GEOLOGICAL SURVEY OF NEW JERSEY.

ANNUAL REPORT

OF THE

STATE GEOLOGIST,

FOR THE YEAR

1885.

TRENTON, N. J.:
JOHN L. MURPHY, STATE PRINTER.
1885.

MAP OF SANDY HOOK

FROM ORIGINAL SURVEYS MADE IN 1885

WITH COMPARISON OF VARIOUS
AUTHENTIC SURVEYS FROM 1685 TO DATE
SHOWING PROGRESSIVE CHANGES
IN THE SHORE LINE.

Scale of Yards 1000 0 1000 2000

Julius Bien & Co. Photo Lith.

OCEAN

NAVESINK RIVER

HIGHLANDS OF NAVESINK

SPERMACETI COVE

SANDY HOOK BAY

FALSE HOOK CHANNEL

FALSE HOOK

SANDY HOOK

ISLAND BEACH

FORT

Note. *The curved contour lines, on land, are lines of equal elevation for every five feet above mean tide. The dotted lines, in water, are lines of equal depth for every ten feet.*

LEGEND.

Shore line by Keith's Survey 1685
" " *William Lawrence's Survey (prior to 1764)*
" " *Lieut. John Hill's Survey* 1782
" " *U. S. Coast Survey* 1836
" " " " 1844
" " " " 1853

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C. CLARKSON VERMEULE, Topographer.....New Brunswick.

NEW BRUNSWICK, December 22, 1885.

To His Excellency Leon Abbett, 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 1885.

With high respect,

Your obedient servant,

GEO. H. COOK,
State Geologist.

REPORT.

The Geological Survey has been continued throughout the year. The work done in it is presented in this report.

The results of the year's operations may be properly arranged under the five following heads:

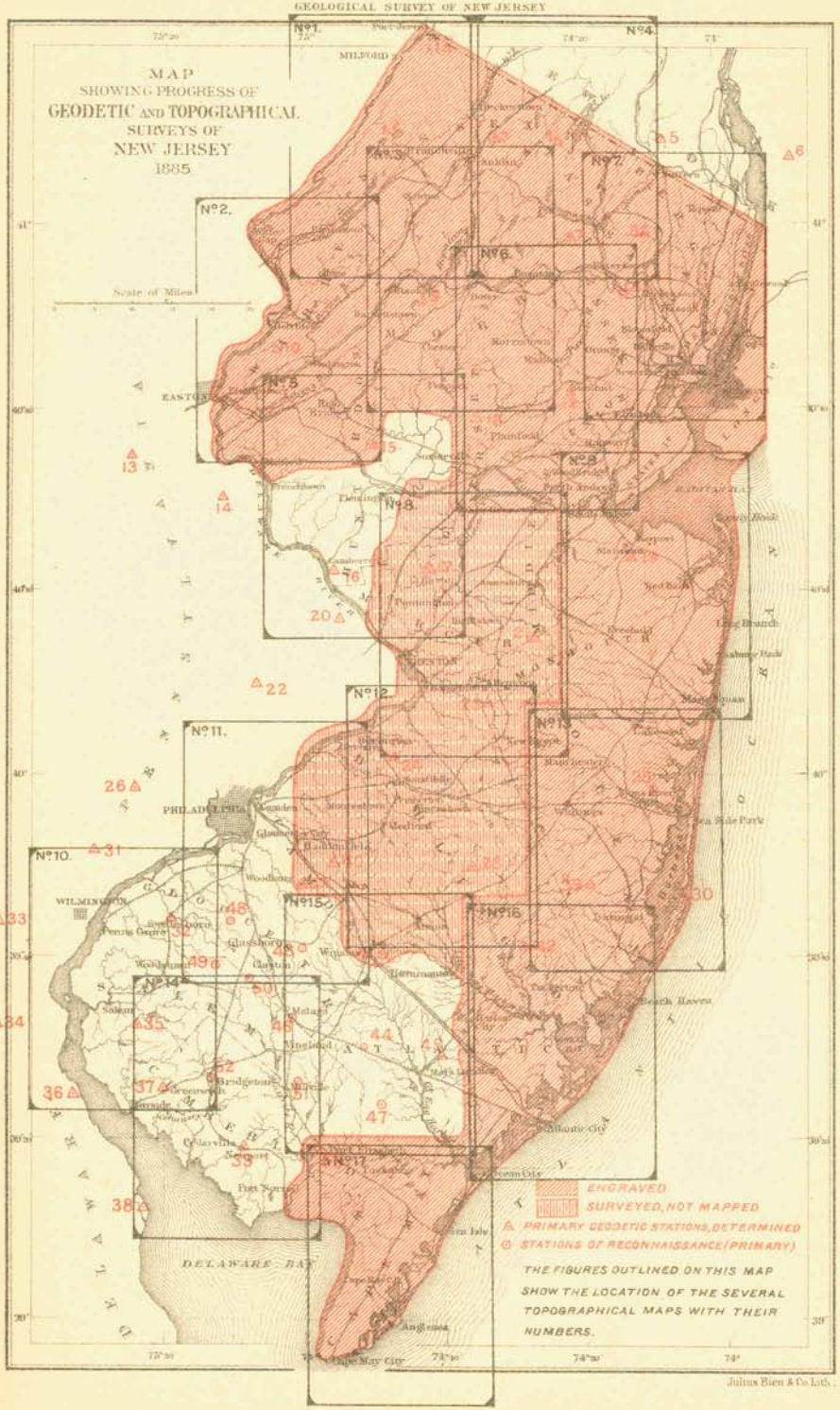
I. Geographic, Including Geodetic and Topographic Surveys.

II. Geological, Including Structural and Lithological Geology.

III. Economic Geology, Including Mining, Quarrying, Water-Supply, Drainage, Agriculture and Forestry.

IV. History of the Geological Surveys of the State and Industrial Interests During their Progress.

V. Miscellaneous Papers.


MAP
SHOWING PROGRESS OF
GEODETIC AND TOPOGRAPHICAL
SURVEYS OF
NEW JERSEY
1885
Nº1.
Nº2.
Nº3.
Nº4.
Nº5.
Nº6.
Nº7.
Nº8.
Nº9.
Nº10.
Nº11.
Nº12.
Nº13.
Nº14.
Nº15.
Nº16.
Nº17.
Scale of Miles
ENGRAVED
SURVEYED, NOT MAPPED
PRIMARY GEODETIC STATIONS, DETERMINED
STATIONS OF RECONNAISSANCE (PRIMARY)
THE FIGURES OUTLINED ON THIS MAP
SHOW THE LOCATION OF THE SEVERAL
TOPOGRAPHICAL MAPS WITH THEIR
NUMBERS.
DELAWARE BAY
PHILADELPHIA
Julius Bien & Co Lith.

I.

GEOGRAPHIC SURVEYS—GEODETIC AND TOPOGRAPHIC.

The work included in this part of the survey has all been done under the direction of the State Geologist, though the chief part of its cost has been paid by the United States: the geodetic portion by the United States Coast and Geodetic Survey, and the topographic by the United States Geological Survey. The large expenses required for carrying on such work is far beyond the moderate appropriation made by our State, and we are fortunate in getting the benefit of these government surveys, at a time when they can be so well combined with our own.

GEODETIC SURVEYS.

The United States Geodetic Survey has been conducted in New Jersey, for several years past, by Prof. Edward A. Bowser, assistant in United States Coast and Geodetic Survey. The work to be accomplished is that of determining with precision the latitudes and longitudes of points in all parts of the State, so that surveys made may be adjusted around them in their true geographical position. These points are established on mountain or hill-tops, or on other elevated ground, so that there may be unobstructed vision from one to another. The lines joining these points constitute a net-work of triangles which, when completed, will cover the whole State. The points are at distances of from ten to thirty miles apart, and in the same triangle are located so as to make the sides as nearly of the same length as possible. The reconnaissance for ascertaining and selecting these points is excessively tedious and laborious, on account of the great uniformity of the surface and the large tracts of wooded country. It requires the climbing of trees, the erection of signals, and finally the construction of high and substantial platforms. And when the reconnaissance is

satisfactorily done, the angles of all the triangles have to be measured, and the measurements repeated till extreme accuracy is attained. The angles can only be measured when the air is clear and of nearly uniform temperature. Days are frequently spent without a single satisfactory observation, sometimes whole weeks together. It will then be understood that such surveys are conducted with extreme slowness. This of New Jersey has now been going on, in a rather limited way, for 11 years, and it will yet require 2 years more for its completion. The work still to be done is in the counties of Gloucester, Atlantic, Salem, Cumberland and Cape May.

The small map of the State, facing this page, shows the primary triangulation points. Those marked with a small triangle have been occupied, and those marked with a small circle are still to be occupied. Prof. E. A. Bowser, assistant in the United States Coast and Geodetic Survey, who is conducting the work in New Jersey, reports that, during the season, he has occupied and finished the observations at the Primary Stations Martha (42) and Blangie Place (45), and has occupied the Primary Station (41) Hammonton and got about two-thirds through with it. Observations have also been made from these primaries upon the Tertiary Stations at West Plains, Spring Hill, Bear Swamp, Jemima Mount, Batsto, Hammonton Church, Indian Mills, Atco, West Creek church spire, Lower Bank church spire, Egg Harbor City church spire, Tuckerton church spire, Port Republic church spire, Third Hill, Minerva, Bass River, Harrisville factory cupola staff, Tuckahoe church spire, Estellville, Mays Landing court house, English Creek, Miry Run, Elwood church spire, Williamstown church spire, Clayton church spire, Sharps Mount, and Crowley Town church spire. The reconnaissance has also been continued for establishing primary stations at Muskee Hill, Fairton and Bridgeton.

TOPOGRAPHIC SURVEY.

The Topographic Survey of the State has been vigorously prosecuted during the entire year, and the progress made has been highly satisfactory. The work done is indicated on the small map of the State here inserted. The order in which the surveys have been made has been mainly directed by the progress of the Geodetic Survey, and its determination of the latitude and longitude of points necessary to be used in the adjustment of topographic surveys, upon the maps.

The plan pursued in drawing the maps, and locating and dividing them so as to cover the whole State, was given in last year's report, and is here reprinted. They are all on a scale of one inch to a mile, which is 1 to 63,360, and are all to be of the same size, and as large as they can be conveniently printed on a single sheet of paper. After a number of trials to ascertain what would best fit the irregular shape of the State, and the geological belts which cross it obliquely, having regard also to the location of important centers of population and business, the plan shown on the accompanying small map of the State was adopted.

The entire State requires 17 sheets to cover it. Each sheet is 24x34 inches in size. At first view it will be thought that they overlap each other and require an extra amount of engraving. The overlapping is not more than enough to give room for titles to the maps, and the engraving is not increased, as the printing is not done from the engraved stones directly, but from transfers which can be joined together in any way that may be required.

The numbering of the maps is generally from the north towards the south, and they are arranged so that those covering the same geological formation can be easily grouped together, thus:

Nos. 1, 2, 3 and 4 cover all the Archæan and Paleozoic rocks.
Nos. 2, 3 and 4 cover all the Archæan rocks and all the iron ore district of the State.
Nos. 5, 6, 7 and 8 cover the red sandstone formations.
Nos. 8 and 9, with 10, 11 and 12, cover the clay and marl districts of the State.
Nos. 9, 13, 16 and 17 cover the entire Atlantic shore.

The sheets can be taken separately or the whole together. The maps are all drawn on the same system of projection so that any two adjoining ones can be cut, fitted accurately to each other, and made into a single map, or they can be folded across and put in an atlas of 17x24 inches. These, with a map of the whole State, on a scale of five miles to an inch, and which will go on the same sized sheet with the others, will make a complete atlas of New Jersey.

The contour lines are drawn on these maps so as to show every rise of 20 feet elevation in the hilly portions of the State, and every 10 feet in the more level portions.

Of the work for 1885, Mr. Vermeule reports as follows:

During the season for field-work the party has numbered from ten to fourteen. The detail of assistants has been about as follows: two men to the office, two to setting monuments and running primary lines of levels, and from eight to ten to the field-work of the topographical survey proper. This last party has been divided into sub-parties of two each, one of which prosecuted a survey of roads and reconnaissance, the results of which have been embodied in sketch-maps in the office for the use of the topographers; and the rest have been engaged in leveling and topographical sketching, with those sketch-maps as a basis. For transit-surveys these sub-parties have usually been combined in parties of five or six. I have personally executed the trigonometrical survey, with temporary assistance secured in the vicinity of the stations. The present condition of the work is shown by the small map accompanying this report. At the close of 1884, the total area surveyed was reported to be 4,438 square miles. During this year an area of 1,390 square miles has been completed; making the whole area now surveyed 5,828 square miles, which is more than three-quarters of the State.

The field of operations this season has been the district covered by atlas sheets Nos. 8, 12 and 11, the surveys for 8 and 12 being now completed. In addition to the 1,390 square miles completed, a survey of the roads, and triangulation in advance of the contouring, has been extended over 475 square miles, embracing the remainder of atlas sheet No. 11.

The survey of this district, which is for the most part in a rich agricultural region, has involved running the traverse over 4,500 miles of roads, and leveling 3,000 miles of secondary lines for the contours. To insure accuracy of the elevations, 571 miles of primary levels have also been run. Detailed transit surveys of Sandy Hook and of the Delaware river for 35 miles, have been made, the telemeter having been used with continued success for lineal measurements.

In order to furnish a sufficient number of accurately located trigonometrical stations for checking the surveys of details, a tertiary triangulation has been extended over an area of 1,700 square miles, to supplement the primary triangulation of the United States Coast and Geodetic Survey. Fifty-three stations have been located with sufficient accuracy for plotting on the scale of 3 inches to a mile; and these, together with the 24 stations available from the work of the

above-mentioned survey, make a total of 77 stations, or an average of one to 23 square miles. They are, therefore, at an average distance apart of about five miles; somewhat less in the important districts, and more in country less developed.

PLOTTING AND ENGRAVING.

During the first four months of the year, the topographers were engaged in mapping the area surveyed during the season of 1884, and when field-work was resumed, May 1st, the total area mapped was 4,438 square miles. Of this area 2,910 square miles were reported engraved at the close of 1884, and the atlas sheets including this area had all been published at the beginning of this year. Since May 1st, the remaining 1,528 square miles have been engraved, and atlas sheets Nos. 1, 9, 13 and 17 are now ready to go to press. When they have been printed, the following will present the condition of the topographical atlas: published sheets Nos. 1, 2, 3, 4, 6, 7, 9, 13, 16 and 17—10 in all. The surveys for Nos. 8, 12 and half of 11 are made, and the original maps will be prepared this winter. The sheets remaining to be surveyed are 5, 10, 14 and 15.

PRIMARY LINES OF LEVELS.

The running of primary lines of levels has formed an important part of the season's work. The objects of this work may be stated as follows: (1) To insure accuracy in the determination of elevations for topography; (2) To ascertain the exact elevation of a series of permanent bench-marks, above mean sea level, by which means any future elevation or depression of the earth's crust may be detected and measured; (3) To furnish a series of reliable bench-marks throughout the State for the use of city and railroad surveys and all engineering purposes, in order that such surveys, by being all referred to a common datum, may constantly add to the general fund of information as to the surface of the State, and that the value of the Topographical Survey, as an aid to such surveys may be increased by having all referred to the same datum plane. In order that the above ends may be served, a statement of the methods used and results attained, in running these lines, is here in place. The following lines have been

run during the season: No. 1. From Sandy Hook, down the coast, to Cape May. This line is duplicated, or run over a second time in reverse direction, throughout. No. 2. From Toms River on line No. 1, via Whitings to Winslow and returning to Absecon on line No. 1, making a closed circuit. No. 3. From Winslow to Camden, returning via Mt. Holly to Whitings on line No. 2; a closed circuit. No. 4. From Mt. Holly on line No. 3, via Trenton, to Bound Brook, by way of the Delaware and Raritan canal, to secondary B. M. XIII. of Geodetic Levels of the United States Coast and Geodetic Survey (*see* report of the State Geologist for 1881), which line of levels runs across the State from Sandy Hook to Phillipsburg.

Line No. 1 is the most important and will serve as the initial line for all of the State south of New Brunswick and Trenton. It was run with an excellent fifteen-inch Y level of the ordinary pattern made by W. & L. E. Gurley for engineering purposes; a New York rod, with target, was used and read to 0.001 foot. The other lines were run with another level of the same kind, but with a Philadelphia rod, read to 0.01 foot, with the telescope. The average length of sight was 125 yards, and the leveling was done along railroads, or level highways, principally, so that the foresights and backsights could be carefully equalized. The work was stopped only for storms or very high winds. The average rate of progress was 23.8 miles per week, no allowance being made for time lost because of storms. In short, the work was done under the same conditions as ordinary leveling for engineering purposes, and with the same instruments. The following results may serve as a guide to those who wish to make use of the elevations:

Line No. 1—

Locality of B. M.	Distance.	First Elevation.	Second Elevation.	Difference.
Sandy Hook	0.0 miles	9.283	9.283	.000 feet.
West End	9.0 "	16.725	16.705	—.020 "
Mantoloking	26.5 "	5.419	5.381	—.038 "
Toms River	40.3 "	32.694	32.656	—.038 "
Tuckerton	67.6 "	9.697	9.626	—.071 "
Absecon	86.6 "	24.295	24.251	—.044 "
Ocean View	113.6 "	17.628	17.677	+.049 "
Cape May	135.6 "	6.491	6.457	—.034 "

Line No. 2—Length of closed circuit, 94.6 miles; error of closure, 0.33 foot.

Line No. 3—Length of closed circuit, 102.5 miles; error of closure, 0.16 foot.

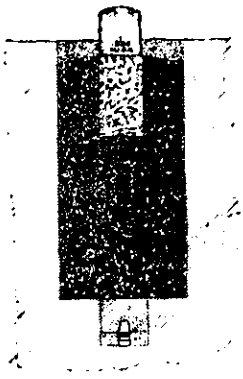
Line No. 4—Length of closed circuit, 192.3 miles (including 40.3 of line No. 1 and 44.5 of United States Coast and Geodetic Survey levels); error of closure, 0.14 foot.

On this last circuit a distance of 148 miles was run, reading entirely with the telescope to nearest .005 foot, with an error amounting to 0.365 foot. This was in part a preliminary line to line No. 1.

The above discrepancies have been carefully adjusted in the accompanying list of elevations of bench-marks.

For bench-marks small crosses, cut on the door or window-sills, water-tables or coping stones of the more permanent structures of stone or iron along the route, are used so far as is possible; but it not infrequently occurs that a bench-mark is needed where no such structures exist; special monuments are then constructed for the purpose.

The ordinary marks of reference used in surveys may be divided into two classes: First, those which depend for their safety on secrecy, or the fact of their inconspicuous or hidden position, and valueless character, so far as ordinary utility goes; second, those which depend on their stability and durability, and the protection afforded by those intelligent members of the neighboring community who understand their important uses. Experience has shown that the first-class can hardly be relied on in a populous country. The planting of any kind of underground mark is sure to excite the curiosity of the ignorant, and this curiosity increases with the lapse of time. Hence many such marks have been found disturbed during the prosecution of the survey, and if not disturbed the difficulty of finding them is a serious one. It was, therefore, decided to adopt a monument of the latter class for the primary bench-marks. The cut on the following page shows one of these bench-marks, part in elevation and part in section. A granite post about 2½ feet in length and 8 to 10 inches square is selected, and 9 inches of one end is dressed to a cylindrical shape. The end is cut to a spherical surface, with a radius of 9 inches. Exactly 9 inches below the summit of this spherical surface a shoulder is cut at the base of the cylinder, and just over this shoulder the number of the monument, the letters N. J. G. S., and the year of erection are cut. The remainder of the stone is left rough. In setting, a hole is dug about 4 feet deep and 2 feet square. In the bottom of this a smaller hole, 9 inches deep, is excavated, and in it is set a glass insulating cap,



VERTICAL SECTION AND ELEVATION OF BENCH-MARK.

such as is used on telegraph poles, with sufficient hydraulic cement run around it to hold it in place. The elevation of this underground mark is taken by holding the rod on the convex top of the glass. The small hole is now filled with ashes, or cinders. The large hole is next filled with a coarse beton, of broken stone or brick, and hydraulic cement, to such a height that the stone post, when stood on the beton, will project six inches above the ground. This stone is then set in position and beton run in around it to the level of the base of the cylinder, and gravel three or four inches deep forms a covering for the cement and completes the filling. When the whole is in place it forms a monolith weighing about a ton. It is set some time before the elevation is taken so as to allow shrinkage and settlement to take place. This sometimes amounts to 0.02 feet. The elevation is then taken by holding the rod on the exact summit of the monument. Should the top of the monument be destroyed, then the shoulder, 0.75 feet below, may be used; and if this has also disappeared, then the underground mark of glass will still record the elevation.

Eighteen of these bench-marks have been erected during the season. They have been located on public property as far as possible. Along the coast the lots of the United States Life Saving Service were chosen, and county court-yards also offered a good site. When such sites cannot be obtained, the monuments are set at the intersections of highways. In such cases they are placed entirely below the surface so as to be out of the way of vehicles.

When the topographical lines of levels are properly adjusted to

these primary lines it will be possible to furnish bench-marks in every village in the State, although these will be somewhat less accurate than those of the primary lines. The bench-marks of the latter lines will be classed as primary and secondary, while those of the topographical levels will be tertiary.

A list of bench-marks, with descriptions and elevations, is furnished herewith.

DESCRIPTIONS AND ELEVATIONS OF BENCH-MARKS.

All elevations are in feet, and refer to mean sea-level at Sandy Hook, as determined by a series of observations by the United States Coast and Geodetic Survey, extending from October 21st, 1875, to October 31st, 1881, in a continuous series. For bench-marks of the United States Coast and Geodetic Survey, from Sandy Hook to Phillipsburg, *see* Report of the State Geologist for 1881. .

NEW BRUNSWICK—PRIMARY.

Elevation, 70.951 feet.
Elevation of underground mark, 65.709 feet.

This monument (No. 1) is on Rutgers College campus, at a distance of 35 feet, measured on a perpendicular from the face of the front wall of the main college building, the perpendicular being erected from the middle of front entrance door, which door is in the middle of south side of the building.

NEW BRUNSWICK—SECONDARY.

Elevation, 17.616 feet.

A cross cut on a large coping stone at south end of lock-chamber and on the east wall of the second, or "deep" lock of the Delaware and Raritan canal.

FREEHOLD—PRIMARY.

Elevation, 186.635 feet.

A cross cut 2½ inches south of the intersection of the three joints formed by the three most southerly stones in the south corner of the large triangular base of the Monmouth Battle-Field Monument. The cross is 2½ inches south of the north apex of the stone which abuts on its south sides against the octagonal gun pedestal, which is built at the south corner of the triangular base.

FREEHOLD—SECONDARY.

Elevation, 178.146 feet.

A cross cut on east end of stone door-sill of the sheriff's office, being the most easterly of two doors in the middle of the front of Monmouth county court-house.

FARMINGDALE—SECONDARY.

Elevation, 71.704 feet.

On most easterly intersection of rails in the frog at crossing of Freehold and Jamesburg and New Jersey Southern railroads.

MONMOUTH BEACH—SECONDARY.

Elevation, 10.252 feet.

A cross cut on east end of lower stone step of southern flight at entrance, forty feet from and in front of Episcopal church, near Life Saving Station No. 4.

