improvements in the geological coloring, and much has been added, in new places along the sea-shore—and the life-saving stations have been put on.

The results of the Survey are intended for the benefit of the citizens of the State, and the Board of Managers have charge of and direct the distribution of its collections, reports and maps. The addresses of the members of the Board are given on page 3 of this report, and application made for publications to them, or through them to the State Geologist, will be received and given due attention.

XI.

EXPENSES.

The expenses have been kept strictly within the appropriation of $8,000 a year, and all bills and liabilities incurred are regularly paid every quarter.

XII.

PERSONS EMPLOYED.

My own time has been employed in conducting the business of the various branches of the Survey, and in bringing forward work, so that it may be properly closed with the end of the present appropriation in 1886. Some time has been given to the study and discussion of unsettled questions in our geology.

Prof. JOHN C. SMOCK, Assistant Geologist, has also been employed in the Survey, throughout the year. His work has been in collecting materials for further use in the Survey when the proper maps shall have been made. The red sandstone, the iron ores, the fire and potters' clays, and the development of other natural products, have received his attention.

In consequence of the pressing need for Topographical Surveys and maps upon which to properly locate and describe the geology, and limited funds at our disposal, it has been thought proper to spend all that could be saved of the appropriation on the Topography. And neither Professor Smock nor myself have drawn pay for full service, but have found partial occupation in other scientific work.

C. CLARKSON VERMEULE, C.E., assistant in the Topographical Survey, has been fully employed in field and office work in his department throughout the entire year.

PETER D. STAATS, A.M., assistant to Mr. Vermeule, has been engaged principally in surveying and mapping roads during ten months of the year.

FRED. W. BENNETT, B.S., assistant to Mr. Vermeule, has been engaged in leveling and sketching for topography during five months.

PHILIP H. BEVIER, B.S., assistant to Mr. Vermeule, has been engaged in leveling and sketching for topography during six months of the year.

NATH. B. K. HOFFMAN, B.S., rodman, for two months.

SOLOMON LE FEVRE, B.S., rodman, for two and a half months.

GEO. W. BLAKELEY, student Rutgers Scientific School, rodman, three months.

H. R. WORRALL, student Rutgers Scientific School, rodman, two weeks.

FRANK VAN BRAKLE, student Rutgers Scientific School, rodman, two weeks.

WM. L. HAYNES, student Rutgers Scientific School, rodman, two weeks.

PHILIP LINDSLEY, student Rutgers Scientific School, draughtsman, three weeks.

——— DEMOTT, rodman, one week.

In the chemical department no chemist has been steadily employed, but needed chemical investigations have been made by Dr. Peter T. Austen, Professor of Chemistry in Rutgers Scientific School; F. A. Wilber, M.S., Assistant Professor of Chemistry, &c.

Prof. J. S. Newberry, of Columbia College, New York City, has nearly completed his monograph of the fossil fishes of our Triassic sandstone, and it will soon be ready for publication, with full descriptions and drawings.

Prof. R. P. Whitfield, of the American Museum of Natural History, is making progress with his work of figuring and describing the invertebrate fossils of the Cretaceous formations of New Jersey. 91 species and 199 drawings of fossils are now done and ready for the engraver.

XIII.

WORK TO BE DONE.

PLAN FOR THE COMING YEAR.

The work of the Survey is now mainly directed to perfecting and arranging materials for publication. The essential and important part of this is to have accurate and reliable maps upon which to delineate the various results which have been attained. For this purpose the Topographical Surveys will be prosecuted with all the dispatch the means at our disposal will allow. There is now a sufficient area mapped to warrant the beginning of engraving for another sheet, and we shall hope to have it out for use early next year. And other maps will come on in succession. The iron ore region is nearly done, and the next surveys will probably be along the seashore, where settlements and improvements are now going on so rapidly.

Questions connected with the economic uses of geological and natural products are continually arising, and we give to them as much attention as possible at the time they are brought up. And geological notes are being collected and made ready for use whenever a final report shall be prepared.

The collection of fossils, and preparing the drawings and descriptions of them is going on, and it is hoped that some part of this work may be completed and ready for publication in the course of the year. In collecting fossils we are largely dependent on friends and amateur collectors for the use of choice specimens for description.

The collection of the plants of the State is going forward, and we are glad to report that several hundred amateurs are helping to fill out and perfect it.

ERRATA.

Page 32, ninth line, insert "to" after "belonging."
Page 40, twenty-fifth line, omit comma after "quartzose."
Page 42, twelfth line, after "Sufferns" insert "New York."
Page 45, fourteenth line, read "No. 4" instead of "No. 3."
Page 76, eleventh line, insert "the" before "Raritan."
Page 98, second line from bottom of page, read "bored" instead of "board."

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GEORGE H. COOK, STATE GEOLOGIST
JOHN C. SMOCK, ASST. GEOLOGIST
GEOLOGICAL MAP
OF
NEW JERSEY
1882.
Scale 6 Miles to 1 Inch
Statute Miles
JULIUS BIEN & CO.
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DELAWARE BAY
ATLANTIC OCEAN
PHILADELPHIA
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Upper Marl Bed
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Middle Marl Bed
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Lower Marl Bed
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Laminated Sand and Clay Marls.
Clay and Sand Soils.
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Shales.
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and
Trap-Rocks
Shale and Trap Soils
Limestone Soils
Marcellus Shale
Cherty Limestone
Slaty Soils
Cauda-Galli Grit
Oriskany Sandstone
Limestone
Lr. Helderberg Limestone and Wal Lime
Sandstone
Red Slates and Sandstone.
Conglomerate Soils
Sandstone and Cong. of Kittalinny Mt.
Slate
Shales, Roofing Slates and Slaty Sandstones
Fossiliferous Limest'e
Limestone
Magnesian Limestone
Sandstone Soils
Sandstone, Slaty Grit and Green Pond Mt. Conglomerates.
Serpentine.
Limestone and Gneissic Soils
Gneiss
Crystaline Limestone
Granite
POST TERTIARY
TERTIARY
CRETACEOUS
TRIASSIC
DEVONIAN
SILURIAN
Atlantic Ocean
Tide Level
Sand with Gravel and Sandy Clay
Glass Sand
Clay
Glass Sand
Clay
Upper Marl Bed
Yellow Sand
Middle Marl Bed
Red Sand Bed
Lower Marl Bed
Clay Marls
Plastic Clays
1000 feet below Tide level
Section from Philadelphia to Atlantic City
SCALE {Horizontal - 1 inch - 6 miles
Vertical - 1 inch - 1000 feet