NORTH LONG BRANCH—SECONDARY.

Elevation, 7.262 feet.

On a marble monument, 150 yards north of Charles Van Note's blacksmith shop, at east side of Ocean avenue, just north of a low place in the road.

WEST END—PRIMARY.

Elevation, 12.256 feet.

Elevation of underground mark, 7.574.

This monument (No. 3) is erected according to the description already given (page 14), but its top is placed even with the surface of ground.

It is located on the lot of Life Saving Station No. 5, West End, and is placed at a distance of 10 feet measured perpendicularly from the middle of the west end of the station building. The line of face of north abutment of the Ocean avenue bridge over Lake Takanassee passes 6 feet to south of center of monument, and the magnetic bearing of this line is S. 75° 30′ E. The monument is 224½ feet back from the line of Ocean avenue.

LAKE TAKANASSEE BRIDGE—SECONDARY.

Elevation, 16.715.

A cross cut on north end of west wing wall of the northern abutment at the foot of the iron post at end of railing of bridge over Lake Takanassee (Green's Pond), on Ocean avenue, near Life Saving Station No. 5, West End.

ASBURY PARK—SECONDARY.

Elevation, 22.184 feet.

On water-table at southwest corner, just over the corner-stone, of First M. E. Church, at corner of Grand and First avenues, Asbury Park.

OCEAN BEACH—SECONDARY.

Elevation, 20.151 feet.

A cross cut on south end of stone door-sill of front entrance of brick school-house at Ocean Beach.

SPRING LAKE—PRIMARY.

Elevation, 18.351 feet.
Elevation of underground mark, 13.978 feet.

This monument (No. 4) is located on the lot of Life Saving Station No. 8, Spring Lake, on the east side of Ocean avenue, between Ocean Beach and Spring Lake. At the time of setting the monument the station building was so located that the northerly edge of the roof was about on the line of the lot, but the front was about 25 feet on the avenue. The monument was set 27.6 feet back from the west end of station, and 5 feet south of its south side. It may also be located as follows: Beginning at the point where the line of south curb of St. Clair avenue intersects the center line of Ocean avenue, and running thence N. 22′ 15″ E., 973 feet along center line of said avenue to a point in line with south side of station; thence along the station, 52.6 feet; thence at right angles to station, 5 feet to the monument.

The monument was set with its top level with the surface of ground, which was a little higher than the surrounding surface.

SEA GIRT—SECONDARY.

Elevation, 19.470 feet.

A point of an arrow-head cut in the stone under second pillar of the piazza at northeast corner of the northern of the two four-story buildings of the Beach House, Sea Girt.

MANASQUAN—SECONDARY.

Elevation, 21.780 feet.

A cross cut on east end of sand-stone door-sill of the First National Bank on Main street, just east of entrance to South street.

MANTOLOKING—PRIMARY.

Elevation, 4.146 feet.
Elevation of underground mark, 0.780 feet.

This monument (No. 5) is located on the lot of Life Saving Station No. 11, Mantoloking, on the beach about half a mile south of the railroad station. It is placed N. 67° E., 2 feet from the southwest corner of the lot. The location with reference to property line surveys is as follows: Beginning at a corner on the salt meadows, which is S. 14° W., 281 feet from the point of meadows at east side of mouth of a small creek, and N. 85° W., 150 feet from head of same creek; running thence N. 86° E., 550 feet to the intersection of this line with the produced west line of above-mentioned lot; thence N. 22° E., 33½ feet to southwest corner of lot; thence N. 67° E., 2 feet to the monument.

[This monument is set 3½ feet deep, and rests on the old meadow which underlies the beach at this place. The turf of the meadow was not disturbed, but an area of cement was spread right upon it. It can scarcely be entirely depended upon, but shrinkage of the new cement and settlement of stone had only amounted to .014 feet one month after setting.]

TOMS RIVER—PRIMARY.

Elevation, 30.380 feet.
Elevation of underground mark, 25.400 feet.

This monument (No. 6) is placed in the southwest corner of the Ocean county court-yard, 3 feet back from the iron front fence and 3

feet east of west line of lot. Measured parallel with Washington street, it is 28.75 feet west of the west line of Allen street produced, 72.3 feet west of center line of court-house, and 145 feet west of southern marble true meridian monument which stands in southeast corner of the yard. The monument is also distant 69.6 feet southwesterly from the southwest corner of court-house.

TOMS RIVER—SECONDARY.

Elevation, 32.675 feet.

A cross cut on east end of stone door-sill of main entrance of Ocean county court-house, Toms River.

WARETOWN—PRIMARY.

Elevation, 12.664 feet.
Elevation of underground mark, 8.429 feet.

This monument (No. 7) is located at the cross-roads at the Hopkins House, where the center line of the road from Waretown station, New Jersey Southern Railroad, to the shore of Barnegat bay, intersects the easterly fence line of the main shore road. It is 86.2 feet from southwest corner of hotel, 17.7 feet from northeast stone pier under porch of store, and 20.7 feet from center of willow tree standing just to southwest of it. Measuring along the produced first course of the road running by a small graveyard to the bay, the distances are, to edge of upland, 1,540 feet, to ordinary high-water mark, 2,850 feet.

The top of monument was placed just below the surface of the road.

WARETOWN—SECONDARY.

Elevation, 20.721 feet.

On center of southwest side of large granite (Falkinsburg) monument, on top of small, flat projection of the top base-stone directly under the polished inscription-face, upon the bottom of which is cut, "Died May 10, 1855." The monument is in the Waretown cemetery, east of main shore road.

BARNEGAT—SECONDARY.

Elevation, 35.764 feet.

A cross cut in east end of lowest flagstone step on south side of the basement front door of Baptist church.

TUCKERTON—PRIMARY.

Elevation, 22.632 feet.
Elevation of underground mark, 17.972 feet.

This monument (No. 8) is set in the northwest corner of the Presbyterian churchyard, at the corner of Main and Cedar streets, 3.2 feet back from the front fence, being in line with the south fence line of Main street, west of Cedar street, and 3 feet east of the east line of Cedar street. It is 32.9 feet from the northwest corner of the church.

LEEDS POINT—PRIMARY.

Elevation, 52.691 feet.
Elevation of underground mark, 48.648 feet.

This monument (No. 9) is located just west of the hotel at forks of roads to Port Republic and to Absecon. It is at the intersection of the center line of Absecon road with the south line of Port Republic road. The following measurements were taken: To northeast corner of store at southwest corner of roads, 52.5 feet; to center of small cedar north of and opposite the store, 69.2 feet; to center of wild cherry tree at southeast road corner, 22.5 feet, and to center of maple tree standing on the south side of Point road, east of forks of roads, 75.9 feet.

The top of this monument is just below the surface of the road.

ABSECON—PRIMARY.

Elevation, 24.232 feet.
Elevation of underground mark, 19.561 feet.

This monument (No. 10) is located in the small triangular grass plot where the main road from Philadelphia and Egg Harbor City, enters the main shore road from Absecon to Leeds Point. It is set in the center line of the Philadelphia road and 12.75 feet west of the center line of the Shore road (the road being 49.5 feet wide). It is also 64 feet from the corner of old house standing in yard at the west street corner; 62.6 feet from corner of house on the south street corner, and about in range with its northeast end, and 131.9 from corner of new house on the east street corner.

The top is level with the surface of ground.

ABSECON—SECONDARY.

Elevation, 30.656 feet.

On east end of stone door-sill of Methodist Episcopal church, about 220 yards west of the above Primary Monument.

MOUNT PLEASANT—SECONDARY.

Elevation, 13.962 feet.

A cross cut on bluestone door-sill of northerly door at east side of Atlantic City water-works pumping station, just north of Mount Pleasant.

ATLANTIC CITY—PRIMARY.

Elevation, 8.954 feet.

On an old United States Coast Survey tidal bench-mark cut on northwest side of base of Absecon light-house. It is under the south end of a window-sill, and is a small shelf cut in the convex water-table, with the letters "U. S. C. S." cut above it.

ATLANTIC CITY—SECONDARY.

Elevation, 10.184 feet.

A cross cut on north end of stone door-sill of Atlantic City National Bank, at northerly corner of Atlantic and North Carolina avenues, the door being on Atlantic avenue.

SOMERS POINT—PRIMARY.

Elevation, 28.840 feet.
Elevation of underground mark, 24.596 feet.

This monument (No. 11) is placed on the brow of the hill in front of the old Somers homestead, a brick building on the Shore road just south of the railroad crossing, at Somers Point. It is set in the center line of the road which runs to the west and is 75 feet from the southeast corner of the house; 52 feet due west of a small cedar standing on the east side of road, and N. 63° E., 52 feet from a large cedar standing at the southwest road corner.

The monument was placed with its top level with surface of ground.

OCEAN CITY—PRIMARY.

Elevation, 10.298 feet.
Elevation of underground mark, 5.320 feet.

This monument (No. 12) is set about 3 feet south of the north corner of the new life saving station lot, which runs from the corner of Atlantic avenue and Fourth street, northeasterly 100 feet along said avenue, and southeasterly 130 feet along said street. It is set about 2.1 feet southwest of the northeast line of the lot. It is about 400 feet from high-water line at this time.

SEA ISLE CITY—PRIMARY.

Elevation, 5.193 feet.
Elevation of underground mark, 1.130 feet.

This monument (No. 13) is set just south of the north corner of the new United States light-house lot, which is located on the east side of the Sea Isle and Ocean City Railroad, in the south corner of block 62 and is bounded on the southeast by the beach, and on the southwest by Whelen street.

The monument is set 2 feet from the northwest line of the lot and 2 feet from the northeast line, which makes it 2.8 feet from the north corner of the lot.

CAPE MAY COURT HOUSE—PRIMARY.

Elevation, 19.498 feet.
Elevation of underground mark, 14.961 feet.

This monument (No. 14) is set in the east corner of Cape May county court-yard, 4 feet from the front or street fence, and 5 feet from the line-fence between the court-yard and the M. E. church-yard. It is also 81.7 feet from the center of the south "true meridian" post, 62 feet from the north one, 54 feet from east corner of court-house and 42 feet from south corner of M. E. church.

COLD SPRING—SECONDARY.

Elevation, 20.703 feet.

A cross cut on north end of northerly stone door-sill of Cold Spring Presbyterian church (brick).

CAPE MAY—PRIMARY.

Elevation, 6.409 feet.
Elevation of underground mark, 1.829 feet.

This monument (No. 15) is located on the Cape May light-house lot, just southeast of Cape May Point and about two miles west of Cape May City.

The Cape May and Sewell's Point Railroad divides the light-house property into two parts.

The monument is set in the east corner of the south part, 2 feet from the line-fence of the railroad and 2 feet from the southeast line of the lot. The United States Life Saving Station stands on the south and the light-house on the north part of the lot. The corners of the lot are marked by square granite posts.

Beginning at the southwest corner of lot, the line runs S. 62° 40′ E., 206.8 feet to south corner; thence N. 28° 30′ E., 214.25 feet to a point 2 feet southeast of the monument, the whole distance to the next corner being 424.6 feet. From the first-mentioned corner the magnetic bearing is N. 1° 40′ E., from the second N. 10° W., and from the third N. 28° W., to the center of the light-house.

CAPE MAY—SECONDARY.

Elevation, 8.244 feet.

On northwest corner square stone monument in southeast corner of light-house lot.

CAPE MAY—SECONDARY.

Elevation, 13.187 feet.

On United States Coast Survey tidal bench-mark of 1867 cut on east side of projecting water-table at base of Cape May light-house.

WESTON—SECONDARY.

Elevation, 42.970 feet.

A triangle cut on the coping of Delaware and Raritan canal lock and six feet north of east edge of lock bridge.

EAST MILLSTONE—SECONDARY.

Elevation, 45.480 feet.

A triangle on the southwest corner of a stone supporting south gate post at entrance to N. S. Wilson's brick residence, south of Thatcher's drug store at easterly corner of Market street and Railroad avenue.

GRIGGSTOWN—SECONDARY.

Elevation, 44.070 feet.

On summit of stone, indicated by an arrow, standing at east corner of Edgar's mill on west side of canal at Griggstown.

GRIGGSTOWN—SECONDARY.

Elevation, 50.530 feet.

A triangle on the coping of west lock wall under east edge of bridge at Delaware and Raritan canal lock, half a mile south of Griggstown.

ROCKY HILL—SECONDARY.

Elevation, 43.910 feet.

Center of triangle cut on the east end of stone door-sill at entrance of old stone grist-mill beside race, 50 rods west of railroad station.

KINGSTON—SECONDARY.

Elevation, 57.710 feet.

A triangle cut on the east edge of west wall of Delaware and Raritan canal lock.

MILLSTONE AQUEDUCT—SECONDARY.

Elevation, 58.940 feet.

A triangle cut in the center of the memorial plate on top of the south end of the west abutment of aqueduct carrying the Delaware and Raritan canal over the Millstone river, two miles south of Kingston.

PRINCETON—PRIMARY.

Elevation, 208.510 feet.

Center of triangle cut on the north end of the door-sill at west entrance to the Hall of Science on college campus.

PRINCETON—SECONDARY.

Elevation, 217.180 feet.

A cross cut on top of water-table at the northeast corner of East College, on Princeton College campus.

TRENTON—PRIMARY.

Elevation, 54.250 feet.

On broad water-table, 3.2 feet above pavement, in re-entrant angle of stone moulding. The point is indicated by an arrow-head, and is 1.1 feet south from produced line of south jamb of the most southerly window on the west side of the United States Government building, at the northeast corner of Montgomery and State street.

TRENTON—SECONDARY.

Elevation, 56.36 feet.

A triangle cut on the coping of north side of stone pivot-pier of railroad bridge over canal at entrance of feeder, one block north of Perry street.

TRENTON—SECONDARY.

Elevation, 52.610 feet.

A triangle cut on the northeast corner of the most northerly coping stone of west lock-wall of Prison lock of Delaware and Raritan canal.

BORDENTOWN—SECONDARY.

Elevation, 15.530 feet.

A triangle cut on the west end of stone door-sill at the south entrance to fire-room of Bordentown Reservoir and Water Co.'s pump-house, near the outlet lock of the Delaware and Raritan canal.

BORDENTOWN—SECONDARY.

Elevation, 24.170 feet.

A triangle cut on coping stone at the east end of the north abutment of railroad bridge over roadway, just north of lower Bordentown railroad station.

WHITE HILL—SECONDARY.

Elevation, 14.240 feet.

On a protuberance indicated by an arrow and the letters B. M., on the southeast corner of the flagstone coping of the northwest wall of bridge over ice pond, on the road to Burlington, one mile west of White Hill.

BURLINGTON—PRIMARY.

Elevation, 12.530 feet.

Cross cut on dressed stone at west end of door-sill of main entrance to Baptist church, at northwest corner of Broad and Stacy streets.

BURLINGTON—SECONDARY.

Elevation, 11.300 feet.

A cross on northwest corner of projecting ledge of iron post at northwest corner of iron bridge over Assiscunk creek, on Main street.

DEACON'S—SECONDARY.

Elevation, 80.560 feet.

A triangle cut on water-table at southwest corner of brick schoolhouse, on east side of turnpike, $\frac{3}{8}$ mile southeast of Deacon's station.

MOUNT HOLLY—PRIMARY.

Elevation, 185.470 feet.

On the northwest corner of granite monument, located on the summit of Mount Holly, which marks the United States Coast and Geodetic Survey triangulation point, Mount Holly.

MOUNT HOLLY—SECONDARY.

Elevation, 16.880 feet.

On northwest corner of door-sill of National Bank, on northeast corner of Main and Mill streets.

MOUNT HOLLY—SECONDARY.

Elevation, 42.970 feet.

On the northwest corner of marble door-sill of main entrance to Burlington county court-house.

BIRMINGHAM—SECONDARY.

Elevation, 31.290 feet.

On the most southerly of two bolts on the top of northwest wing-wall of bridge over race, 100 yards north of Birmingham railroad station.

PEMBERTON—SECONDARY.

Elevation, 39.23 feet.

On the southwest corner of granite block, upon which rests the south end of west iron arch of bridge over mill pond, South Pemberton.

WHITINGS—PRIMARY.

Elevation, 173.460 feet.
Elevation of underground mark, 170.583 feet.

This monument (No. 16) is located at the cross roads in Whitings, where the road from New Egypt to Toms River crosses the road running along the west side of the New Jersey Southern Railroad from Woodmansie to Manchester. It is set in the center line of the former road, and in line with the trees planted along the west side of the latter road, between the sidewalk and wagon track. It is 41.5 feet southwest of the southwest corner of Mr. Wright's store; 11 feet from the west line of the street running nearly north and south; 88 feet to center of the main track of the New Jersey Southern Railroad; 21 feet to center of nearest maple tree of the row on the north; 45.4 feet to center of the next; 21.7 to center of nearest maple tree of the row on the south, and 46.9 feet to the next.

The top of this monument is below the surface.

WHITINGS—SECONDARY.

Elevation, 172.530 feet.

On granite monument marking northwest corner of roads. It is seven yards distant from southeast corner of large hotel, now unoccupied.

MERCHANTVILLE—SECONDARY.

Elevation, 80.110 feet.

On the west end of marble door-sill (close by corner of brick work), of the east front door of new railroad station.

GLOUCESTER FERRY—SECONDARY.

Elevation, 5.910 feet.

A cross cut on southeast corner of slate slab on top of rubble wall, southeast of Gloucester ferry pier, and 56 yards in a southerly direction from Buena Vista Hotel.

CAMDEN—PRIMARY.

Elevation, 30.640 feet.

A cross cut on southeast end of highest step of main entrance to new Camden county court-house, on Federal street.

CAMDEN—SECONDARY.

Elevation, 21.230 feet.

A cross cut on north end of north door-sill on east side of station at junction of Camden and Atlantic and Pennsylvania Railroads, at corner of Tenth and Market streets.

CAMDEN—SECONDARY.

Elevation, 34.530 feet.

On easterly corner of pedestal, over the builders' names (Krips & Shearman), of the soldiers' monument, on Haddon avenue, just north of city hall.

PHILADELPHIA—PRIMARY.

Elevation, 11.680 feet.

On a granite post, at the southwest corner of Swanson and Reed streets, about 8 inches square, and projecting 1 foot above the ground, close to the corner of the Delaware Sugar Refinery and one and a half feet north of Reed street. This bench-mark was established by the U. S. Coast and Geodetic Survey, and its height above mean low-water at the old navy yard on the Delaware, from their tidal observations, is given as 15.029 feet. The range of tides is given as 6.01 feet at the same place. This would make the elevation of the bench-mark above mean tide in the Delaware 12.024 feet, and would make the elevation of mean tide as determined by the levels—0.34 feet, or four inches lower than mean tide at Sandy Hook.

KIRKWOOD—SECONDARY.

Elevation, 60.040 feet.

On cross on southeast corner of slate slab on south side of outlet of pond, on dam opposite railroad station.

WINSLOW—PRIMARY.

Elevation, 112.019 feet.

Elevation of underground mark, 107.779 feet.

This monument (No. 18) is located in the grass plot, 22.5 feet west of flag pole. It is in the center line of road running south of New Jersey Southern Railroad station, and is about in center line of roads running to Hammonton and Waterford. The following measurements were taken from the monument: N. 46° 30′ E., 57 feet to large oak; N. 6° 30′ W., 41 feet to another large oak; 123.25 feet to southeast corner of Hay & Co.'s store; 50 feet to corner of glass works fence; 55 feet perpendicularly to south line of road to New Germany; 58 feet to southwest street corner, and 73 feet to northeast corner of house on this southwest corner.

WINSLOW—SECONDARY.

Elevation, 112.760 feet.

A cavity cut in foundation at south corner of brick chimney, at south corner of Hay & Co.'s steam flour mill, at Winslow. An arrow-head points to it, and it is 1.8 feet above surface of ground.

APPLE-PIE HILL—PRIMARY.

Elevation, 207.570 feet.

On summit of the monument which marks the United States Coast and Geodetic Survey triangulation point on Apple-pie Hill, 3 miles southeast of Shamong station, and three-quarters of a mile northwest of Harris station, on New Jersey Southern Railroad, in Burlington county.

HAMMONTON—SECONDARY.

Elevation, 102.820 feet.

A cross cut on the water-table on south side of front door, and 3.1 feet from corner of three-story concrete store standing on east side of Bellevue street, and on north side of Camden and Atlantic Railroad.

DA COSTA—SECONDARY.

Elevation, 80.143 feet.

A cross cut 0.40 feet from each edge of stone at southeast corner of coping of southeasterly culvert wall on Camden and Atlantic Railroad, one mile west of Da Costa station.

EGG HARBOR CITY—PRIMARY.

Elevation, 56.573 feet.
Elevation of underground mark, 52.511.

This monument (No. 17) is located on southwest side of Agassiz street and the southeast side of Buffalo avenue, 5 feet from the street and avenue lines, and 3 feet inside of center of hedge which stands 2 feet from the street and runs around the School Park. There are three parks on the southwest side of Agassiz street, the School Park being in the middle. Excursion Park lies northwest of Buffalo avenue; School Park lies southeast of it and runs to Agricultural Fair Grounds, and these Fair Grounds extend from School Park to St. Louis avenue.

The monument is 251.8 feet to the northwest of the north corner of the school-house, 26.5 feet from center of a large maple tree on Buffalo avenue, 12.45 feet from center of another tree standing to to northeast of former, and 44.93 feet from center of large maple tree standing on southwest side of Agassiz street.

EGG HARBOR CITY—SECONDARY.

Elevation, 60.274 feet.

A cross cut on south corner of upper outside flag-stone step in front of side door of brick store on the north corner of Philadelphia avenue and Agassiz street.

DOUGHTY'S—SECONDARY.

Elevation, 25.755 feet.

A cross cut on coping stone at east end of south wall of culvert on Camden and Atlantic Railroad, 60 yards east of 11–49 mile-post, just west of Doughty's station. The cross is 0.75 feet from the corner.

COMPARISON OF TIDES ALONG THE COAST OF NEW JERSEY BY MEANS OF THE PRIMARY LEVELS.

At Sandy Hook the United States Coast and Geodetic Survey has taken a series of observations, with a self-registering tide-gauge, extending continuously from October 21st, 1875, to October 31st, 1881. The mean of all the readings of this series is taken as mean sea level at this place and is the datum plane (the zero) for all elevations. This series of observations makes the mean rise and fall of the tide at Sandy Hook 4.7 feet. The gauge was placed at the New Jersey Southern Railroad wharf on the inner side of the Hook.

In the following lists the observations compared by means of United States Coast Survey tidal bench-marks, as they give a series representing very closely the mean of tides at the given date, are most exact. It should be mentioned, however, that from contraction or broadening of the inlets from year to year it is almost certain that the mean of the tides in all of the bays, &c., changes from year to year. Observations of the present height of high-water are necessarily approximate, being from single observations or from testimony of residents familiar with the tides, but are believed to be correct within one or two-tenths of a foot.

Elevations of the tide-marsh do not necessarily correspond to present high-water, but the marshes are probably slightly higher than any mean high-water that has prevailed for any length of time, for perhaps a half century past.

It will be noticed that high-water in the bays is much lower, generally, than in the ocean, but, as the range of tide is much less, both mean tide and low-water are much higher than in the ocean. The fact is that high-water is of too short duration to enable the bays to fill through the contracted inlets. The study of the tides in Barnegat bay reveals the fact that for some time after high-water the tide sets in the inlet, and later from a central point in the bay in both directions, *i. e.* toward the head of the bay and toward the inlets, and high tide at the head of the bay is several hours later than in the ocean outside the beach. It is hoped that as the survey progresses it will be possible to gain much more information as to the tides.

LOCALITY.	ELEVATION IN FEET.			
	TIDE MARSH.	HIGH WATER.	MEAN TIDE.	LOW WATER.
Sandy Hook, U. S. C. S..	.....	2.35	0.00	-2.35
Perth Amboy, Lewis street	.....	2.40	.....	.....
One-quarter mile N. W. of Matawan	2.84	.....	.....	.....
Flat creek; road from Keyport to Keansburg	3.14	.....	.....	.....
Two miles west of Port Monmouth	.....	2.76	.....	.....
Red Bank, Navesink river, 1884	.....	1.62	.....	.....
Clay-pit Creek, Navesink river, 1884	.....	1.76	.....	.....
Parker's creek, 1 mile north of Oceanport, 1884	1.91	.....	.....	.....
Manasquan river, north side	2.05	.....	.....	.....
Mantoloking, on Barnegat bay	1.40	.....	.....	.....
Bay Head, Barnegat bay	0.98	0.67	.....	.....
Metedeconk river, 1 mile east of Cedar Bridge, range of tide about 0.70 ft	.....	0.85	.....	.....
Kettle creek, U. S. C. S., gives range of tide 0.47	.....	.....	.....	.....
Toms river, U. S. C. S. observations of 1876, west of Island Heights	.....	0.89	0.52	0.16
Toms river, 1885, at village bridge	.....	0.80	.....	.....

LOCALITY.	ELEVATION IN FEET.			
	TIDE MARSH.	HIGH WATER.	MEAN TIDE.	LOW WATER.
Cedar creek, 1885, at shore road	.....	2.76	.....	.....
Cedar creek, U. S. C. S. observations, 1874, range of tides 0.75	.....	.....	.....	.....
Waretown (Barnegat bay)	.....	1.31	.....	.....
Barnegat. End of Bay avenue	1.40	.....	.....	.....
Barnegat Landing, on Double creek, range of tides, U. S. C. S. observations, 1874, 0.75	.....	.....	.....	.....
Barnegat inlet, range of tides in the bay, 2.04, from U. S. C. S. observations, 1866	.....	.....	.....	.....
Osborne's island, north side of Great bay	.....	1.59	.....	.....
Great bay, mouth of Mullica river	.....	1.94	.....	.....
Willett's house, north shore of Great bay, 1 mile back from New inlet	2.21	.....	.....	.....
Willett's house, from U. S. C. S. observations of tides in Great bay, 1872. (Compare above for 1885.)	.....	2.70	1.00	–0.73
[For reason for this change of about –0.70 in height of high-water, see maps showing changes at New inlet.]				
Wharf at Bond's Long Beach house, range of tide 2.35 feet, from U. S. C. S. observations, 1873	.....	.....	.....	.....
Oswego river, at Bridgeport, 1884	.....	1.42	.....	.....
Mullica river, at Lower Bank bridge, 1884	.....	1.45	.....	.....
Mullica river, at Gloucester landing, 1884	.....	1.26	.....	.....
Port Republic, Nacote creek, 1884	.....	1.80	.....	.....
Absecon creek, shore road, 1883	.....	1.75	.....	.....
Absecon bay, west side, 1883	2.17	.....	.....	.....
Absecon inlet, range of tide inside of beach 3.95, from U. S. C. S. observations, 1872	.....	.....	.....	.....
Atlantic City, draw-bridges	2.08	.....	.....	.....

LOCALITY.	ELEVATION IN FEET.			
	TIDE MARSH.	HIGH WATER.	MEAN TIDE.	LOW WATER.
Great Egg Harbor bay, Somers Point, April, 1883	.....	2.01	.....	.....
Great Egg Harbor bay, Somers Point, September 8th, 1885	.....	2.05	.....	.....
Great Egg Harbor bay, mouth of Tuckahoe river	2.36	.....	.....	.....
Great Egg Harbor bay, mouth of Great Egg Harbor river	2.06	.....	.....	.....
Tuckahoe bridge, 1884	2.37	.....	.....	.....
End of shore road, Beesley's point, 1884	2.46	.....	.....	.....
Corson's inlet	2.67	.....	.....	.....
Sea Isle City	2.56	.....	.....	.....
Ocean View, at Van Gilder's mill pond, 1884	1.74	.....	.....	.....
Jenkins' sound, Shell-bed landing, 1884	2.40	.....	.....	.....
Cape May Landing, 1884, from a short series by the U. S. C. and G. S.	.....	2.70?	0.35?	-2.00?
Fishing creek, Delaware bay shore, 1884	2.59	.....	.....	.....
Dyer's creek, bay shore road, 1884	2.60	.....	.....	.....
Dennis creek landing, embanked meadow, 1884	(1.37)	.....	.....	.....
Mauricetown, Maurice river, 1884	.....	2.32	.....	.....
Fortesque beach, east shore of Delaware bay, U. S. C. S. observations, 1880, range of tide 6.00	.....	.....	.....	.....
Philadelphia, Old Navy Yard, U. S. C. S. observations of 1878, compared by bench-mark at Swanson and Reed streets	.....	2.67	-0.34	-3.34
Rancocas creek, Mount Holly	.....	.....	3.33	.....
Delaware river, Burlington	.....	.....	3.80	.....
Delaware river, Bordentown	.....	.....	3.70	.....

NOTE.—When no other date is given, observations were made in 1885.

II.

GEOLOGICAL SURVEYS—STRUCTURAL AND LITHOLOGICAL.

The completion of the topographical maps is furnishing the basis from which to study, describe, and lay down with accuracy the various geological phenomena and features of the State. And the work is fairly begun, both in the older and the newer formations, and satisfactory progress has been made.

The work in the older rocks has been done by Dr. N. L. Britton, assisted by Mr. F. J. H. Merrill. With the topographical maps in hand, section lines were drawn in a northwest and southeast direction entirely across the Archæan rocks which constitute the Highlands. The first of these was along the boundary line between New Jersey and New York, and then others were drawn nearly parallel to these, and at intervals of about five miles, until the Delaware was reached. There were eleven of these drawn, the last following the bank of the Delaware river. These sections were carefully surveyed, the structure of the outcropping rocks examined and recorded, and specimens of all the varieties of rock were taken for further examination. The topographic maps have furnished the data from which to draw the sections, and the result of the work thus far is given in the following report by Dr. Britton:

ARCHÆAN ROCKS.

The geological study of all Archæan regions is difficult, as compared with that of simple sedimentary rocks. The stratigraphy is complicated; the strata contain no fossils by which we can accurately determine their age, and are often very similar over great areas. We have to depend on the kinds of rock; to measure very carefully the amount and direction of the inclination of the beds, and to consider the surface features of the region, and then have some means of graphically rep-

resenting all the field observations and the results of laboratory work, before conclusions of value can be drawn. To this end, accurate maps are an absolute necessity. These have recently been supplied in the sheets of the topographical survey of the State, which are now engraved and printed for the entire Highland area. Besides the ordinary features given on most maps, they show the absolute height of all points, to within a few feet. This is accomplished by means of contour lines of equal altitude, which represent as well the exact position of every mountain, hill and valley. With these maps, much more accurate work can be accomplished than has been possible without them.

WORK ALREADY DONE.

The Archæan, metamorphic rocks of New Jersey have been described in various reports of the State Geological Survey, and the geographical areas underlaid by them have been laid down on geological maps which have accompanied these reports, and on the large wall-map of 1868. The geological structure of the system, including its general northeast and southwest strike, its prevailing southeast dip and other salient features, have been elucidated. The phenomena of faults have also been made plain. The physical features of the Highland mountain ranges have been noted, and the numerous deposits of magnetic iron ore in them have been described.

The geology of the Highlands was first studied by Professor Henry D. Rogers, and, in his first report as State Geologist,* he briefly describes the Primary Region. He gives five geological sections across the State, three of which cross the Highlands, and represent the mountain ridges as anticlinal folds, the strata exposed along the southeastern side of a ridge dipping towards the southeast, while those on the opposite side dipped northwestwardly. In this his sections are quite imaginary, very few, if any, of the ridges being simple anticlinal folds, and the southeast dip is generally as prevalent on one side of a mountain or hill as on the other, though often differing perceptibly in degree. He paid much attention to the deposits of iron and zinc ores, which he regarded as veins filled originally by molten ore from below, a view which has not been entertained by any members of subsequent surveys. They are abundantly proven to be integral parts

*Report on the Geol. Survey of the State of New Jersey, 1836.

of the stratification and contemporaneous in origin with the other Archæan rocks. Professor Rogers appears to have thought that the white crystalline limestones were derived from and hence of the same geological age as the blue magnesian limestones, the agent of alteration being the heat introduced by outbursts of molten ore with others of granite and syenite. It has been conclusively shown that this theory is erroneous; the supposed dykes of granite are strata conformable to the white limestone, as are the iron and zinc ore beds contained in it, all geologically older than the blue limestones with the associated quartzites or sandstones, and slates, which compose the lower silurian system. In his final report of 1840, he further discusses the Primary rocks of the Highlands,* describing many of the iron mines, and briefly refers to the area of gneissic rocks at Trenton.

Dr. William Kitchell,† in describing the Physical Geography and Geological Formation of Sussex county, mentions the metamorphic rocks as "gneiss, hornblende slate and white crystalline limestone"; subsequently‡ he described the Archæan formation with much detail, noting its relation to the sandstones, limestones and slates of newer formation, the kinds of rocks recognized by him, the boundaries of the areas, and the occurrence and properties of the iron ores.

In 1868, all the information regarding the Archæan rocks which had been gathered by the present survey up to that time, was brought together in the "Geology of New Jersey," in the chapter on the Azoic Formation.§ The boundaries of the formation were minutely described; its structure was discussed and the kinds of rock and their mineral constituents were noted, especial attention being given the crystalline limestones. The metamorphic rocks of Trenton, Jersey City and Hoboken were described and discussed. The Highland series was here divided geographically, for convenience of description, into four belts, corresponding with the more prominent mountain ranges and running nearly parallel with each other from southwest to northeast.

In 1873‖ the subject was again opened, and additional facts and conclusions relating to the Archæan were presented. The subdivision

* Rogers' Report of 1840.

† First Ann. Rep. Geological Survey of New Jersey, 1854, p. 169.

‡ Second and Third Ann. Rep, 1855 and 1856.

§ Geology of New Jersey, pp. 43–69 and 309–326.

‖ Ann. Rep. State Geologist, pp. 11–96.

of the region into four belts was here more fully described, and names were given these as follows:

(1) The *Ramapo Belt*, along the southeastern side of the area, its most prominent ridges being Ramapo, Trowbridge and Mine Mts.; its northward extension in New York State is marked by the Dunderberg, on the Hudson river. (2) The *Passaic Belt*, next towards the northwest, a generally elevated table-land area, but including some marked ridges, as Mt. Hope and Fox Hill; this, also, is continued into New York, and on the Hudson is marked by the lofty Crow's Nest and Storm King Mts., below Cornwall; it is bounded to the northwest by a continuous valley, in which lie Greenwood lake, Macopin pond, Denmark pond and other bodies of water, and known to the southwest as German valley. (3) The *Musconetcong Belt*, including the Wawayanda, Hamburgh, Schooley's, Pohatcong and Musconetcong mountains, and containing the highest land in the State; this belt also extends into New York, but does not reach the Hudson; and (4) the *Pequest Belt*, including Pochuck mountain, in New Jersey and New York, and the detached mounts, Adam and Eve, in Orange county, southwestwardly continued in the Pimple hills, Jenny Jump, Scott's and Marble mountain to the Delaware, and in Pennsylvania known as Chestnut Hill; this belt forms the northwestern side of the Highlands. The geographical positions of these belts were shown on an accompanying map. A list of iron mines, then opened in the State, with notes, is appended.

In 1879* the magnetite deposits were again discussed, and a list given of the mines; they were geographically classified in the four belts above described. A chapter was devoted to the exploration for new deposits.

In 1880† a revised and extended list of mines was presented.

In 1881‡ additional notes on a few iron mines were supplied and some analyses of ores published.

In 1883§ the whole subject of Archæan Rocks was again discussed. Their geographical extent and surface features, the rocks and their mineral composition, the geological structure of the system and its dip, strike, pitch, folding and faulting were described and many of

*Ann. Rep. State Geologist, 1879, pp. 36–101.
†Ann. Rep. State Geologist, 1880, pp. 98–130.
‡Ann. Rep. State Geologist, 1881, pp. 33–39.
§Ann. Rep. State Geologist, 1883, pp. 27–158.

these points illustrated. A complete list of iron mines was given and the methods of exploration for mines and the location of new deposits were discussed. A short account was given of the dykes and veins of igneous rock, which occur in the formation.

In last year's report* the results of the season's field-work were presented. It was then concluded that the former geographical subdivision of the Archæan area into the four belts has little geological value, that the rocks of one belt might almost pass as representative of them all, and some more rational and valuable geological subdivision was sought. It was shown that there are great areas of practically unstratified rocks in the Highlands, and on each of the two section lines which were examined—one beginning at the Ramapo river, near Oakland, and followed northwestwardly across the system and the included Paleozoic areas to Milton, the other extending from Pompton to the vicinity of Deckertown—these massive areas were crossed. Their location was in the old second or Passaic belt. The rocks of these unstratified areas were described as consisting mainly of feldspar, quartz and hornblende, the amount of mica being inconsiderable in proportion to the other constituents. They are mainly the granulites, quartz, syenites and hornblendic granulites of the present report, though all these occur also in beds, and often well stratified elsewhere in the system. Their relation to the stratified rocks by which they are surrounded was not ascertained, no contacts being observed. These massive areas were described as occupying the elevated table-lands, and the suggestion was made that our Archæan might naturally be divided into massive, granitoid and stratified gneissic rocks. Another list of iron mines was given, with additional notes and analyses.

KINDS OF ROCKS.

In the study of the numerous specimens collected during the field-work of the past season, as well as of those previously obtained, it has been found necessary to considerably augment the list of rocks composing the Archæan system. As there is much difference of nomenclature in the published works on lithology, it is thought advisable to briefly describe the structure and mineral composition of each kind of rock recognized by us, so that in alluding to them we shall not be misunderstood. The following include only metamorphic

*Ann. Rep. State Geologist, 1884, pp. 27–69.

rocks; those of undoubted igneous origin, occurring in dykes and irregular masses injected into or through the others, are now being critically examined with the aid of the microscope. These dykes are quite abundant in the Highlands; fine examples were seen at the Buckwheat Mine, Franklin, at Gordon's limestone quarry, near Montville, and about the limestone area near Oxford church. Great numbers of them occur in the cuts of the New York, West Shore and Buffalo railroad, along the Hudson river from Stony Point to Cornwall, in New York. They are especially abundant in the Dunderberg. The rock is dark-colored, generally fine-grained, and of variable composition; in decaying, it often presents a peculiar slaty cleavage, which may be mistaken for stratification. Among our crystalline rocks we have nearly all the different kinds that have elsewhere been observed. They are all combinations of a few minerals, and by the various mixtures of these and the structure of the rock, the kinds are distinguished. The minerals which may be regarded as the only important ones in rock formation in the Archæan of New Jersey, are feldspar (principally orthoclase, but incidentally oligoclase or albite, these latter two often referred to as plagioclase), quartz, hornblende, mica (mainly biotite, the black mica, though some muscovite has been seen), magnetite, calcite, dolomite, graphite, talc, serpentine, garnet, franklinite, chlorite, tourmaline. These are arranged about in the order of their relative abundance. A multitude of other minerals occur, but none are important constituents of the rocks. A list of New Jersey minerals may be found in the appendix to the "Geology of New Jersey of 1868."

The following names are but provisional, and it may ultimately be necessary to substitute others for some of them. The whole subject of lithological nomenclature is now under consideration by a Committee of the International Geological Congress, which met this summer in Berlin, and reassembles in London in 1888.

GRANITE consists essentially of orthoclase feldspar, quartz and mica, the latter either biotite or muscovite; oligoclase or other plagioclase feldspars are commonly present in small quantities. It occurs only as a massive rock; is found in some of the unstratified areas before noted, as, for example, in the Sparta mountain; as irregular masses, segregated from the enclosing stratified rocks, and in dykes which intersect these. One of these granite dykes, in a cut on the

Delaware, Lackawanna and Western railroad, near the Pequest Furnace, was illustrated in the Geology of New Jersey, 1868, p. 61, and others were mentioned in the Annual Report for 1883, pp. 76–77.

HORNBLENDIC GRANITE, or SYENITIC GRANITE, contains hornblende in addition to the above-named constituents; its occurrence is similar to that of granite.

PEGMATITE consists of quartz and orthoclase feldspar, with plagioclase feldspars as accessory. The component minerals are in large pieces, making this a very coarse-grained rock. Found mainly as irregular masses of various sizes, segregated from the enclosing rocks, and is particularly abundant along the northwestern side of the Highlands, though of frequent occurrence throughout the system.

SYENITE consists essentially of orthoclase feldspar and hornblende, with little or no quartz.* Is not of very common occurrence in New Jersey, but has been observed both as a bedded and a massive rock.

QUARTZ SYENITE, composed of quartz, orthoclase feldspar and hornblende, with plagioclase feldspars as accessory constituents, is, perhaps, the most common rock in the massive areas, and is locally persistent in very great extents of territory; it occurs also as a stratified rock, and in a very coarse form as segregrated masses with the pegmatites, differing from these in the presence of hornblende. It is, in part, the *hornblendic gneiss* of former reports.

GRANULITE is a rather fine-grained mixture of quartz and orthoclase, sometimes containing scattered flakes of mica, and occasionally plagioclase feldspars and garnet. A very common rock in the massive areas, but occurring also in the stratified condition. Differs from pegmatite in its fineness of crystallization and its occurrence. In part, the *feldspathic gneiss* of former reports. In many specimens the feldspar is greatly in excess of the quartz.

HORNBLENDIC GRANULITE contains small quantities of hornblende in addition to the above-named constituents, and is of similar occur-

* The term was applied to rocks of this mineral composition by Werner. The rock of Syene, Upper Egypt, from which the obelisks were quarried, was called Syenite by Pliny. It contains much mica, however, and in the nomenclature adopted by recent writers, is a Syenitic Granite.

rence. When containing considerable hornblende, it grades easily into *quartz syenite.* These three last kinds of rock frequently contain magnetite in disseminated grains, and when they are stratified contain some of the largest ore-bodies in the State. The Mt. Hope mines, for example, are in these rocks.

GNEISS is a bedded rock, composed of quartz, orthoclase and mica; occasionally plagioclase feldspars are present. The mica of the Highland rocks is mainly biotite, the black mica making this generally a *biotite gneiss.* Of common occurrence except in the massive areas. Found also at Jersey City* and at Trenton.

HORNBLENDIC GNEISS contains hornblende in addition; it is abundant and of the same distribution.

GARNETIFEROUS GNEISS contains garnet in appreciable quantities. It is an uncommon rock in New Jersey, but has been observed about Lake Hopatcong and elsewhere.

GRAPHITIC GNEISS, containing graphite or black lead, has been observed in several localities.

MICA SCHIST, consisting mainly of mica, which in our rocks is generally biotite, or in some cases lepidomelane, is of frequent occurrence in the iron mines. Quartz, feldspar and hornblende are accessory minerals, and the rock grades into biotite gneiss; many outcrops of the latter have a somewhat schistose structure, but true mica schists are rare in the Highlands except in proximity of the magnetite bodies. It is always stratified.

CHLORITE SCHIST is composed essentially of chlorite or ripidolite, and occurs with the iron ores. Fine specimens were obtained at the West End mines.

TALC SCHIST is mainly the mineral talc. It is of limited occurrence in the State, but characterizes portions of the northwestern Highlands and is quarried for paper-weighting on the east side of Jenny Jump mountain, near Great meadows, above Marble mountain, on the Delaware river, and on the Pennsylvania shore opposite. No

*See Geology of New Jersey, 1868, p. 323.

true talc has been observed in the serpentine rocks of Hoboken, but it occurs in their southwestern extension on Staten Island, interbedded with serpentine.

HORNBLENDE SCHIST consists mainly of hornblende. There are two varieties, one containing quartz with the hornblende, the other orthoclase feldspar. It is abundant in the Highlands, and especially well represented along their northwestern side; in places it is so thinly bedded and fine-grained that it resembles slate. This feature is well shown in the ravine back of Roxburgh village, Warren county.

GARNET ROCK consists of garnet and hornblende. It is of rare occurrence. Collected on the west shore of Negro pond, on the State line, in Passaic county, and above Iona Island, New York.

CRYSTALLINE LIMESTONE is composed of calcite or dolomite. Our rocks show every gradation in chemical composition* from a pure carbonate of lime to the double carbonate of lime and magnesia. In New Jersey it has been observed in but two belts; one of these is of great extent in the Northwestern Highlands, extending southwestwardly in isolated outcrops to the Delaware river, at Marble mountain, and is characterized by the association of manganese-bearing minerals; the other is in the Northeastern Highlands, and is exposed only in isolated patches, the most southern of these being near Mendham, Morris county, the others lying to the northwest of the Ramapo mountain range, all characterized by the abundance of magnesian minerals, such as serpentine, magnesite, &c. These crystalline limestones are always found to be stratified, though from the great thickness of the beds this feature is often obscure.

SERPENTINE occurs at Castle Point, Hoboken, where it forms the greater part of the hill, and as a mineral in several of the iron mines, notably the Split Rock mine, in Morris county, and abundantly in the eastern limestone belt above described. It occurs also in the northwestern crystalline limestone belt at Franklin, and in Frankford township. (*See* Rogers' report of 1836, p. 120.) Our serpentines are all of metamorphic origin, differing in this from many of the

* For some analyses of these rocks, see Geology of N. J., 1868, pp. 401–404.

foreign ones which have been conclusively shown to result from the alteration of igneous rocks containing the mineral olivine or chrysolite.

OPHIOLITE, an intimate mixture of crystalline limestone and serpentine, occurs in the eastern limestone belt. It is also known as verd antique marble. The name ophiolite is in reference to the sinuous snake-like bands of serpentine, a feature beautifully shown at the quarries near Mendham.

GRAPHITE is found and mined at several localities. At Bloomingdale, Passaic county, there is a bed several feet thick, mined and worked by Messrs. Ryerson, of that place. A bed of impure graphite, four feet thick, on the farm of Elias Engelmann, near Peapack, was noted in the "Geology of New Jersey," 1868, p. 715. At the Mendham quarries it is disseminated through the ophiolite, and forms a *graphitic schist* to the east of it. This is also extensively developed about High Bridge, Morris county, and elsewhere in the Eastern Highlands. Graphite is also abundant in the western limestones, occurring as disseminated black flakes. Professor Smock found a graphitic gneiss along the road to the Parrott mine, about one mile south of Warwick, Orange county, New York.

MAGNETITE, or magnetic iron ore, occurs in beds in stratified portions of the crystalline rocks, excepting, perhaps, the hornblende schists, etc., of the northeastern parts of the Archæan area and other schistose districts. During the past season considerable attention was given to the position of the ore bodies in the series, though no attempt was made to visit all of them. Those examined are all in stratified rocks, though in many cases near the junction of these with the massive ones. The beds of iron ore are often traceable for several miles, and are of variable thickness.

FRANKLINITE occurs in immense masses in the crystalline limestones of Franklin and Ogdensburgh, Sussex county.

TOURMALINE ROCK, composed mainly of tourmaline and quartz, occurs in the well stratified rocks of Marble mountain and Ragged ridge, Warren county, and in large segregated masses in the crystalline limestone quarry at Lower Harmony, where fine crystalline tour-

maline was observed. This mineral has also been noticed in white crystalline limestone at Sterling Hill and Franklin.*

These are all the kinds of rock so far determined. A few others may yet be found. No true quartzites have been noticed in the Highland Archæan, though some of the granulites are heavily quartziferous.

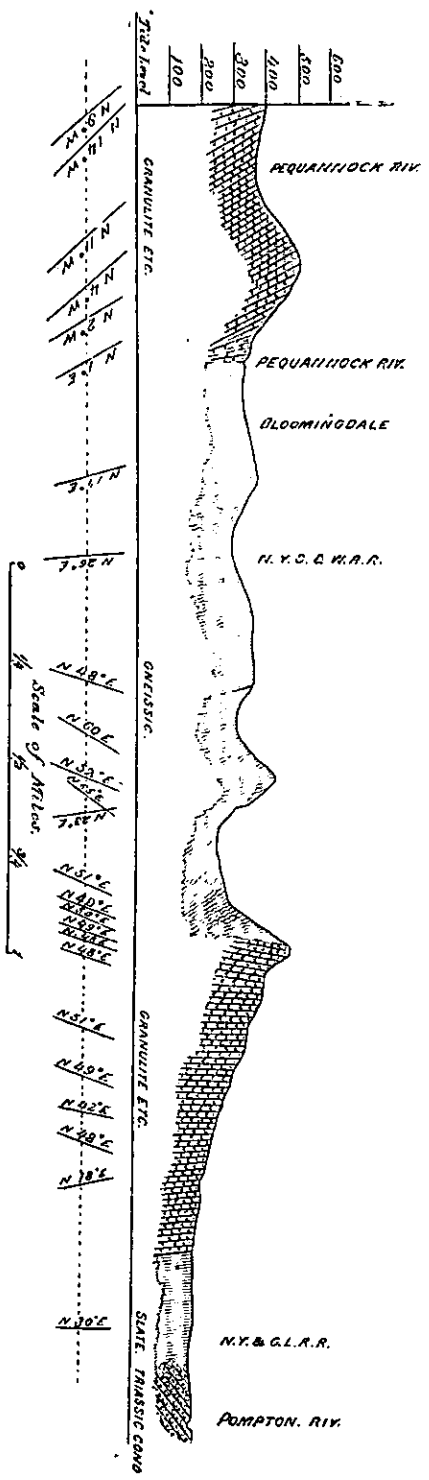
WORK OF THE PAST SEASON.

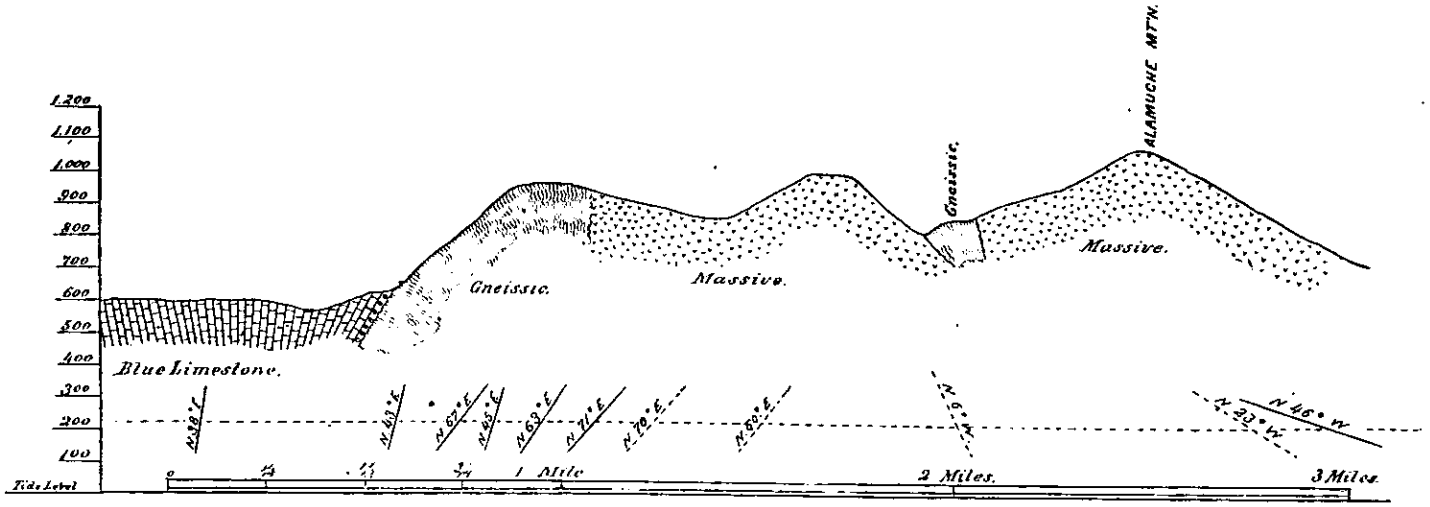
The field-work of the past season has had for its object the development of previously-ascertained facts; the location and study of the massive areas previously discovered, with search for others, and their relation to the surrounding stratified rocks; a continued study of the stratigraphy of the system, with a view of ascertaining if there be a series of folds, or if the whole is but one vast succession of strata; the relation of the crystalline limestones and magnetite iron ore deposits to the enclosing rocks; the contact phenomena along the junctions of the crystalline rocks with the paleozoic and triassic strata, and other matters of importance in the accurate study of the region. Eleven section lines, about five miles apart, crossing the Highlands from southeast to northwest, were examined, and some time was spent in the study of territory between these sections. Strike and dip were carefully measured on all stratified outcrops found, and corrected for magnetic variation by accompanying readings on a solar compass. On the new topographical maps, which have now been engraved for the entire Highland area, these have all been located. Numerous specimens, to illustrate the lithology, were collected, which have been studied, labeled and catalogued as far as time has permitted. As much of the area north of the terminal moraine† is heavily covered with glacial drift, and the southern portion of it being unglaciated, is generally overlain by the products of its own decay, except where streams have cut down to the solid rock, or this has been artificially exposed through railroad cuttings or other excavations, there are many gaps in the sections, which it is hoped may be, in part at least, filled in by examining the country a short distance to the northeast and southwest of the lines traversed, where these gaps are left.

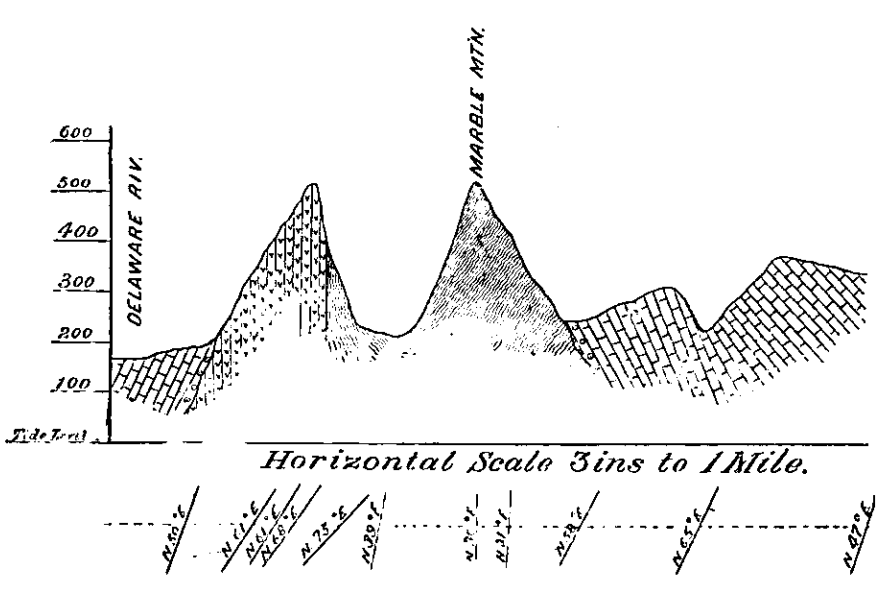
A preliminary section extending along the west bank of the Hud-

*See Henry D. Rogers' Rep. on Geol. Survey, N. J., 1836, pp. 119–120.

†For the southern boundary of the glacial drift, see the Ann. Rep. of the State Geologist, 1877.







son river, from Stony Point to Cornwall, was first studied, for here the rock cuts of the New York, West Shore and Buffalo railway afford an excellent opportunity for the study of the system, and this proved very valuable as a comparison with the others running across the mountains. Unstratified but somewhat laminated quartz syenites, granulites and hornblendic granulites compose the cores of Dunderberg, Crow's Nest and Storm King mountains; and between these lofty elevations, as on the southeastern slope of Dunderberg and the northwestern side of Storm King, lie series of stratified rocks—those on the immediate flanks of the ridges of nearly the same mineralogical composition as the cores or central portions—but grading off into gneisses, hornblende schists, &c., in the depressions and minor hills between.

The section lines followed across the Highlands were as follows:

(1) The New Jersey and New York State line from Suffern on the southeast to the Wallkill river. Its general direction is about N. 57° W., which proved nearly at right angles to the average strike of the system and its enclosed paleozoic areas, and all the subsequent lines were run nearly parallel with this.
(2) From the Ramapo river near Darlington, Bergen county, to Deckertown, Sussex county.
(3) From Pompton to Franklin Furnace, Sussex county.
(4) From near Whitehall, Morris county, to White's pond, Sussex county.
(5) From Parsippany, Morris county, to Long pond, Sussex county.
(6) From Morristown to Tranquility, Sussex county.
(7) From Bernardsville, Somerset county, to Shiloh, Warren county.
(8) From Fairmount, Hunterdon county, to Sarepta, Warren county.
(9) From Lebanon, Hunterdon county, to Roxburgh, Warren county, on the Delaware river.
(10) From Pattenburg, Hunterdon county, to the Delaware river, below Harmony Station.
(11) Along the Delaware river from Holland Station to Marble mountain, following both shores.

AREAS OF UNSTRATIFIED ROCK.

The presence of large areas underlaid by unstratified crystalline rocks was recorded in last year's report, and has been fully con-

firmed in the field-work of the past season. These consist in the main of quartz syenites, granulites and hornblendic granulites of various degrees of coarseness. Locally they contain some black mica, becoming then granites, but this rock is not nearly as abundant as the three first named. Along the Hudson river, unstratified but somewhat laminated quartz syenites, &c., are found in the Dunderberg, Crow's Nest and Storm King mountains, flanked on either side by bedded rocks. On the first or State line section, two areas were seen in the mountains east of Greenwood lake, separated by a narrow strip of gneisses, bedded quartz syenites and granulites. Others occur in the region between Long House creek and Wawayanda creek. On the second section they were crossed to the northwest of the Windbeam mountain at Stonetown, where there appear to be three separated areas, and in the Wawayanda mountain there is a massive area nearly three miles wide. The third section line crossed them between Smith Mills and the Kanouse mountain, between Wallace Corner and Stockholm, and again to the northwest of Two Bridges. On the fourth section they were found in two separated areas to the northwest of Gordon's limestone quarry, near Montville; to the northwest of the northern end of Splitrock pond; about Greenville and in two areas in the Sparta mountain. The fifth section line crossed massive rocks in the Sparta mountain, and again about a mile to the southeast of Long pond, Sussex county. Along section six a broad area is indicated in the tableland country between Washington valley and Suckasunna plains, but, as this is an unglaciated region, the outcrops are poor. The loose rock is mainly granulite and quartz syenite; a small area occurs to the northwest of Drakesville, and two in the Alamuche mountain. Massive areas are indicated along the seventh section in Mine mountain and Schooley's mountain, but few outcrops were noticed; the eastern ridge of Jenny Jump mountain is here composed of unstratified rocks. On the eighth section indications of these rocks were found in the country between the south branch of the Raritan river and the Musconetcong, and the southwestern end of Jenny Jump mountain is apparently massive. Along section nine indications of unstratified rock were found in the Musconetcong and Scott's mountains, but the outcrops are insufficient for positive assertion. Similarly along the tenth section line, across the Musconetcong mountain, the loose work indicates a massive area, but no outcrops were found. The Delaware river section shows no unstratified rocks. Part of the ridge

northwest of Marble mountain is composed of granulite, etc., but it is poorly though evidently stratified or at least laminated.

It is apparent that these unstratified rock-masses underlie the bedded crystalline rocks, but the lines of separation are poorly defined, for stratified rocks of the same mineral composition commonly occur on the sides of the massive areas, and there is apparently a gradual passage from massive to stratified series. This feature was noticed in many places, and at no point has any actual unconformability been found. Several abrupt changes within a short distance have indeed been noticed, but these may have been produced by faulting or by erosion and subsequent greater folding. Lines of lamination and poorly-marked bedding-planes occur locally in all the massive areas, and these agree with the general stratification of the surrounding bedded rocks. These facts, when considered with the occurrence of great areas of evidently bedded rocks of the same kinds as those composing the massive series, indicate that these are massive only because the stratification has for the most part been destroyed through greater metamorphism.

The massive rocks are then older than the gneisses, schists, crystalline limestones, &c., and they form the base of the geological column in New Jersey.

RELATIONS OF THE MASSIVE AND STRATIFIED ROCKS.

In but few places can we show a direct superposition of the stratified rocks on both sides of a massive area. The tilting of the strata in the processes of mountain-making has been unequal in different parts of the region, and in many places very great, locally even throwing them past the perpendicular. This explains the prevalent southeastwardly inclination of the system. The schistose series commonly dip more steeply along their southeastern margins than along their opposite sides, and often reach the perpendicular; thus the *axial planes* of the folds are often inclined towards the southeast. This is not invariable, however. Marble mountain, above Phillipsburg, Warren county, is shown by the section exposed along the Delaware river, to consist of quartzose and feldspathic hornblende schists, fine-grained gneisses, masses of segregated granite and pegmatite, and a small amount of crystalline limestone. The strata dip forty to fifty degrees towards the northwest, along the whole breadth of the

mountain, and are quite evenly bedded. The ridge northwest of Marble mountain is composed of well-bedded gneiss on its southeastern side, which grades into a very massive granulite, somewhat laminated. Between this ridge and the Marble mountain is a bed of talc schist, which dips southeastwardly. The structure is illustrated in a cut. The rocks of the ridge are older, and those of the mountain have been folded against them, the valley between the two having been formed by subsequent erosion. The axial plane of this fold inclines towards the northwest, and a few others have been made out, but most of them dip towards the southeast.

The unconformability shown at certain of the contacts with the Potsdam and other Paleozoic rocks, proves that while considerable folding of the Archæan beds occurred before these were deposited, this action was continued after these newer strata were laid down, they being generally appreciably tilted, and along certain lines, such as the Green Pond, Copperas and Bearfort mountain ranges, the Silurian and Devonian beds are as much disturbed as are those of the Archæan. Indeed, it is indicated from the tilting of the Triassic and Cretaceous strata that the uplifting of certain areas and depression of others continued through all geological time, and the alterations of coast elevation which have occurred in recent times, and which are still in progress, as marked by the gradual depression of the shore at the present time, are proofs that a similar process is yet in operation.

THE DEPOSITS OF IRON ORE.

A detailed re-examination of all the mines has not been attempted this year, but many have incidentally been visited. Comparatively few of them have been in operation during the past season, owing to the low prices obtainable for ores. Those which have been studied confirm the statements made in previous reports.* The beds are uniformly conformable to the stratification of the enclosing rocks, which, in most cases, is a rather thickly-bedded granulite or gneiss, with or without hornblende, and the magnetite occurs in grains and small masses, often with a parallel arrangement to that bed, through these rocks to a considerable distance—in places as great as one hundred feet—from the main deposit. No extensive beds were seen in

*See, in particular, "Geology of New Jersey," 1868; Ann. Rep. State Geologist, 1883.

the areas of schistose rock; none are known in the hornblende schist, gneiss, granite and pegmatite series of Marble mountain, Ragged ridge, &c., of the northwestern side of the Highlands, but several deposits of hematite ore have been found and mined in this series.

The magnetite ore-bodies contain as common mineral constituents, hornblende, pyroxene, biotite and lepidomelane micas, epidote, serpentine, pyrite, apatite, chlorite and ripidolite; these are seldom all present in the same ore-body, and vary in amount in the different deposits. There is evidence, in the presence of these minerals and in the structure of the beds, that there has been considerable segregation accompanying the metamorphosing processes, and intense chemical action must have taken place at the time of formation of the magnetite.

These ore-beds and their enclosing rocks, generally with a northeast and southwest trend, are, in cases, traceable for several miles, though frequently of much more limited extent. They are not of uniform thickness throughout, but are locally very thick, and, again, reduced almost to nothing. At their ends they are lost in the enclosing rocks, or "pinch out," as this feature is termed by the miners. In beds of small extent this produces somewhat lenticular ore-bodies, which have frequently been called "magnetic ore lenses."

AGE OF THE ROCKS.

In referring to our crystalline rocks as a whole we have called them *Archæan*. This name has been adopted by the International Geological Congress at its recent meeting in Berlin, Germany. They have been variously termed Primitive, Azoic and Eozoic. The name Primitive was rejected by the International Congress. Azoic, which was used in the earlier reports, is an unsatisfactory designation, for while no undoubted fossil organisms have been found in our rocks, there is strong evidence in the immense crystalline limestone deposits, and in the graphite, apatite and iron ores, that life of some kind did exist at the time of their deposition. Certain writers on geology have attempted to explain away these occurrences, and to show that these minerals do not necessarily imply the existence of living bodies. The term Eozoic, implying the beginning of life during the deposition of the rocks, is questionable, for we do not know when, in geological time, the first organisms were created.

Many attempts have been made to subdivide the Archæan rocks. Those of Canada were first carefully studied, and were separated by lithological differences into two systems, the older called Laurentian, the newer Huronian. The Laurentian comprised gneisses, syenites, hornblende and mica schists, granites, crystalline limestones, magnetites, graphite, &c., and as a whole agrees very closely with our Highland system. The Huronian is composed largely of quartzites, with chlorite and talcose schists, &c., with immense quantities of diorite, and has no parallel with us.

Out of these two original divisions numerous others have been proposed and given names, generally on lithological differences alone. Dr. T. Sterry Hunt has proposed the term Norian for the Labradorite rocks of Canada and the Adirondacks, and Montalban for rocks resembling those of the White mountains, consisting largely of mica schists. We have so far been unable to identify either of these in New Jersey. Professor J. D. Whitney and Dr. M. E. Wadsworth,* in a paper on "Azoic Rocks," have recently proposed ten lithological divisions for the rocks older than the Potsdam sandstone. They place all magnetite, hematites and similar highly ferriferous minerals in a distinct series which is called by them *Siderian*. Our magnetite deposits are interstratified with gneisses, granulites, &c., probably of Laurentian Age, and we have been unable to refer them to any special geological horizon other than this. They omit the crystalline limestones entirely, regarding them as segregated masses; with this conclusion we cannot agree, for the white limestones of the Vernon and Wallkill valleys are unquestionably stratified and of immense thickness; they are a prominent and important feature in our Archæan geology. And they are interbedded with gneisses, hornblende schists, &c., and contain, near Franklin Furnace, Sussex county, at least one great deposit of magnetic iron ore and several of franklinite. Messrs. Whitney and Wadsworth group the mica schists in the series Montalban. Of these rocks we have little or no representation in New Jersey. Under the name Laurentian they group granites, gneisses and syenites, and regard them as the base of the Archæan system.

We are of the opinion that lithological distinctions alone are of little value in the classification of crystalline rocks. They must be connected with stratigraphical relations which can only be determined by careful and patient field observations.

* Bull. Museum Compar. Zool., Vol. VII., pp. 331–565, 1884.

Up to the present time we are unable to divide the New Jersey Archæan farther than to say that the massive or laminated and heavily-bedded granulites, quartz syenites, etc., geologically underlie the well-stratified gneisses, hornblendes, schists, talc schists, crystalline limestones, ophiolites, graphite, etc., which consequently constitute a newer series; possibly the schistose rocks, gneisses and pegmatites of the northwestern border of the Highlands may constitute a distinct member of this newer series, as they are lithologically somewhat different from the well-stratified rocks elsewhere found in the Highlands, though this is a difference of degree rather than kind. We cannot reasonably hold that all are more than parts of a single geological system, which answers very well to the Laurentian. We may, perhaps, say that we have a lower and an upper Archæan series, but between these we can at present draw no exact lines. Further field-work may enable us better to define the lines of demarkation and to map out the older areas, which are evidently very irregular in outline.

CONTACT PHENOMENA WITH THE PALEOZOIC ROCKS.

But few places are known where the actual junction of Archæan rocks with the Potsdam sandstone may be seen. One of these, on "Owen's Island," two-thirds of a mile south of the State line, in Sussex county, was described by Professor Rogers in his report of 1836. The two were there found quite unconformable; the Potsdam, resting on the upturned edges of the Archæan strata, inclined 20 degrees towards the northwest; the dip of the Archæan was 70 degrees southwestwardly. A contact near Franklin Furnace was described and figured in the "Geology of New Jersey," 1868, pp. 72–73, where a similar unconformability was shown. And the same conditions appear persistent along the entire northwestern margin of the Highlands in New Jersey, though no other actual contacts have been observed along this line. In Pennsylvania, a few miles southwest of the Delaware river, Professor Rogers found the two sets of rocks unconformable.

Similar conditions are found farther southwest, along the Alleghanies and Blue Ridge. Near Balcony Falls, Virginia, the basal member of the Paleozoic series is seen in unconformable contact with a hornblendic granulite; it contains fragments of this rock, and is

heavily feldspathic. In Doe river gorge, East Tennessee, a vitreous quartzite is in contact with a coarse pegmatite, and contains abundant fragments of decaying feldspar.

Several contacts have been noted along the margins of the Paleozoic rocks enclosed by the Archæan. At Wawayanda creek, above New Milford, nearly on the State line, in Sussex county, the rocks are exposed very nearly in conjunction. The Potsdam, here several feet in thickness, dips fifteen to twenty degrees towards the north; the Archæan, here a massive granulite, has no well-marked bedding planes at the contact. Near Vernon the conditions are similar. At each of these last-named places the features are perplexing, for the Potsdam quartzite and conglomerate is so heavily feldspathic near the junction that it appears to shade gradually into the older rock, fragments and masses of which are included in it. So at Franklin Furnace, the actual line of junction is ascertained only by the most careful scrutiny, there being so much feldspathic matter in the quartzite.

These facts indicate the formation of the Potsdam by the wear of the crystalline rocks and subsequent agglomeration of the debris.

Along the southeastern margin of the Highlands, between the Archæan and Triassic formations, is a belt of Silurian rocks exposed in detached outcrops. This extends into New Jersey from Pennsylvania on the southwest, and is exposed in isolated patches above Holland Station, Little York, Clinton and Pottersville, in Hunterdon county; Peapack, in Somerset county; Pompton, in Passaic county, and Oakland, in Bergen county, and through New York State, at several points, to Stony Point and Tompkins Cove, on the western side of the Hudson, where it has great development. Crossing the Hudson, it is seen at Verplanck's Point, and extends for a long distance up the narrow valley known as Peekskill Hollow, in Westchester and Putnam counties, New York. Throughout this entire extent its rocks maintain a great similarity, and they are more highly metamorphosed than strata of the same geological age farther to the northwest.

They are quartzites, somewhat crystalline-blue or light-colored limestones, and shining slates, which have been termed "hydro-mica slates," because their metamorphism has been so far advanced as to change them partially into a mica-like mineral; this is distinguished from the micas, however, in containing water, hence the name.

Between the rocks of this belt and those of the Archæan, the unconformability is much less pronounced. No satisfactory contacts are known in New Jersey. At Pompton the slate ledges in the Pequannock river

have very nearly the same dip and strike as the nearest Archæan outcrops. The two are not seen near enough together, however, to warrant any conclusions as to their relations.

In the hills bordering the northwestern side of Peekskill Hollow, New York, the slates and Archæan rocks are seen in several places very nearly in contact; their deviation in strike is very little, and both dip steeply to the southeast; the slates are greatly contorted. Along the southeastern side of this same valley, and to the southeast of the bluish limestones, which occupy the greater portion of it, strata of quartzite are found, and are well exposed about the old furnace stack at Annsville Cove. This quartzite comes directly in contact with a crystalline rock of variable composition, consisting of orthoclase and oligoclase feldspars, quartz and some black mica and hornblende, and is directly conformable to it; at least, the divergence of dip and strike is small enough to be inappreciable. The strata have been subjected to an overturn, causing the quartzite to dip under the older rock, and it is difficult to say exactly where the line of separation is. The contact features of this eastern Silurian belt indicate that the Archæan was not extensively folded along this line before the newer rocks were deposited on it, but that all have been folded and uplifted together and without much alteration of their original relative positions.

QUATERNARY AND RECENT FORMATIONS.

THE WORK in the newer formations has been done by Mr. F. J. H. Merrill, since the field-work in the Archæan rocks closed. The various phenomena along the Atlantic shore from the mouth of the Raritan to Cape May have been examined and notes made following out the explanations and directions here given, with the following paper of instructions, viz.:

INSTRUCTIONS for the geological phenomena to be noted in the survey of the sea-coast from Sandy Hook southward. These may be arranged in the order of their age, beginning with the most recent. They are:

1. THE TIDE-MARSHES.—These are of recent origin, some of them are in process of formation now, and all are undergoing changes of elevation of their upper surfaces. They may occur in all places where the hard bottom is below high-water mark, and the shore is protected from the violent action of the waves.

2. ALLUVIAL DEPOSITS.—In most places the upland comes down to the level of high-water with a gentle slope, and in this condition of the shore lands it is noticeable that the soil is generally of a more loamy character than that away from the sea-side, that it contains more organic matter and is more fertile. This fringe or border of alluvial lands extends up to an elevation of from fifteen to thirty feet above high-water mark. The upper margin is difficult to define accurately, as it has been exposed, for centuries, to the wash from heavy rains and torrents of water. It appears, however, to mark the level of high-water at some former time, though as the shore is not worn by the force of waves, but remains smooth and even, the line must have been made since the beaches were in their present places, to break the effects of the open sea.

3. BEACHES.—This term is applied to the islands and banks of loose sand which line or border on the sea-coast of the State from Sandy Hook to Cape May. The beaches are of two kinds, (*a*) dunes or hillocks of rather coarse, clean sand, which may drift with the wind, and (*b*) long, low ridges of fine, slightly yellowish sand, which are usually almost parallel with the shore, and have probably been first formed as bars under the water, by waves and currents, and brought above the surface in violent storms by the waves and currents, or by slower geological changes of level.

4. TERRACES.—In the few places where there are bluff banks from forty to sixty* or more feet above the sea-level, terraces are to be seen in protected places, resting against them. The highest of the terraces bordering the tide-waters are in the northern part of the State, where they are seventy or eighty feet high, and they are found of less and less height as we go south till, in Atlantic county, they are but little over thirty feet high, and in Cape May they can hardly be distinguished from others of the alluvial deposits. Other terraces of less elevation are to be seen in many places. Of course the terraces

*The terrace on which Mt. Pleasant cemetery, in North Newark, is located, is about sixty-five feet above mean-tide. The terraces on the Raritan above New Brunswick, are something over fifty feet above; that at Trenton is about fifty feet; that at Leeds' Point, in Atlantic county, is thirty-five feet above, and the south end of Cape May, extending back from Town Bank, is twenty feet above mean-tide. There are many others still to be measured, when a more accurate result can be made out, but at present the terraces appear to diminish in height, going southward, at the rate of about three inches to one mile.

are not to be expected unless there is higher ground near, which could supply the material to make them.

5. The Yellow Gravel and Earth.—This constitutes the surface material everywhere outside of the lines within which the alluvial and formations occur. It varies much in quality, but is everywhere marked by the presence of quartzose pebbles, which are of a rusty white or yellow color, and many of them contain fossils of well-known Silurian and Devonian species. The gravel is mixed with clayey earth in the higher grounds, while in lower places the sorting effect of the rains has carried away the clayey matter—has separated the sand and deposited it in lower places, and the gravel itself is very irregularly exposed. It, however, constitutes a greater or less portion of the surface material over more than half the State—all of that portion south of the glacial drift. It is evidently older than the several formations mentioned, while it is newer than the stratified materials of the various Tertiary, Cretaceous and older formations which it overlies.

6. The Lower Tertiary and Cretaceous Formations.—These are exposed at various places along the sea-shore from Long Branch to Deal, but not so fairly as they are at many places farther inland. The grains of greensand, and stony masses of marl and fossils, washed up by the ocean waves, show that these formations do extend out under the sea.

The several classes of phenomena mentioned above give evidence—

(*a.*) That there is a change in the relative level of the sea and the land going on now: the sea is rising upon the land. The marshes now cover land which, since the first settlement of the country, has been above tide-level and cultivated in farm crops. Trees formerly grew where the salt-marsh now covers the surface, and only salt-grass or other marsh vegetation can grow. This has gone on to a large extent, so much that stumps of trees with their roots still firm in the hard ground where they grew are found under the marsh where ditches are dug, 4 or 5 feet beneath the surface, and in the thoroughfares and other water-courses in the marshes such stumps are found at very much greater depths. In many places, too, Indian shell heaps are found in the marsh, and, going down to hard ground: the marsh has evidently grown around them since they were begun. Marsh sods are found under the beaches and along the strand, which, though in their places

of growth, are several feet below the tide-level. The storms and waves of the sea appear to have greater effect in wearing away and changing the shore line than they had in former times. This would naturally occur if the sea rises higher on the land than it formerly did. It is desirable to collect all the facts possible bearing upon this general subject and their location and character, giving as much precision as possible to all measurements of time and distance.

(*b.*) It would appear that preceding the present advance of the sea, there was a period of withdrawal of the ocean waters, so that the land in which the stumps are found below tide was above the sea-level, and these trees could grow. It is desirable to get any facts which will mark the lowest point to which the sea receded. They may be found in the depth at which fixed stumps occur, and perhaps in the meadow sods found on the sea-side, or in sinking wells or holes in the sand.

(*c.*) The occurrence of alluvial deposits indicate that preceding the last-mentioned recession of the sea-level, there was an advance of the sea upon the upland which continued until it reached the height shown by the upper margin of these lands. It is desirable to get all facts possible which throw light upon this point. It is also important to ascertain whether the upper margin of these alluvial deposits is parallel to the present sea-level, as it appears now to be, though it is not fully proved. In a number of places on the upland, but not far above tide-level, sea-shells, apparently of the species now found living in the adjacent waters, have been found buried in the earth. In some cases they were found in digging wells, cellars, pits, etc., and in other cases in banks, and in places where they can be dug out as marl, and used to fertilize the soil. The facts connected with these should be fully and carefully ascertained and noted, for while it is the simplest explanation to consider them as of the same age with the alluvial deposits in or under which they are found, there may be reasons for assigning them to an earlier period.

(*d.*) The material of which the beaches are composed has all been washed by the ocean. It is clean, white quartz sand, with a few small pebbles or gravel stones. The clay which may have once been mixed with it, is now all washed out, the rusty color or coating on the grains of sand has all been washed off, or else worn off by the attrition of the grains against each other. A bare inspection of the sand of the beaches is sufficient evidence of this, but as attention has not generally been called to this, it is important to collect as many facts

to corroborate it as possible. The formation of sand bars parallel to the shore, the appearance of new bars above the surface, the changes which have taken place in the form and location of the beaches in modern times, and the changes of the strand in quiet and in stormy weather, all lend support to this view. The depth at which sand can be moved forward by the violence of the waves, and the effect of currents which are parallel to the shore, in checking the movement of sand carried by waves towards the shore, need more extended and careful study.

(*e.*) The higher terraces are considered to have been formed at the close of the glacial period, and their upper and flat surfaces mark the level of the ocean at that time. The elevation of these terraces above the present tide-level being variable, and greater at the north than at the south, opens very important questions in theoretical geology, relating to the form of the earth and the curvature of its surface. It is important, then, to measure carefully the elevation of all the terraces that can be identified along the shore of the State, throughout its whole length, from north to south.

(*f.*) The distribution of the yellow gravel is very irregular. It is desirable to note the thickness and structure of the gravel beds wherever they are exposed in gullies, bluff banks, or in artificial cuttings or openings. As this gravel is not confined to the shore, the facts can only be collected for use at some later period, when it has been examined throughout its whole extent.

SANDY HOOK is a good example of the changes to which the beaches on the Atlantic shore are subject. The map inserted at the beginning of this report gives the outline of the Hook as it was in the summer of 1885, and the contour lines give the elevation of its sand ridges and hillocks above the tide-level for every five feet. The Hook was surveyed by George Keith, Surveyor-General of East Jersey, in 1685, and the survey is recorded in Liber L of Warrants, in Proprietors' Office, at Perth Amboy. It is "By virtue of a warrant from the Governor, bearing date at Elizabethtown, the seventeenth of the first month, 1685, surveyed and laid out for Richard Hartshorne, a tract of land within the bounds of Middletown, called Sandy Hook: Beginning at the first hummocks on the said tract, and running due north one hundred and ten chains; then north northwest and three-quarters of a point more northerly seventy chains;

thence northwest forty chains to the end of the hummocks; then the same course to the most northerly poynt along a narrow neck of land twenty chains; the greatest breadth of the said tract being twenty chains, but running to a poynt at both ends in the form of a half-moon, containing with allowance for barrens, two hundred acres, bounded on the south with his own lands formerly surveyed, (a narrow neck of sand betwixt the hummocks on Sandy Hook, and his own land being included in the said tract,) and on all other parts bounded by the sea. [Here follows description of another tract.]

"GEORGE KEITH."

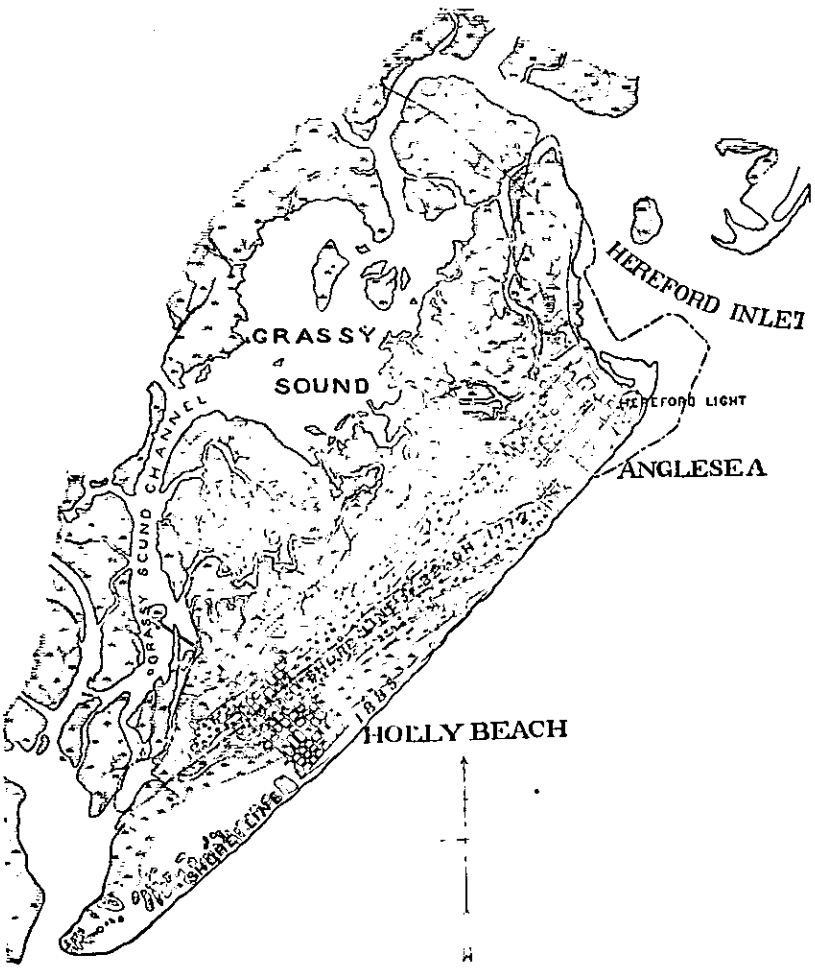
The above survey is only a single line, but from the timber and bushes on the Hook, it would now, and probably would then, have been difficult to run a single line directly up the middle of the wooded part of the beach, and the survey was most likely made upon the strand on one side of it. The most southerly hummocks are easily distinguished now, and the old timber is limited to the westerly side of the Hook. The variation of the magnetic needle was recorded by Keith, in 1687, as being nine degrees west. Taking these facts into consideration, the line is plotted on the map and marked by a series of bars and interposed circles. The Hook is also bounded by a similar line drawn to conform to this description of Keith.

The Hook was surveyed again by William Lawrence at some date earlier than 1765, and a map of it and its connection with the Highlands was made. This map is still in existence, and a copy is in possession of the Geological Survey. The outline of this map is also drawn upon the map of the present Hook, and is marked by a series of bars and interposed crosses.

Lines showing the north end of the Hook at several dates from 1782 onwards, are also drawn upon the map from the United States Coast Survey sketch, in the report for 1853.

It will be perceived that the Hook has increased in length and in breadth so as to include more than four times the area it covered in 1685.

The changes in the extent of the beaches, and in location of the shore line, is also well shown about Little Egg Harbor Inlet. The map here inserted shows the shore lines in 1841 and in 1885. The whole interval between the south end of Long Beach and the east



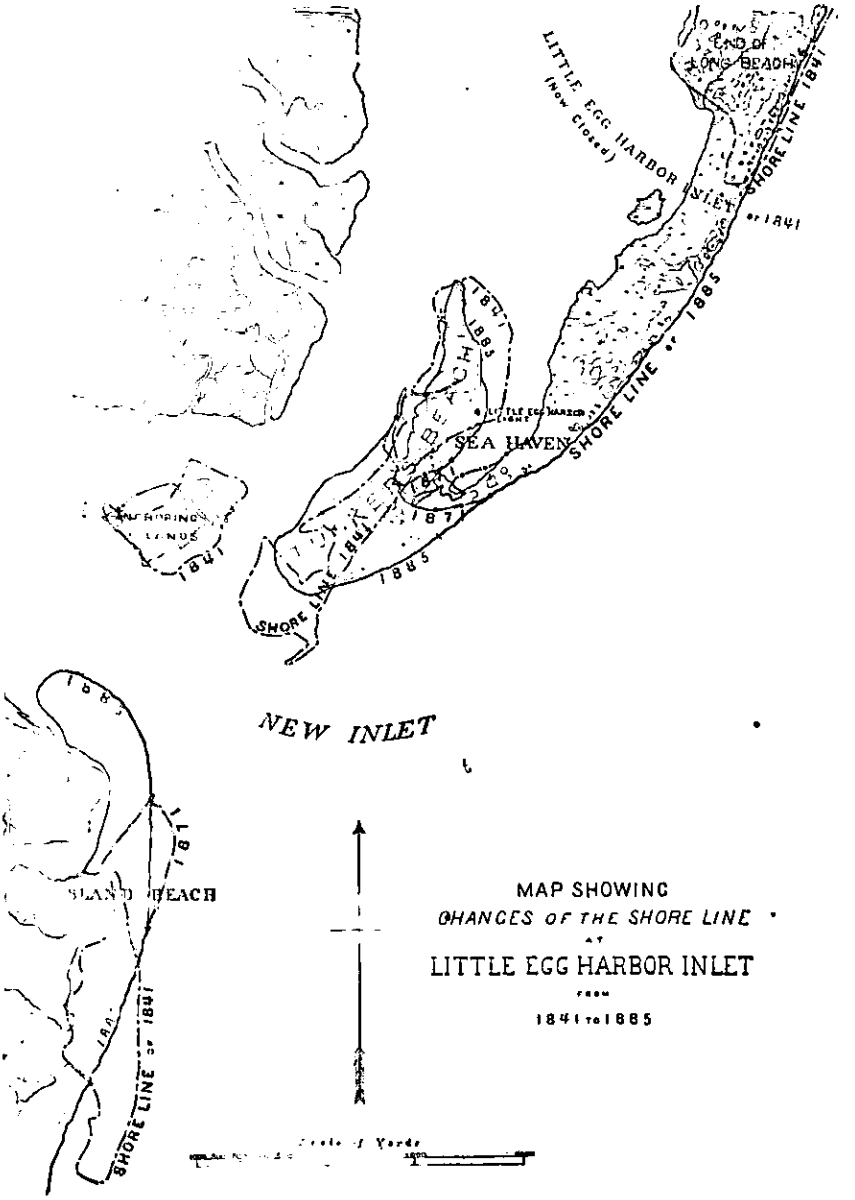
MAP SHOWING CHANGES OF THE SHORE LINE

OF

FIVE MILE BEACH

FROM

1772 to 1885



side of Tucker's Beach, has been filled in with sand, and the shore of Island Beach, on the south side of New Inlet, has taken an entirely new form.

FIVE MILE BEACH, on the east shore of Cape May, has also undergone remarkable changes in the wearing away on the sea-side at its north end and the large accretions made at its south end. The accompanying map shows the beach as it is in 1885. The beach was surveyed in 1772, and a map, on a scale of ten chains to an inch, was made for the purpose of dividing it among several heirs. This map is still in existence, and the Geological Survey has a copy. The thoroughfare on the west side of the beach, as shown on this map, agrees singularly well with that on the present map, and this affords a satisfactory means of comparing the shape and area of the beach of 1772 with that of 1885. The accretions have nearly doubled its area, but the old holly and oak trees sufficiently characterize the beach of 1772 and distinguish it from that which has formed since.

OBSERVATIONS ON THE RECENT FORMATIONS OF THE ATLANTIC COAST OF NEW JERSEY.

The following is a report of field-work on the Atlantic coast of New Jersey, from October 1st to December 8th, 1885. In view of the limited time available, the aim of this season's investigation has been to cover the whole ground as well as possible rather than attempt an exhaustive study of any one formation or district, and to obtain all possible information with regard to localities of interest which might be carefully examined at another season. The material thus obtained is discussed in the following pages, under the heads mentioned in the paper of instructions, viz.:

1. Tide-marshes.
2. Alluvial deposits.
3. Quaternary fossils.
4. Beaches.
5. Terraces.

TIDE-MARSHES OR SALT-MEADOWS.

These formations cover a great area along the New Jersey coast, and consist of mud, at or below the level of high-water mark, over-

grown by certain grasses, which are favored by moisture and the saline influence.

As they can thrive only on protected shores, and will not grow on upland soil, the formation of meadow-sod, which in places attains a thickness of some feet, is confined to the bays, channels and creeks on the west of the beaches or the sheltered portions of the estuaries, where the hard bottom lies at or below high-water mark, and has been covered with mud, or the unctuous alluvial deposit which forms so plentifully in the protected waters mentioned.

These plants will moreover only spring up and take root on a surface which is at times out of water, consequently the sod begins to grow, ordinarily, just above the level of low-tide, in the bays and thoroughfares. Where, however, the marsh borders the upland, overflowing tides gradually deposit alluvium upon the latter, and in this case the salt grasses spring up near high-water mark.

Hence the marshes are geologically younger or more recent than the beaches, and as the latter have been deposited late in the Quaternary, the marshes may all have formed within the historic peroid.

With regard to the growth and wear of the salt-meadows, it is impossible and useless to attempt a consideration of the changes which occur in them, as they are subject to the variations of winds and currents, and the general statement must suffice, that in sheltered localities they grow rapidly, and where exposed to wind and wave are as rapidly removed. As a rule, however, it is noticed from Bay Head to Cape May, that the meadows which fringe the main shore, are worn away on their eastern edge, while those bordering the west side of the beaches are growing. Thus the general tendency of the bays and thoroughfares throughout this region, is to work westward.

As these meadows are of such recent date, we might expect to obtain from them abundant evidence of any change of level which may have occurred during their formation, and in this expectation we are not disappointed. We find, in fact, conclusive evidence of a general subsidence of the coast or rise of the water-level to an extent of from ten to twenty feet within a short period of geological time, but at a rate which is not yet quite definitely established.

The points of evidence alluded to are as follows:

1st. The encroachment within the present generation of the salt-meadow on the upland, in many places killing timber along the border and rendering arable land unfit for cultivation.

2d. The stumps of trees in the mud, with their roots imbedded in hard bottom, many feet below high-water mark, and at a level where they could not possibly have grown previous to the formation of the marsh.

3d. The occurrence of Indian or aboriginal shell beds resting on hard bottom, and partly or wholly submerged in the meadow to the depth of some feet. These were unquestionably formed on knolls of upland which projected above the surface, and have since become buried by the rise of the meadow.

4th. The existence of old bridges and crossways of poles or corduroy roads several feet below the surface of the marsh. The time of their construction is unknown to the present generation of inhabitants, and there seems to be no authentic record of any bridges, built within the memory of the residents on the shore, having settled or sunk in the marsh to an appreciable extent; so we may, with justice, conclude that they have been buried by the upward growth of the meadow.

5th. The occurrence discussed under the head of beaches, of meadow-sod below low-water mark on the outer shore, at a level where experience and observation show the grass could never have grown.

The first four points of evidence will be enumerated in geographical succession, proceeding southward over the area examined during the past season.

In the tide-marshes bordering the Navesink and Shrewsbury rivers, but little change has been noticed, except lateral growth, and no cases of encroachment on the upland have been recorded, because not thoroughly searched for.

In the marsh near the railroad on the southwest branch of Deal lake, stumps are said to have been found at a depth of ten to twenty feet in digging for peat. The bottom of this and Sunset lake is everywhere full of logs and stumps, and doubtless is the site of a former cedar swamp.

Near Point Pleasant, I am informed by Mr. Joseph Borden, Sr., that at certain points along the upland border in the vicinity, arable land has become sour and unfit for use.

Any changes which have taken place on Barnegat bay, north of Kettle creek, under the saline influence, occurred when Cranberry inlet was open and the water was salt up to Bay Head. This closed about 1812, and at present the water of the Metedeconk river is but

slightly brackish. It is therefore possible only for those who are able to recall the time when the inlet was open, to have noticed any change in the meadows.

Stumps are said to have been found in the marsh near Ellis' Point, on the west side of the beach, and at other places below Bay Head. A low ridge of sand occurs at the west edge of the meadow, which fringes the beach, and also along the west shore of the bay.

Mr. J. G. W. Havens, Superintendent Fourth District United States Life-Saving Service, informed me that on the north shore of the Metedeconk river, an old meadow-sod occurs at a depth of eight to ten feet below the surface. The rise of the tide here is about six inches, and evidently this must have formed when the river was open to the sea, and the salt water rose and fell in an ordinary tide.

Assuming the rise of mean tide at this spot as five feet, which is probably far in excess of the actual rise, we would have the sod three to five feet below low-water mark, and as it could never have grown there, the difference is probably due to subsidence.

From Bay Head, almost all the way to Seaside Park, the meadow-sod on the inside of the beach is only a few inches thick and underlaid by sand. This is thrown up in a ridge on the west border, as before stated.

Near Osbornville, and westward in the Metedeconk river, and on the meadows, are many stumps, some in five to ten feet of water. Mr. Isaac Osborn estimated that the water-level is about eight inches higher than it was fifty years ago.

Some masses of the meadow-sod which had been washed out of the bottom of the river and lay on the shore, were about two feet thick, and of considerable size.

At Silverton, Mr. Cornelius Clayton stated that he had noticed an appreciable encroachment of the meadow on the upland. It chiefly occurred while Cranberry inlet was open. Stumps are plenty in the meadow west of Green's island, but not at any considerable depth. He says, moreover, that when the inlet was open, timber used to die off along the edge of the meadow.

Mr. Edwin Irons stated that stumps abound in the meadows on all sides of Green's island.

According to Mr. Daniel Clayton, stumps occur two feet below the surface of the meadow, and are found in Kettle creek.

Stumps also abound in the meadow about Mosquito Cove. Mr.

Samuel Kelvey stated that he had found "huckleberry brush" 3 feet under the mud, rooted in the sandy bottom, and that he had noticed timber dying out along the upland border.

At Coates' Point, northeast of Toms River, stumps are numerous in the meadow for some distance from the border, and the encroachment of the marsh on the upland is quite apparent, as the tall grass of the meadow is growing among the pine trees of the border. Cedar stumps are abundant in Toms river and in the meadow along its shores, particularly in the ditches beside the track of the Pennsylvania railroad, where it crosses the marsh on the west side of Barnegat bay.

Near Good Luck, stumps are found in the meadow and the encroachment has been noticed.

In Cedar creek and the surrounding meadows, stumps occur, and the marsh has gained on the upland.

Forked river, near the village, is full of stumps, which are found at a depth of 3 feet. An old bridge of poles was discovered here in a ditch 2 feet below the surface of the meadow, which also contains stumps. It is evident that at one time the cedar swamp, which surrounds the river, grew nearly a mile further east than it does now, and has since become submerged.

At Waretown, cedar stumps and pine knots abound in the meadow, the latter being probably the remnant of pine timber, which was less durable than the cedar.

From Barnegat to Manahawken there is an extensive cedar swamp, and stumps and fallen timber occur as far out as the east edge of the meadow, in great abundance. In Log creek, east of Manahawken, they occur in 8 to 10 feet of water.

As no attempt has been yet made to ascertain the extreme depth at which the stumps occur in the meadow, no detailed account will be undertaken.

There are numerous shell beds in the meadows between Barnegat and Great Bay, but as the depth below the surface of the bottom on which they rest has not yet been determined, their description will be left to a future report. Three in particular are of considerable size, and are most interesting relics of the former inhabitants of the country. One of these is Cedar Bonnet, east of Manahawken; another is the island known as Ned's Nose, near the mouth of Manahawken creek, and the third is Cedar Hammock, southeast of Tuck-

erton. This is about 160 feet long by 50 feet wide at the broadest part, and is about 9 feet high. It has several large red cedars on it, one of which is 5 feet 3 inches in circumference, and it is entirely composed of fragments of the shells of oysters and round clams, with some mussels, winkles, &c. Its depth below the surface of the meadow has not been measured, and the portion exposed has been about half carted away for fertilizer. Throughout the region mentioned, the encroachment of the marsh on the upland is very noticeable, and is appreciated by all observant residents who interest themselves in natural phenomena.

The most striking evidences of this encroachment are to be found near Tuckerton, in the marsh bordering Great Bay. Here, within the memory of the old residents, many knolls or islands of upland which were once wooded, are now level with the surface of the meadow, the timber has died off and the stumps may be seen in the surrounding marsh. Mr. Elkanah Palmer informed me that just west of the road to Osborne's island, on the border of the meadow, are corn rows overgrown with salt grass. No one living remembers when corn grew there. In this vicinity the upland border, which is now barren of trees, once bore many oaks, the stumps of which are now in the edge of the meadow. Hickory island some 20 years ago was farmed, it is now but little above the marsh and the timber on it is dying out. Encroachment of this kind has been noticed on Wells' and Osborne's islands. Between Barnegat and Manahawken, on Cedar run, is an old corduroy road, at about the level of low-water; the oldest inhabitant had no knowledge of its construction. Near West creek there are said to be some crossways of the kind several feet below the surface of the meadow, and resting on the sand. At Tuckerton, in a ditch adjoining the farm of Dr. T. T. Price, there is a pole crossway 4 feet below the meadow surface.

In the meadows bordering the north shore of Mullica river stumps occur abundantly. Mr. Samuel Headly, of Tuckerton, stated that stumps had been found near Ballanger's creek, about 18 inches below the surface. They had apparently been cut with an axe. An old corduroy road was also found in this vicinity, at about the same depth.

Mr. E. Palmer states that within his recollection the marsh has encroached about 20 yards on a knoll of upland, called Eagle Nest island, near Ballanger's creek. The trees have all died off. About 50 years ago the buried timber in the meadows about the creek was mined and used for shingles. Mr. Richard Bogan, of Wells' island,

informed me that in the thoroughfare between Bass and Wading rivers, there is a cross-bridge of poles 3 feet below the surface of the marsh. Stumps occur there also in 15 to 16 feet of water. In the vicinity of Port Republic, in Nacote creek and the surrounding meadows, are a great abundance of stumps. This creek is surrounded by a cedar swamp, where it is beyond the reach of salt water, and it is evident that the growth of timber at some previous time extended to the mouth of Mullica river, or perhaps farther. Timber has been raised from the meadows and worked to some extent. In the Mullica river stumps are found by oystermen at a depth of 30 to 35 feet. This extreme case, however, is probably due to the undermining of the stumps by the river current.

Mr. Richard Higbee, of Higbeeville, stated that the oysters occur much farther up the Mullica river than formerly, being now found in Swan bay. He estimated the advance at about 1 mile in 15 years, and attributed it to an increase in the saltness of the water. Mr. Eli Bowen, of Leeds' Point, informed me that timber had died out on the islands near by. There are in the meadow the stumps of trees which were living when he was a young man. He is now 85 years old. There is a pole bridge on the long ditch near Leeds' Point, which is 2 feet or more below the surface of the meadow. It was built more than 85 years ago, says Mr. Bowen, as he has no knowledge of its construction. Other residents inform me that stumps occur in many places in the meadows near by.

Near Oceanville are some large Indian shell beds, of unknown depth; they are almost entirely covered by the meadow. Mr. Peter Boyce, who lives two miles north of Absecon, found stumps at a depth of 2 to 3 feet, in digging a ditch through the tide-marsh, 200 to 300 yards from the upland. He thinks the meadow is higher than formerly, as some stumps which used to be exposed are now covered with the marsh-sod. There is on the meadow southeast a large shell bed, once overgrown with cedars, but now partly covered with salt meadow grass. Judge Doughty, of Absecon, informed me that there were many stumps in the meadows in that vicinity.

Mr. Jacob Chamberlain stated that he had known a great number of trees to die out along the border in his vicinity. There are two large shell beds in the meadows north of the C. & A. R. R.

Senator J. J. Gardner, of Atlantic City, informed me that in the meadow back of his house stumps were found at a depth of 18

inches below high-water. One of them appeared to have been cut by a sharp instrument.

At Mount Pleasant, near by, Mr. Silas Robinson informed me that he had found cedar stumps in the marsh about 2 feet below the surface and a quarter of a mile from the upland. On Adams' ditch, west of the C. & A. R. R., is a large and deep shell bed. There is another on Scull Harbor beach.

At Pleasantville Mr. Lucas Lake stated that he had found pine stumps in the meadow 4 to 5 feet below the surface, and 300 to 400 yards east of the upland. A large shell bed is on the marsh near by. South of Bargaintown, on Cedar Swamp creek, some encroachment of the marsh on the upland knolls has been noticed. Stumps abound in the meadow.

At Leedsville Captain Mark Townsend told me he knew of a piece of land, once cultivated, but now part of the salt meadow. There are stumps in the marsh near Scull's Bay.

Mr. Thomas Robinson, of Sea View, has frequently found stumps in the east meadows 18 inches below the surface.

At Beesley's Point Mr. Frank Stites informed me that a cedar post which stood in the meadow as the corner of a 1,000-acre tract of land about 8 years ago, was 1 inch above the surface; 15 years previous it stood at least 6 inches above the surface. Mr. Thomas Stites said that the meadow was encroaching on the shore of Bunnell's island, which lies in the marsh about two miles west. The timber is dying out, and stumps occur beneath the sod. The same is true of all the islands he has noticed.

Mr. Joseph Collins, between Seaville and Palermo, stated that the tide-marsh was encroaching on a wooded island northeast of his house, and the timber on it was dying out.

Mr. Elva Corson, of Palermo, had noticed that there was considerable encroachment on the upland border just east of Cedar Swamp creek. He had also noticed it on the islands between Cedar Swamp creek and Hughes' creek. Stumps occur in the marsh bordering Tuckahoe river.

Captain Joseph Golder, west of Beesley's Point, said that the meadow was gaining on the islands. Some, which bore oaks and luxuriant vegetation years ago, are now unfit for upland plants. He stated that he thought the water-level was about 6 inches higher in that vicinity than it was 50 years ago.

Between Beesley's Point and Seaville many large shell beds occur on and under the meadow-sod. As their depth has not yet been determined no description is necessary.

At Tuckahoe I was informed by several hay-makers that the marsh is encroaching on the upland, and that small sandy islands which were formerly bare are now covered with meadow grass. Along the river bank trees are dying out continually. Stumps occur in the creeks at a depth of 7 to 8 feet.

Between Seaville and Cape May Court House, but little information of value was obtained from the residents. Stumps occur in the marshes, shell heaps abound and the encroachment of the salt meadow on the upland is plainly evident.

Mr. John Gandy, of Cape May Court House, says that there is the remnant of an old corduroy road or pole bridge 3 feet below the surface of the marsh on the thoroughfare known as Scotch Bonnet.

On the property of Mr. S. H. Bennett, in ditching a meadow, an Indian shell bed was found resting on the yellow sand under the sod, which was about 14 inches thick. The deposit of shells was from 4 to 10 inches thick.

Mr. George W. Husted, of the Gravelly Run mill, stated that the edge of the salt meadow had apparently gained on the upland near his house several rods in the course of 35 years. In digging ditches for the new mill many stumps were found 50 to 75 yards from the upland border, and with their tops about 3 feet below high-water.

Along the edge of the meadow, east of the Court House, the smaller shrubs and trees appear to be dying out, and near a small fresh-water bog the marsh elder (*Iva frutescens*) was evidently replacing the button bush (*Cephalanthus occidentalis*).

About one and a half miles northeast of the Court House, on the road to the landing, a deposit of shells is exposed in a ditch, quite similar to that at Mr. Bennett's place. It lies about 6 inches below the surface. At the landing itself is a large Indian shell bed, apparently overlaid by the meadow. Others occur near Mayville and on Seven Mile Beach, but their description will be deferred until they have been sounded.

Near Cold Spring, on the farm of Captain George H. Hildreth, an old corduroy road was found about 2 feet below the surface of the meadow.

Captain William Bennett, of Cape May City, stated that stumps had been found in the Pond creek meadows about 4 feet down.

It may not be out of place here to state that the edge of the meadow or tide-marsh which borders the water is estimated, as a rule, to be about 4 inches higher than the inner portion. This difference, I am inclined to attribute, in a measure, to subsidence, as the constant, though gradual rise of the water-level would cause the sediment contained in the water to be deposited at a gradually increasing height near the outer edge as the meadow grew laterally. This, however, at present, is merely a suggestion.

ALLUVIAL DEPOSITS.

It has been observed along much of the upland border of New Jersey that the soil is richer below an elevation of 20 to 30 feet than it is on the higher ground. The above limit, as a rule, may be excessive, most of the more fertile soil lying below 20 feet. Good examples of this may be seen on the low grounds of Manasquan and Point Pleasant, at Manahawken and Tuckerton, and along the border of Atlantic county, especially near Absecon, Pleasantville and Leedsville, or Linwood. While the determination of the natural limit of this formation may throw valuable light on some interesting points in recent geological history, serious difficulties present themselves in this work, as will be evident upon consideration of the facts.

The basis of the soil being chiefly quartz sand, its superior wealth of plant-food is due to an accumulation of humus or decaying vegetable matter, which yields to the vegetation taking root in it a portion of the nourishment it absorbed from the earth in which it grew. The rich alluvial soils are, therefore, much darker than the poorer ones, and the amount of humus contained is the chief means of distinguishing them.

When, therefore, we attempt to ascertain how far up the border-slope the dark soil extends, we find that the wash of poorer sand from above has covered it for some distance and mingled with it in places, while elsewhere more frequent and careful cultivation, with the addition of fertilizers conta' ing vegetable matter, has extended the limit beyond its normal pl oy forming a rich artificial soil quite similar to the natural.

As but little de ite information in this line has been collected during the past autumn, it seems best to wait until another season has afforded opportunity for more careful study before attempting any generalization on this subject.

QUATERNARY FOSSILS.

In the quaternary border plains of the coast, fossil shells of existing species have been found at various places. A brief mention of some new localities is appended, together with a description of two previously known.

On Metedeconk Neck, about three-quarters of a mile south of Osbornville, on the property of Mr. Rogers, shells were found in a well at a depth of 8 to 9 feet in white gravel. The surface stratum here consisted of about 3 feet of yellow sand and gravel, with ferruginous conglomerate. The shells were 1 to 2 feet above mean tide.

At Absecon Judge Doughty stated that two oyster shells were found, in digging a well, about 20 feet below the level of the C. & A. R. R., which is here nearly 10 feet above mean tide. In the same well a pine cone was found.

Near Bargaintown, Mr. Constant Somers informed me that clam and oyster shells have frequently been found in wells at a depth of 4 to 10 feet. As the precise localities are not known, I am unable to state the height at which these shells occurred. The general surface height of the land in this neighborhood is between 10 and 20 feet.

At Somers' Point, I am told by Capt. Mark Townsend, of Leedsville (or Linwood), a large shell bed was found at a depth of 15 feet. The surface height here is between 10 and 20 feet, and the material is chiefly yellow sand.

Capt. William Bennet, of Cape May, informed me that at the north point of what was once known as Cape Island he had found clam and oyster shells in a well at a depth of 10 to 14 feet. This was probably near the level of mean tide.

On the road from Tuckahoe to Dennisville, and about five-eighths of a mile south of Tuckahoe river, or about 300 yards south of the school-house, is a most interesting deposit. It is a reddish, clayey sand, with many pebbles in it, which, in spots, are cemented into a solid mass by limonite or oxide of iron. Most of these masses contain casts of clam shells, which resemble the Venus mercenaria, though the specimens obtained were not perfect enough for specific determination. The carbonate of lime of the shell has been entirely removed, and nothing remains but the impression of its surfaces. The material of the formation is not essentially different from that of the gravel

drift, though its deposition here may be more recent. The casts occur at about 20 feet above mean tide.

By the courtesy of Mr. Frank Stites, of Beesley's Point, I was enabled to visit a deposit of shell-marl, about 5 miles southwest of the point, and about a half mile west of the shore road. The surface height here is about 20 feet, and the marl lies beneath about three and a half feet of sandy soil. The material is a fine blue clay, free from grit, and containing an abundance of shells of the common littoral species—*Ilyanassa obsoleta*, the small "winkle;" and *Urosalpina cinerea*, the "oyster borer." Besides these, oyster shells were abundant.

Besides animal remains, buried timber is often found in the terraces.

At Highlands, in a well at Thompson's Hotel, a cedar stump was found at a depth of 25 feet. As the terrace here is about 40 feet high, the stump was 15 feet above tide. About 150 yards north of the drawbridge, on the low plain which has an elevation of about 6 feet, I was informed that stumps were found at a depth of 7 feet in wells.

In a well near the post office at Red Bank it is said that pine bark was found at a depth of 18 feet. The surface height here is about 40 feet.

BEACHES.

Under this head we are to consider the narrow sandy strips of land bordering the Atlantic coast of New Jersey from Sandy Hook to Cape May, and in many cases separated from the upland border by bays and channels fringed by tide-marsh or salt meadow.

Strictly speaking, it is inaccurate to apply the term *beach* to them, as this word properly refers only to that portion of a sandy or gravelly shore which is washed by the tide or waves. This, on the coast of New Jersey, is commonly known as the *strand*. Where the strand immediately adjoins the upland border, as in the vicinity of Monmouth Beach, or between Deal and Point Pleasant, and the dunes extend westward some distance from the shore, this whole sandy area is known as the "beach."

Professor Dana has described such formations where they are separated from the main shore under the name of *sand reefs*, and it were certainly desirable that such a term should be used; as, however, since the settlement of the State they have been called *beaches*

by the inhabitants, we must submit to custom which "makes the language," and in a report to the people of New Jersey describe its various natural divisions under the names most familiar to them. Beaches, therefore, as we are to understand them, are sand bars of considerable magnitude, which have been formed at a greater or less depth by currents depositing sediment under favorable conditions, and subsequently brought above water by the waves, as at the present day, or perhaps in some cases by the changes of sea-level which have evidently occurred in Quaternary time. This we may justly conclude to have been the origin of most of the beaches, for sand bars are continually forming along the shore and doubtless have been formed since the ocean first began to roll. Where the beaches adjoin the upland their origin is obviously due to the action of the waves, sorting out the finer material from the sea bottom and the upland border.

Once above water, a new formative agency began to act upon the sand reefs and built up hills along their borders—namely, the wind, which, blowing upon the shore, caught up the particles of dry sand and carried them inland until, meeting some obstacle, they were dropped out of reach of the tide, and by ceaseless repetition of the process, built up at a short distance from the strand those picturesque and often desolate adjuncts of a sea-beach landscape called *dunes* or sand hills.

The literature of the subject is quite limited, one of the most recent papers having been read before the International Geological Congress of 1878, by Dr. F. C. Winkler, of the Teyler Museum, Harlem, Holland, in a paper "On the Maritime Dunes of the Low Countries."

The study of these formations, however, is quite simple, and at the same time they are of sufficient interest to warrant the devotion of a short space to their further consideration.

After the formation of these primary beaches, various causes might combine to change their original extent. On one side they might be worn away by storms and tidal currents, on another added to by the same agencies, and finally they might be greatly extended in course of time by the action of currents running in a constant direction along their shores, and depositing sediment at one of their extremities, as happens now at the point of Sandy Hook, and the south ends of most of the beaches at the inlets.

The mean height of the secondary beach or sand flat formed in this

way would probably be that of high-water, were it not for the action of the winds, which, as soon as the tide fell and exposed the subaqueous deposit to their influence, would catch up the surface grains of sand as fast as they dried and carry them back from the shore. If the surface were level and free from obstacles no dunes would be formed, but the sand would be dropped evenly on the plain and a general increase of height would result.

If the beaches be wide and there are obstacles, such as trees, shrubs, ridges, &c., to catch the sand, a wind blowing from the sea does a rapid work of elevation, and dunes are quickly formed; when the wind changes to the opposite direction such sand as it can catch up is driven back, to be returned at the next change in endless repetition.

As a rule the dunes are quite persistent, especially where they are formed over growing vegetation, and when beach grass or other plants spring up on them in sufficient abundance to keep the surface intact. At times they retain their size and form for years, and then, without warning, silently steal away under the influence of the first heavy wind, to form again in another spot, leaving their former site, perhaps, bare and level. Frequently these sudden removals may be traced to some disturbance of the sand which has allowed the wind to penetrate and act on it to an unusual extent.

On the other hand, if the beach be narrow, low and quite free from obstacles which may catch the sand, a large proportion of it will be carried over, and should the beach be bounded by water on both sides, it will drop in and fall to the bottom, remaining there until the waves bring it above the surface and the winds gather it up and carry it whence it came.

Should the side opposite to the prevailing winds, however, be bordered by salt meadow the sand carried over falls among the grass and sinks down permanently in the mud; the blown sand will thus be deposited on the meadow at the expense of the beach until the former loses its soft, miry consistency and becomes a solid surface which may in time be covered with dunes.

In this discussion the action of wind alone has been considered without reference to wear of the beach by tidal or other currents. As will be stated farther on, the action of the sea on the shore, in most cases, wears away the east edge of the beach, and the wind carries the dunes constantly westward, so that in time all the sand lies immediately on the meadow-sod, which is often exposed in the surf.

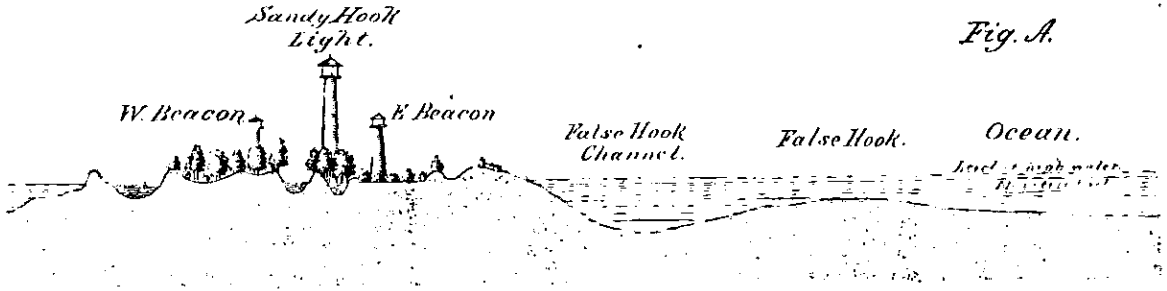


Fig. A.

Section of Sandy Hook. ½ mile S.W. of the Lighthouse.

Horizontal Scale 2 in 1 mile. Vertical Scale. 1 in 1520 ft

Fig. B.

We distinguish, therefore, on our beaches of the present day, three principal features:

1st. *Parallel ridges,* with troughs or depressions between them. These occur only on the older portions of the beaches, where they have been protected somewhat from the wind, and have probably changed little in character since they first emerged from the ocean, in which they were formed as sand bars.

2d. *Dunes,* which cover the greater part of the beaches, and, where the latter adjoin the upland, extend westward several hundred yards upon it.

3d. *Sand flats* of very recent formation, deposited by currents at the extremities of some beaches.

Beginning in our examination of the beaches at the extreme northeast point of New Jersey, Sandy Hook, we find, north and northeast of the N. J. S. R. R. pier, a densely timbered area of undulating surface, but having an average altitude of 10 feet above mean tide. The trees on it are nearly all of great size and age, and we may infer that it, with its southern continuation, is the oldest portion of "the Hook." It extends southerly in a narrow ridge to the breakwater or dyke, at the mouth of Spermaceti Cove, and lies a little east of the railroad.

Figures *a* and *b* show the structure and relations of the various parts of Sandy Hook, crossed by the planes of these sections.

The old "Hook" covers the area contained in a survey of 1685, and north of the pier is almost completely surrounded by salt marsh, while the marsh in turn is enclosed by ridges of sand, having about the same altitude as the inner promontory, and nearly parallel to its outlines. These probably belong to the category of parallel ridges previously described.

History tells us that the Sandy Hook lighthouse, which was erected in 1764, stood near the end of the point, which is now nearly a mile distant, in a northwesterly direction. This growth, as well as that which has taken place along the east shore, is due to a northerly current from the vicinity of Long Branch, which carries with it and deposits along the "Hook" the material it has taken into suspension on the way. The existence of this constant current has been determined and explained by the United States Coast Survey, under which organization a series of careful experiments have been carried on. It is found that during the flood tide the water flowing into New York

Bay draws with it a stream through the channel between the "False Hook" and the adjoining shore, while at the ebb the outward flow produces the same effect. A similar northerly stream is produced on the west side of the Hook. For more than seven hours out of twelve a northward current flows through False Hook channel; on the inside it flows for more than eleven hours out of twelve.

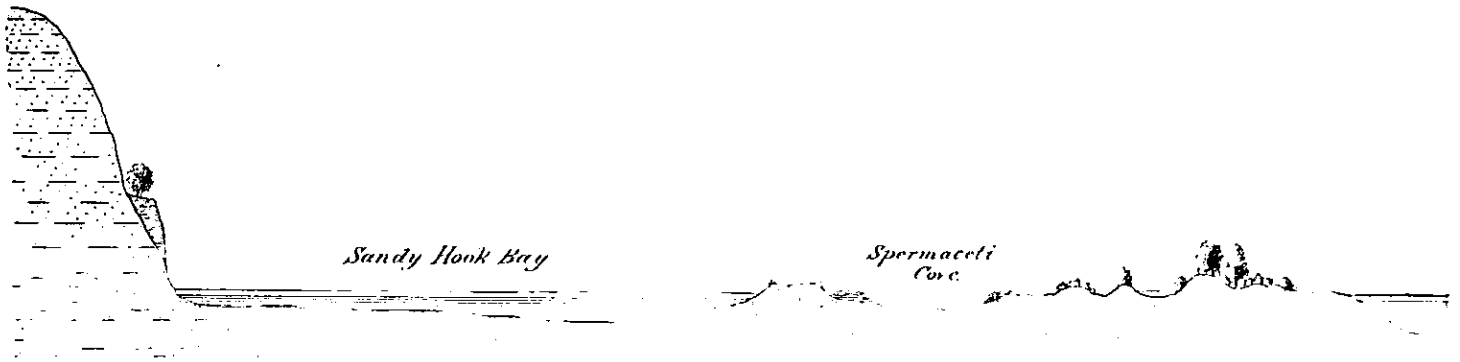
From the edge of the meadow surrounding the "Old Hook" northward to the fort is a region of dunes overgrown with trees, but none of them are so large as those on the inner ridge, and this area is evidently younger. East of the meadow is a broad stretch of dunes. They are composed of moderately fine white sand with a few fragments of shells scattered through it. Here and there unbroken shells occur, the following species being represented: *Mya arcuaria*, the soft clam; *Mactra solidissima*, the sea clam; *Ostrea virginiana*, the oyster; *Venus mercenaria*, the round clam; the mussels, *Mytilus edulis* and *Modiola plicatula*; and the gasteropods, *Natica* or *Lunatia heros;* the round winkle, *Melampus corneus*, and the sedge winkle, *Crepidula fornicata*. The sand hills bear a scanty covering of red cedar, bayberry, reindeer moss and *Hudsonia tomentosa*.

East of the dunes and south of the life saving station, is a more level plain, about 5 feet above high-water mark. It is nearly 500 feet wide, and bears red cedars of small size, perhaps 3 or 4 years old. This area is consequently quite recent, and its east edge is about 100 yards from mean tide mark.

I am informed that within 5 or 6 years no material change in the shore line has been noticed near Sandy Hook Life Saving Station, No. 1. Of its previous condition within 30 or 40 years we have as yet no accurate information.

Immediately south of the West Beacon the beach has worn quite rapidly, and the advance of the sea in storms has killed the vegetation near the edge of the bank, chiefly red cedar and poison ivy. The bluff here is about 10 feet high, well stratified, and the sand in it contains about 20 per cent. of *glauconite*, or green-sand. If this be the composition of the "Old Hook," its great fertility is accounted for.

The ridge extending along the shore, north of the railroad docks, evidently was a submarine formation. It has been extensively worn away since its elevation to the surface, but within the last year does not appear to have changed much. West of the light-house is a broad



Section across Raritan & Highlands near Sandy Hook.
Showing Position of Hilton Rock
Horizontal Scale 1 inch to [illegible]

tract of dunes, covered with a young growth of red cedar, bayberry, beach plum, etc. All the sand of the beach and dunes contains an appreciable amount of glauconite.

West of the railroad track, along the Horseshoe, is a sandy plain, which is about 3 feet above tide; it bears many large cedars, some of them measuring 4 feet in circumference. Along its northern part there are few dunes, but southward, toward Spermaceti Cove, it is bordered by a high ridge. Near the head of the Horseshoe the shore is wearing away rapidly. Several large cedars have been uprooted or killed by the waves, and the shrubs are also injured.

The east shore, abreast of Spermaceti Cove Life Saving Station, No. 2, has grown out, I am told by Captain J. W. Edwards, about 250 yards during the last 30 years, and this growth has occurred for about 1 mile south to a greater extent, the total increase within this time having been about 300 to 350 yards. Northward, for about 1 mile, the growth has been somewhat over 200 yards within the last 5 years, but little increase has been noted here or further north, as already noted.

From a point about one and one-third miles north of Highlands to about one mile south of it, near Bellevue, on the N. J. S. R. R., the beach has been washed away and remade again and again since the settlement of the country, and doubtless previously by the Shrewsbury inlets, once important to navigators. This beach is now only about 50 yards wide in its narrowest point, about a half mile north of Highlands, but northward and southward it is broader, and its average breadth is not far from 150 yards. The inlets which, in the history of the State, have twice broken through this narrow barrier, were characterized by a tendency to work northward. They opened in the vicinity of the present Bellevue Hotel, and during periods of 9 to 10 years slowly worked northward till they reached a point about a quarter of a mile north of Island Beach, and there closed up.

The dates of the inlets, which have been handed down mainly by tradition, are as follows, the information regarding the two last having been obtained from a number of old residents on the shores of the river, and whose statements, taken independently, agreed so closely that there is little room for doubt of their general accuracy.

Previous to 1778 Sandy Hook was connected with the Highlands of Navesink by a narrow isthmus or bar, and the Navesink or North Shrewsbury river was open to the ocean on the east, there being no

beach for about three miles north of the present Seabright. In 1777–8 a passage was broken through the isthmus, and the tidal currents flowing through this channel allowed the waves to build up gradually a bar or sand reef, which closed the eastern passage or old Shrewsbury inlet in 1810. From this time on the outer beach continued, and the Navesink river flowed through its present outlet until 1830 or 1831, when a breach was made in the sand reef, and the second Shrewsbury inlet was formed.

Shortly after a bar formed across the present mouth of the river, and connected Sandy Hook with the mainland, just north of Highlands, by way of Island Beach. This was 50 yards or more in width and was the means of communicating with the "Hook," it being possible to drive a team over it at high tide. About 1835 the residents of the vicinity undertook to open a channel through this bar, and after much labor cut a ditch through it, which was gradually widened and deepened by the tides until it became navigable.

The second inlet opened in 1830 or 1831, and closed about 1840. The third opened in 1837 or 1838, and for a time there were two navigable inlets—the second or more southern being most used. The last inlet closed in the latter part of 1848.

Within the past 35 years the sea has made occasional breaches in the strip of beach under discussion, but the efforts of property owners, and especially of the railroad company, since the buikding of the road, have prevented them from attaining any magnitude. Since the closing of the inlets the beach has shown marked signs of wear, and at almost every storm it is overflowed in places. From the Coast Survey chart, and the recollection of men familiar with the region, the wear may be estimated at upwards of 300 feet in 40 years, and this is certainly within bounds.

In the vicinity of Seabright Life Saving Station, No. 3, I am informed by Capt. H. H. West, the shore has worn away about 200 feet in 20 years, and at Seabright the shore is rapidly being encroached upon. For the details of the wear between this point and Deal Beach, I can give no information as accurate as that contained in the Geology of New Jersey, 1868, p. 343. Whether there has been any general westward movement of the beach in the region just discussed is not at present certain, but it is highly probable, from the analogy of the beaches further south, that some such change has occurred.

At Monmouth Beach Life Saving Station, No. 4, the wear of late

has been from 5 to 10 feet per year. From this point southward to Deal Lake, the beach merely forms a border at the foot of upland bluffs, and becomes of minor consequence.

The recent wear on these bluffs, as far south as the Long Branch pier, has apparently been slight, as they are generally overgrown with beach grass, though unprotected in many places, and from 8 to 15 feet high.

For some 200 yards south of the pier the bank is protected by a bulkhead, and there is, consequently, little wear; but about half a mile south the bluff, which is 22 feet high, is rapidly wearing away. From here southward to West End the bluffs are protected by bulkheads and other defenses of greater or less efficiency, and the wear is, in a measure, arrested.

Immediately south of Long Branch Life Saving Station, No. 5, bulkheads are in course of erection, but from here southward past Elberon to Deal Beach, no very recent wear is apparent, as the banks, down to the level of the strand, are covered with *Calamagrostis arenaria*, or beach grass. From the beach east of the railroad station down to Deal Life Saving Station, No. 6, only slight wear is apparent, and most of that has been done by the last storm. It is estimated by an old resident, Mr. Russell White, that the wear immediately north of Deal Lake has been about 1,000 feet in 20 years.

Opposite Asbury Park, stumps have been seen in an old marsh bottom off shore at very low tide, opposite Asbury Park and Ocean Grove.

At the latter place the upland border is much lower, and where it adjoins the beach does not exceed 10 feet in height between Deal lake and Shark River inlet. Its average elevation is between 5 and 6 feet, and the surface of this border plain is covered with low dunes for a distance of 200 to 400 yards from the shore, bearing in greater or less abundance beach grass, bayberry and *Hudsonia tomentosa*, besides salt wort and spurge.

About Shark River inlet no recent change has been observed, though the inlet shifts from time to time to the northward, periodically closing up and reopening to the south. It is now encroaching on Shark River Life Saving Station, No. 7.

The shore line here grows out and wears away under the influence of prevailing winds and currents without permanent change.

North of Lake Como the dunes extend nearly a quarter of a mile

inland, but as at other points along the coast, they are being leveled off by the improvements on the beach. From Shark river to Spring Lake little material change has been noticed; near Spring Lake Life Saving Station, No. 8, however, the bank wears away faster since the dunes have been leveled off. The upland border plain is of the same general height, about 10 feet, between Shark river and the former mouth of Manasquan inlet, north of Squan Beach Life Saving Station, No. 9, and the dunes extend back some distance from the strand. Near Sea Girt there is the same intermittent growth and wear, the latter occurring chiefly in winter and the former in summer. Here the sand hills extend about 100 yards westward and wear a rather luxuriant covering of white cedar, bayberry, Hudsonia and beach grass.

Proceeding southward, we come to a broad, sandy area of probably recent formation, which continues to the mouth of Manasquan inlet. I am informed by old residents of Manasquan that the inlet worked north and closed up periodically before the government jetties were built.

About 50 years ago the mouth of it, as already mentioned, was north of the present site of the life saving station, and the whole beach between that point and the present inlet has been washed away and redeposited within that time. During the same period, it is said, the dunes have moved west about 75 yards.

Captain William Bailey, to whom I am indebted for most of this information, says the shore between Shark River and Manasquan inlets has worn away about 50 feet in 30 years.

SQUAN BEACH.

At Point Pleasant the dunes, where they have not been encroached upon by recent improvements, extend inland about 200 to 300 yards; they bear but a slight covering of "beach grass," and appear to be changing considerably. Immediately east of the railroad station the sand is yellowish, but farther south it is white and contains some glauconite.

Mr. Joseph Borden, Sr., who is now 85 years of age, states that the shore has worn away upwards of 4 chains during his lifetime. He and other old residents have seen meadow-sod with the hoof-prints of cattle in it exposed on the beach at the extreme low-water.

Stumps have also been observed at the same level. At the Bay Head Life Saving Station, No. 10, I was told that there has been no permanent change in 20 years. At times, when the wind is westerly, and the tide very low after a northeast storm, an old meadow-sod is exposed at about the level of extreme low-water. It contains the hoof-prints of cattle. The dunes here do not change much. From here to Mantoloking the beach needs no more detailed description than the statement that it is about 250 yards wide, with a ridge of dunes 10 to 25 feet high along the east shore, and sloping toward the west, which is bordered by salt meadows. At Mantoloking they have been leveled off artificially. Mr. Joseph Borden, Sr., of Point Pleasant, informed me that east of Herring inlet, at the mouth of the Metedeconk river, was an inlet through the beach which closed about 130 years ago. There is at the present day a depression across the beach at this point. Mr. Jacob Herbert, who has lived on or near the beach for a long time, estimates the wear at about 15 feet in the course of the past 20 years. This wear he thinks about uniform with that which preceded it.

At the Mantoloking Life Saving Station, No. 11, I was told that there has been no very permanent change of late, and that there is no prevailing current here, but the northeast winds cut away the shore most. At low tide, with a west wind after a heavy storm, the old meadow-sod is exposed in the undertow in many places between Life Saving Stations, Nos. 11 and 12. About one and one-quarter miles south of No. 11, there are many cedar stumps standing in the hollows between the dunes. The beach here is not essentially different, but the sand seems finer and the dunes are more abundant, covering the whole width of the beach. Near Chadwick's they lie farther back from the flat beach, but retain their height.

Captain William Chadwick informed me that the dunes 35 years ago were confined to a line about 100 yards east of the railroad. Since that time the shore has grown out 200 feet.

No meadow-sod has been noticed in the beach for a mile or two north or south of Chadwick's. Over eight years ago, it is said, there was an old cedar swamp near Mantoloking station, and there was pasture on the beach for cattle from Bay Head to Barnegat inlet. The drifting sands have covered up the meadow for a considerable distance east of the railroad.

At Lavallette the beach is quite flat and the blown sand forms no

high hills except on the west side of the railroad, where the old line of dunes attain a height of 20 to 25 feet. At Toms River Life Saving Station, No. 13, I was told that no permanent change had taken place within 35 years either in the shore line or the dunes. A slight depression in the beach to the northward, probably marks the site of Cranberry inlet, which is said to have opened in 1750 and closed in 1812. Other inlets have opened in the beach opposite Toms River at various times. At Seaside Park the salt meadow is bordered on the west by a narrow beach of white sand. This may have been brought into the bay through the old inlet. In many places along this border the sand has been raised up into a ridge about 2 feet high by the action of westerly winds and waves.

I am informed by Captain George Giberson, of Toms River, that near Lavallette, 60 years ago, there was a swamp with stumps standing in it.

It may be well to observe here that the term "swamp," as commonly applied to wooded areas on the beaches, does not involve the idea of wet or marshy ground as the word might lead one to suppose; many so-called "swamps" bear upland timber.

ISLAND BEACH.

Captain Joseph Reed, of Life Saving Station No. 14, stated that within 16 years there has been no material change on the shore. The dunes have spread eastward from the station to the strand. Between Stations No. 14 and No. 15 the beach is generally low and flat, and the dunes are not more than 10 to 15 feet high. At the Cedar Creek Life Saving Station, No. 15, no change had been noticed in the shore line during 10 years. Meadow-sod had been seen 1 mile north of the station at low tide. Along the west shore, wherever it has a north and south trend, a low sand ridge about 1 to 2 feet above high-water has been formed.

At Forked River Life Saving Station, No. 16, Captain Allgor stated that the beach is constantly making towards the west by the wear of the shore and the drifting of the sand. He estimated the wear at about 50 feet in 40 years. Meadow-sod has been seen on the shore below ordinary low-water mark. About a quarter of a mile south of the station a dead cedar stands among the dunes and stumps protrude through the sand in the neighborhood.

Mr. Derrick Chamberlain, of Forked River, informed me that here upwards of 60 years ago there was a "swamp" of 4 to 5 acres. Most of this area is now east of the shore line. It seems as if on the southern and apparently newer portion of the beach the highest dunes are next the surf, while farther north the main ridge is 100 to 200 yards west. At several points between Station No. 16 and Barnegat inlet the high tide overflows the beach. At the south end, the flat, which is evidently of very recent formation, extends about 600 feet beyond the dunes. The point of this beach appears to be working westward.

LONG BEACH.

Barnegat inlet is rapidly working south without material change of width. It is said that the site of the old light-house, which about thirty years ago stood near the water's edge, is now in the middle of the inlet, a change of nearly three-eighths of a mile. The north end of the beach was once covered with heavy timber, but this is now almost entirely gone. South of the light-house is a wooded area covered with small red cedars, holly and sassafras. At the northeast point the wear has been excessive during the last five years, amounting to about 200 yards, and the sea now threatens the security of the Oceanic Hotel, which stands at this point.

Captain J. H. Ridgway, of Barnegat Life Saving Station, No. 17, stated that the wear here is caused chiefly by the flood tide, while on the northwest side, near the light-house, the ebb does a rapid work of destruction. The beach is, moreover, working westward. On the flat beach, 150 yards east of the life saving station, a red cedar stump projects from the sand. Half a mile south of the station the timber is very scanty and confined to the edge of the meadow; the highest dunes border the strand.

At Loveladies Island Life Saving Station, No. 18, I was informed that the beach was working westward and that sods with cows' tracks have been seen in the undertow during a west wind. The dunes here extend over to the edge of the meadows, and are chiefly overgrown with bayberry, there being little beach grass on them.

The beach at this point is comparatively low and flat, and just north of the life saving station the sea has washed over it. Going south from Station No. 18, the dunes which extend about 150 yards west from the strand are bordered on the edge of the meadow by a

dense growth of bayberry, with some bushes of *Baccharis halimifolia* or groundsel-tree.

At Harvey's Cedars Life Saving Station, No. 19, no permanent change had been noticed of late. Stumps have been seen just south of the house in the edge of the water at low tide and half tide. Much sand is washed across the beach into the bay.

About one-quarter mile south of the station is an old dead cedar about 50 yards west of the dunes; east of it and between the dunes and high-water mark are a number of stumps. There is little of special note in the character of the beach here; it is composed of fine sand and the dunes bear a sparse covering of beach grass with *Myrica cerifera* or bayberry in the hollows and at the edge of the meadows.

About two miles south of Life Saving Station No. 19, on the west side of the beach is a wooded area, the remnant of the Great Swamp.

Captain Cranmer, of West Creek, informed me that in 1822 and previously, there was heavy timber of oak, sassafras, gum, holly, etc., in this swamp. A pond nearly one-half mile long lay in the midst of it, and this was bordered on the east by a ridge of sand reaching to the tops of the trees. This in course of time, being driven westward by the wind, went into the pond and filled it up, having killed off all the timber on the east side of the beach. Captain Lewis Inman, of Manahawken, who was brought up near by, corroborates the statement, and says that this pond lay east of the strip of meadow which now occurs in the center of the beach. He states that there always has been a ridge of sand on the west edge of the beach, but it is somewhat higher now.

South of the Great Swamp there was no timber of importance, and to the north it was confined to the vicinity of the inlet.

At the present time, the remaining trees are chiefly cedar, and are mostly buried in a ridge of quite high dunes which borders the west shore, while between this and the dunes of the east shore, which are about 80 yards wide, is a low strip of meadow.

South of this area the dunes on the west disappear and the beach is much lower.* About one-half mile north of Station No. 20 the beach is flat and forms a glade of 25 acres or more, reaching to the meadow. There is here a cedar stump in the flat beach.

Captain J. W. Truax, of Ship Bottom Life Saving Station, No. 20,

* According to Captain Cranmer, of West Creek, this was the case sixty years ago.

stated that the shore had worn away 75 yards within the last 12 years. This rate agrees with that determined from the Coast Survey maps. The dunes have drifted away rapidly within 2 or 3 years, owing to the loosening of the sand by walking over it, and the surf now flows over and forms a glade. There are stumps in the water's edge 300 yards northeast of the station. I saw one in the beach at about mean tide level.

About three-quarters of a mile south of the station a bed of clam and oyster shells has been seen at very low tide, and meadow-sod occurs all along the shore in the vicinity. The center of the beach is rising by the building up of the sand hills, and most of the shrubbery has grown up within 20 years.

For 2 miles south of the station the beach is quite narrow, and bordered on the west by flat meadow; still further south it is wider, but the dunes do not cover a much greater area and there is a general sameness from Station No. 20 to No. 21. The growth of bayberry is still luxuriant.

At Long Beach Life Saving Station, No. 21, no change had been noticed in 40 years, but the work of the United States Coast Survey shows a growth of 70 yards in 42 years previous to 1871. For a distance of 2 miles north, the same authority shows there has been no wear, and southward for 3 miles there has been a growth of 105 to 170 yards, which diminishes towards the point where the old inlet pierced the beach, about eighteen and one-half miles south of Barnegat inlet. The above data have been quoted from the Annual Report for 1882. As is very evident to the observer, the broad flat beach plain 100 to 200 yards wide which lies between the strand and the dunes to the northward of Beach Haven is of quite recent formation. The sand hills, moreover, are said to be working eastward, another proof of the more recent age of the plain. Just north of Life Saving Station No. 21, meadow-sods have been seen at very low tide under water at the edge of the strand.

During heavy storms, accompanied by high tides, the water flows over the beach and washes down part of the dunes. Mr. Joseph Gaskill, of Sea View, stated that he had seen stumps and the hoof-prints of cattle in the meadow-sod at low-water, on the strand just north of Beach Haven.

South of Station No. 21 the flat beach continues, the dunes are low and extend westward some 150 to 200 yards, and there are many glades between them. From Beach Haven to Bond's the dunes are

low and of limited extent. From a point 1 mile south of Beach Haven to the site of the old inlet, they are bordered by a flat meadow, 100 to 250 yards wide, and west of this is a second range of sand hills which border the marsh. The median strip of meadow bears a thrifty growth of bayberry, with various grasses and herbs. Along the east edge of the beach the dunes are, in many cases, overgrown with beach grass.

At Bond's Life Saving Station, No. 22, Captain J. Marshall, Jr., stated that the beach had worn away 50 yards since 1870. It will be noticed that the Coast Survey maps show a growth of 25 yards between 1839 and 1871.

The appearance of the shore from here northward about 2 miles, or almost to Beach Haven, would indicate that an appreciable wear has been going on of late or within 15 years. I am informed that the wear is chiefly due to the action of northeast winds, but also, in a less degree, to those from the south and southeast. Northwest winds build up the shore slightly.

It may be found, on further examination, that the strip of meadow bounded by dunes in this vicinity was formed in a depression between two parallel ridges, which have originated in the manner previously discussed.

Captain Marshall further informed me that "there was here a glade overflowed by the ocean, and there were no hills between it and the strand. The dunes have formed quite recently." About half-way between stations Nos. 22 and 23 meadow-sod has been seen at a slight elevation above low-water mark in the strand. Divers are said to have found sod running down vertically 4 to 5 feet in working on a wreck outside the bar.

About 45 years ago the inlet was open below the station; it gradually worked south, and closed up southeast of Tucker's island about 1874. I am told that 18 years ago it was northeast of the Little Egg Harbor Light. The lightkeeper informed me that about that time there were stumps on a shoal 1 mile southwest of Bond's, which were covered at half tide. Since the inlet closed there has been a rapid growth of Tucker's Beach to the southwest, in all upwards of three-quarters of a mile, during the past 15 years. From a point east of the light to the extremity of the beach it is very flat, and frequently overflowed. The dunes are few and rarely exceed 5 feet in height. The exact date of the closing of the inlet and its position at the time is in some doubt, as no accurate record has been found.

LITTLE BEACH.

The north point of this is quite flat. . About 1 mile north of Life Saving Station No. 24, the first dunes appear; these are low, infrequent and sparingly covered with grass. Mark's Thoroughfare is now closed up and the meadow and beach meet at a short distance from the north end.

Captain Charles H. Horner, of the life saving station, informed me that this beach has worn away about 100 yards in 8 years on the east shore at a point one-half mile north of the station. Abreast of the house he estimates the wear at 50 yards during the same period. The Coast Survey chart would indicate a wear of about 100 yards for one and a quarter miles north of the station and one-quarter of a mile south during the past 10 years. The point is said to have grown northwest about one-half of a mile in 4 years. At one time the dunes extended nearly half a mile farther north, but they have been blown and washed away under the influence of northeast winds.

The southwest side of Little Beach has worn about 75 to 100 yards in 8 years, chiefly owing to the closing of Mark's Thoroughfare. Captain Horner also stated that 8 years ago dunes extended down to the end of the south point, but they have largely disappeared. On the southwest shore at one point, there is an old marsh-sod exposed about one foot below high-water mark and about one and a half feet below the surface of the beach.

Brigantine inlet is said to have widened over half a mile by the wear of both points.

BRIGANTINE BEACH.

This is low and flat for 100 yards from its northern extremity. The dunes are low and grassy and do not extend far west. On the northeast shore of this beach, meadow-sod 3 feet thick is exposed at low tide, the surface of the lowest layer being about 4 inches above low-water mark.

A small cedar stump occurs with its roots imbedded in this sod, and on the surface of the uppermost layer, which is at about the level of mean high-water, cows' tracks are plainly marked. Near by is another large area of sod about 2 feet thick, its upper surface being also at about high-water mark.

At Brigantine Life Saving Station, No. 25, the wear of the north

point was variously estimated at from 75 to 175 yards per year for the past 5 years. That of the east shore was stated at from 4 to 16 yards per year.

Capt. Bowen informed me that the wear had been greater on the south side of Brigantine inlet than on the north side. Northeast winds do most of the work, though southeast winds produce some wear.

Near the station the beach is quite flat and the dunes are low, extending westward only about 50 yards, it seems not unlikely that the sea may make a breach at this point. Midway between Stations Nos. 25 and 26 the wear is estimated at 75 yards in 20 years. The dunes abreast of Station No. 26 have built up within about 8 years.

Southeast of South Brigantine Station, No. 26, the position of old wrecks pointed out to me by Capt. Wm. Holdzkom show a growth of about 10 yards per year for the past 25 years. About one and one-half miles south the former inlet closed up in the spring of 1882 or 1883. The east shore of the beach is growing from a point about one and one-quarter miles north of Life Saving Station No. 26, to one mile south. Still farther south the shore is wearing rapidly, 75 to 100 yards in 18 months. This wear may be due to the closing of the inlet. The west shore of the beach is growing but little. Inside of the strip of meadow on which the life saving station stands there is a higher ridge of dunes. No timber has grown on the beach for 50 years, but in 1744 there was a considerable growth of cedar on it. One wood was called Harvey's Quarters. Harvey's is said to be a corruption of Harvester's, and the name is found at many points on the beaches, *e. g.* Harvey's Cedars, on Long Beach, as it is claimed these places were formerly frequented by haymakers. In the area occupied by the former inlet, the beach is nearly flat, and there are a few dunes little over 5 feet high and overgrown with "beach grass." Beyond this level space the dunes are 10 to 15 feet high.

At the southeast extremity of the beach opposite Atlantic City, an old meadow-sod is exposed on the edge of the beach. It is about one and a half feet thick, and its surface is about 6 inches above low-water. The upper surface is near 6 feet below the level of the flat beach.

ABSECON BEACH.

Captain A. Bowen, of the Atlantic City Life Saving Station, No. 27, stated that the point on the south side of the inlet has worn away

400 yards in 20 years. Along the east shore the wear has been nearly one-half mile in 30 years. About 10 years ago the jetties were built and this stopped the wear. Apparently owing to a change in the position of a channel, the northeast shore grew out rapidly until 2 years ago, but since then it has been worn to some extent. Two miles southwest of the light-house there has been but little change in 10 years. Formerly (6 to 8 years ago) stumps were to be seen at low tide in the beach southeast of the life saving station. Now, at the northeast point, east of the pier, meadow-sod occurs at about 8 inches below ordinary low tide.

At Absecon Life Saving Station, No. 28, Captain Gaskill informed me that the shore abreast of the station had grown out a little.

Below the station the shore has worn away. The beach here is flat for 200 yards and west of it are dunes 10 to 15 feet in height bearing bayberry bushes and a few stunted cedars. On the west edge of the beach, in the meadow, are trees of considerable height; the dunes, which are also quite high in the middle of the beach, apparently cover an area once bearing grass and timber, as in many places between the dunes are areas of turf with red cedars growing on them. Farther south the meadow on the west of the dunes is itself bordered at a distance of one-quarter mile by another ridge of dunes, the highest point of which is 28 feet above mean tide. These hills bear some large timber and evidently are quite old. This is probably another instance of two parallel ridges formed under water.

At Great Egg Harbor Life Saving Station, No. 29, the shore is said to be wearing rapidly away at the rate of 20 feet per year for 1 mile south.

The extremity of the beach is growing southwest and a little on the outer edge.

The "new inlet" which intersected the beach near Longport worked south until it ran into the old inlet about 26 years ago. That area which lay between the two inlets was called Little Beach and was covered with high dunes. The new beach here is now flat.

PECK'S BEACH.

At Ocean City Life Saving Station, No. 30, Captain James S. Willetts estimated the wear of the north point at 100 yards in 8 years. He says the south point of Absecon Beach has not changed much.

The northeast point of Peck's Beach at one time wore rapidly away, but is now growing out. One-quarter mile south of the station the shore is wearing slightly, but there is no great change in the beach. Stumps and meadow-sod have been seen by several persons on the beach at low-water. Mr. John Gandy, of Cape May Court House, stated that he had seen the tracks of horses and cattle on the sod and scythe marks on the stubble. The surface of this sod was about 1 foot above low-water mark.

Captain L. Godfrey, of Peck's Beach Life Saving Station, No. 31, estimated that the south end of the beach had worn away about 200 yards in 15 years.

As a whole, Peck's Beach is quite low and level, the dunes rarely exceeding 10 feet in height. The strand, at the time of my visit, was also very flat and gradual in its slope. The north end of the beach bears some large trees of red cedar, gum, holly, oak, &c. Numerous beds of oyster and clam shells were found when grading the turnpike, in the dunes, 1 to 2 feet above the meadow.

LUDLAM'S BEACH.

The northern half of this beach is very flat and generally overflowed by storm-tides. At Sea Isle Life Saving Station, No. 33, Captain George Sayers stated that the shore had worn away about 18 yards in 10 years. About 1875, cedars grew on the sand hills at the edge of the water. Their stumps are now projecting from the sand. The roots are 2 to 3 feet below high-water mark, and seem to be imbedded in sand. It is said that a meadow-sod occurs along the beach in many places, extending below low-water mark. The shore up to the inlet is wearing away at about the same rate, but where it is quite flat it probably wears faster. I am told that 40 years ago the north point was heavily wooded, but has worn away about 1 mile during that time. A mile north of Sea Isle City much sand is washing over into the meadows. Ludlam's bay is very shallow and this is probably the reason why no inlet is opened. The wear along the whole beach is said to be about uniform.

South of Sea Isle City the dunes are comparatively low and of small extent, the beach being quite flat. A few stunted cedars are scattered here and there, and some stumps project from the beach below high-water mark. Near Townsend's Inlet Life Saving Station,

No. 34, the dunes are very high, some attaining 25 to 30 feet; they bear a few cedars and a thick growth of beach grass.

Captain Henry Y. Willetts stated that the beach has gained in height near the station. Along the water line it has worn 6 to 8 feet per year on the west shore. The dunes are building out to the east and southeast.

SEVEN-MILE BEACH.

The most striking features of this are the two parallel ridges of dunes which occupy the northern portion of the beach. They both exceed 40 feet in height, and the inner one is heavily timbered. The outer, which joins the inner about 2 miles south of the inlet, though perhaps formed originally as a sand-bar under water, is now a dune in every sense, as it is moving bodily westward, engulfing trees and killing them, the gnarled and mutilated trunks being left behind on the flat beach as a striking evidence of the work of desolation. The sand here is quite fine and contains, besides quartz, a large proportion of some blackish mineral, which gives the formation a brownish tint. The identity of this dark mineral has not yet been established.

Captain R. C. Holmes, of Tatham's Life Saving Station, No. 35, estimated the westward movement of the dunes at 20 yards in 12 years. He says that meadow-sod underlies the sand almost everywhere, as it often is found in wells. Some years ago there was a thoroughfare running along the west side of the beach, called Stone Harbor. This has been filled up about a half mile southwest of the station by sand washed over the beach. One mile north of the station is another glade, where the sea makes a clean breach over into the meadow. On the west side along the meadow, at several points, are low ridges, which have many large dead trees on them. One of these, a red cedar, measured 9 feet 4 inches in circumference. West of the dunes the island is heavily wooded with holly, sassafras, several species of oak, red cedar, &c. One sassafras measured 5 feet 2 inches in circumference. A most striking specimen was a bayberry 15 feet high and 19 inches in circumference.

HOLLY OR FIVE-MILE BEACH.

At the extreme north end it is quite flat, with a few dunes and much timber. Immediately southwest, for a distance of about 3

miles, the surface is interrupted by a series of parallel ridges and hollows, averaging about 100 yards in width, and trending about due northeast. Many years ago the hollows or "slashes" were filled with water, and a favorite resort for wild fowl; they are now chiefly filled up with marsh-grass and bushes. Captain C. Ludlam, of Hereford Inlet Life Saving Station, No. 36, at Anglesea, stated that previous to 1878 the shore wore away rapidly southeast of the light-house, but since that time little wear has occurred. About 2 years ago it began to grow out, and has made eastward about 150 yards. Between Anglesea and Holly Beach City the wear has been about 5 feet per year for 15 years, and much timber has been washed away. Northwest of the light the shore wears about 20 feet per year.

At Holly Beach Life Saving Station, No. 37, there is said to be little or no wear on the east shore as far south as the end of the point. Captain Frank Downs stated that this point had extended one-quarter of a mile in 15 years. From Holly Beach City southward the beach is low and frequently overflowed.

TWO-MILE BEACH.

This is said by Captain Downs to be wearing away fastest on the northeast side, one-half mile north of Turtle Gut Life Saving Station, No. 38. It has here lost upwards of one-quarter of a mile in 40 years. The south end has grown considerably, and Cold Spring inlet has widened. Along the northeast shore the meadow-sod crops out with its upper surface about 6 inches below high-water mark and reaches below low-water. At many points there are stumps and roots of bushes in the upper layer. There is about one and one-half feet of sand over the sod, and this is rapidly blowing away with the west winds. In front of the station a little of the old sand beach is left; here no meadow-sod is to be seen, but farther south there is plenty of it. It is said that the beach was once heavily timbered in the area washed away at the northeast point.

POVERTY BEACH.

Sewell's Point wore away rapidly until it was protected by jetties about six years ago; no growth has taken place, however. At Cold

Spring Life Saving Station, No. 39, Captain George Hildreth informed me that the wear from the end of the beach to a point one-half mile west of the station has been about 30 yards in 10 years. For about one-half of a mile farther west there has been nearly 30 yards' growth in the same time. Beyond this the shore is protected by a stone sea-wall, and no change has been noticed. For about one and one-half miles east from Station No. 40 the wear has been nearly the same as on Poverty Beach.

Meadow-sod occurs almost all the way from Sewell's Point to Cape May Life Saving Station, No. 40. West of this the wear is estimated by Captain C. H. Hand at 30 feet per year for the past 8 years where the shore is unprotected by jetties. The evidences of wear in this vicinity are numerous and interesting. Time does not, however, permit at present to collect them all, or to state accurately the amount of change.

CONCLUSION.—The following general conclusion may be drawn from the preliminary facts above noted:

There is a general wear on the east shore of the beaches along the Atlantic coast of New Jersey. As a result of this, and the action of wind and wave in carrying sand westward over the beaches, there is a change of position whereby most of what were formerly "sand reefs," are now mere accumulations of blown sand on the surface of a former tide-marsh. This lateral movement has, in many cases, amounted to more than the breadth of the beach since the settlement of the State, and is at present going on with undiminished activity. Although in places there has been a certain amount of eastward growth, this has in all cases been dependent on the action of currents which are governed by such local conditions as the position of sand bars, and may at any time be converted into agents of destruction. We must therefore accept it as a rule, on the east shore, that loss is absolute and gain but relative.

The position of the numerous cedar stumps in the beaches at a considerable depth below high-water mark, indisputably proves that there has been a change in the position of the water-level, as it is almost superfluous to say cedars will not grow where their roots are reached by salt water.

TERRACES.

By the word "terrace" in Geology is meant a mass of earth having a natural level surface elevated above the sea and formed at or near the level of water, which, during some former epoch, has stood at this height. Such formations usually consist of alluvial deposits of considerable depth, the material along the coast being chiefly sand and gravel, though clays not infrequently occur in them.

This alluvium has doubtless, in all cases, been chiefly derived from the wash of adjoining high ground, and in the instances under consideration was deposited mainly in quiet seas.

On the Atlantic coast of New Jersey these terraces attain a height of 50 or 60 feet near the mouth of the Raritan river and diminish gradually in altitude as we go south. We may therefore conclude that during the Quaternary Epoch the ocean stood at the level of the highest terraces, its surface not being equidistant from that of the present day.

As the water receded or the land emerged, secondary terraces were formed at lower elevations, so we find at various points along the coast these terraces or plains at different heights. One is very noticeable at a height of about 10 feet, stretching along almost the whole upland border of eastern New Jersey.

About the mouth of Cheesequake creek are a very marked series of terraces of different altitudes. Another interesting group occur in the vicinity of Keyport.

On the shores of the Navesink river, near Red Bank, are a number of these elevated plains.

Excellent examples are also to be seen on the north and east borders of the Highlands of Navesink.

On the shores of the estuaries of Shark river and Manasquan river are another striking series of terraces, as shown in Figures *c* and *d*, facing this page.

At Toms river, on the branches of that stream west and northwest of the town, and also near Island Heights, the alluvial plains are remarkably extensive and are between 30 and 40 feet above mean tide. See Figure *d*.

As the exact levels of these plains have not yet been determined, I have not undertaken to consider them, as even at Toms River the uppermost terraces exceed in altitude the height given.

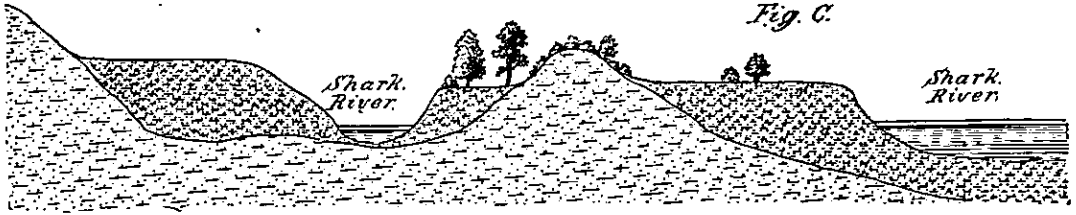


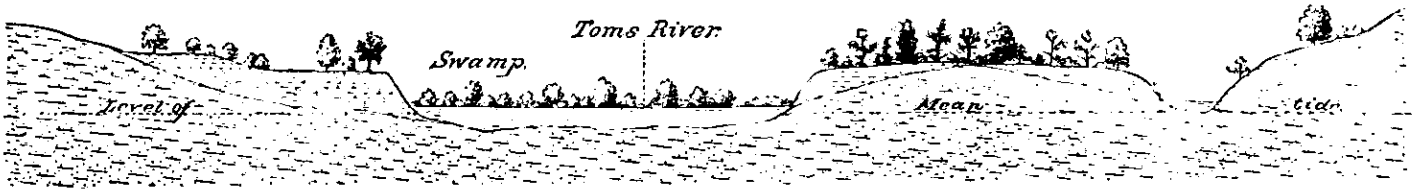
Fig. C.

Section of terraces at Shark River.
3/4 mile W of Key East.

Horizontal Scale 2⅔ in. = 1 mile Vertical Scale. 1 in. = 152½ ft.

Fig. D.

Section of Terraces on Manasquan River.
near the bridge. S.W. of Manasquan.
Horizontal Scale 2⅔ in. - 1 mile. Vertical Scale 1 in. 152½ ft.



Section of terraces at Toms River
½ mile W. of the village.

Horizontal Scale 2⅞ in 1 mile Vertical Scale 1in. - 152½ ft.

Still farther south, the terraces are less noticeable for their abruptness, as there is generally less high land to furnish material for them, but a careful study of the ground, specially directed to the search for these formations, will doubtless make it possible to continue the series much farther.

The accompanying sections illustrate the character of the principal terraces at some of the localities mentioned.

FOSSILS.

Mr. F. Braun, of New York, has, during the past summer, discovered a new locality for triassic fishes, near the eastern end of the New York, West Shore and Buffalo Railway tunnel, at Weehawken. The specimens are in the red shale, and are imperfectly preserved. The stratum lies a few feet below the trap-rock which forms the hill. With the fishes were found specimens of the bivalve crustacean, *Estheria ovalis*, described by Emmons, from strata of the same age, in North Carolina. They were also found near the same place by Mr. Anthony Woodward, of the American Museum of Natural History, New York, and among his collection are specimens of a smaller *Estheria*, probably specifically distinct from the one noted above.

Professor T. C. Porter, of Easton, Penna., in exploring some sandstone quarries in Hunterdon county, has found several good footprints, one of which he has identified as an *Anomœpus*, and distributed photographs. He obtained there also specimens of a *Conifer*, and an *Equisetum*.

Fred. A. Canfield has sent to the Survey a rather imperfect footprint from New Vernon, Morris county.

In the Geological Museum of Columbia College there is a fragment of a well-preserved bone, from the sandstone quarries at Belleville, near Newark. It doubtless belonged to one of the animals which made the footprints we now find in these Triassic rocks, but it is too imperfect for identification.

At a quarry near Pluckamin, specimens of the curious fossil fern (*Clathropteris rectiusculus*) were obtained.

A few years ago several large slabs of rock covered with footprints were obtained in the brownstone quarry near Whitehall, Morris county. Some of these are in the Geological Museum of Rutgers College, and

others are at the New Orleans Exposition, taken from the Museum of the Geological Survey at Trenton. Many of the prints are identical with those figured and described by Professor Ed. Hitchcock, in his book on the "Ichnology of Massachusetts," from the Triassic Rocks of the Connecticut River Valley. Among those from Whitehall are the following:

Tridentipes ingens,
Brontozoum giganteum,
Brontozoum minusculum,
Brontozoum Sillimanium,
Brontozoum isodactylum,
Brontozoum divaricatum,
Grallator formosus,
Grallator parallelus,

And several other species too imperfect for recognition. These foot-prints were originally supposed to have been made by very large birds, but are now known to be the steps of gigantic lizards, which have been termed Dinosaurs, or *terrible lizards.* A partial skeleton of one has recently been obtained in Connecticut by Professor O. C. Marsh, of New Haven.*

The recent discovery of a stratum full of impressions of the plant *Schizoneura Calamites planicostata,* (Fontaine) in the red shales near Doylestown, Penna., by Mr. E. C. Pond, and of bivalve mollusks in those near Phœnixville, Penna., where also a deposit containing cycads is reported, taken with the finds above noted, suggests that the flora and fauna of the Triassic may be richer than hitherto supposed, and encourages further search.

* See Trans. New York Acad. Sci., Vol. V. (1885), p. 17.

III.
ECONOMIC GEOLOGY.

IRON MINING.

The following notes on the mining industry in New Jersey during 1885 are based on information obtained from the managers and superintendents of the various mines, and from personal observation. The past year has been one of universal depression in iron production on account of low prices, and the only mines which have kept up their rate of production were those operated by wealthy corporations, which could place their product on the market at prices, in some cases, not covering expenses, or could carry the stock of ore and wait for a better market.

The last three months of the year have, however, been marked by greater activity. Several mines have been reopened, and in many cases there is a prospect of increased production during 1886. Improved machinery for mining and handling ore continues to be introduced and abundant facility is provided for the production of ore in large quantities as soon as remunerative prices can be obtained. In some cases the pay of the miners has been increased since the end of 1885.

MAGNETITE MINES.

PASSAIC BELT.

LANGDON MINE, Chester township, Morris county.

This mine, which is operated under a lease from Langdon & Nichols, by W. J. Taylor, of Chester, was taken in hand in November, 1885, and the rest of the year spent in preparing for active work. In January, 1886, mining was begun.

HACKLEBARNEY MINES, Chester township, Morris county.

Operated by The Andover Iron Company. Richard George, superintendent.

During 1885 six openings have been worked, four on the east hill and two on the hill southwest of the Black river. Of the two latter, one is a shaft and the other an open cut. The shaft, which has been sunk during the past year, is 40 feet deep and has just passed through the red or weathered ore. The open cut is 50 feet deep and about 300 feet long. There are said to be seven shoots of ore, in all, which vary from 2 to 10 feet in thickness, and are of undetermined depth. Three have been worked on the southwest hill. They do not seem continuous for any great distance, but lie within one broad belt. The lack of continuity may be largely due to offsets. The ore averages 55 per cent. of iron, and is high in sulphur, which is largely removed by the very efficient Taylor & Langdon roasting kiln.

During 1885 a new air-compressor has been put in and three new Rand drills have been employed.

GULICK FARM, Chester township, Morris county.

Operated by Cooper, Hewitt & Co. S. W. George, superintendent.

But little work was done during 1885; 1,500 tons of ore were raised and shipped to the Lehigh and Schuylkill districts.

SAMSON MINE, Chester township, Morris county.

This mine, under the same control as the above, was shut down in September, 1885, on account of low prices.

CROMWELL MINE, Chester township, Morris county.

Owned and operated by The Chester Highland Iron Mining Company. Chas. G. Hoskin, superintendent.*

SWAYZE MINE, Chester township, Morris county.

Controlled by the Andover Iron Company. Richard George, superintendent.

Very little has been done here; about 1,308 tons were shipped in 1885.

* Statistics not given.

COOPER MINE, Chester township, Morris county.

Operated by the Cooper Mining Company. J. D. Evans, superintendent.

A slope has been driven on drill-holes Nos. 2 and 3 (see Ann. Rep. 1883–1884), in continuation of the former slope, to a depth of 120 feet. This showed that the bodies of ore which were penetrated by the diamond drill were only thin *strings*, and demonstrated the absence of any ore body of consequence in the direction penetrated. The result serves as a good example of the fallacious conclusions which may be deduced from explorations conducted with the diamond drill alone, as it had been supposed, previous to the sinking of the slope, that there were important shoots of ore within reach. The mine is now at a standstill, and the shipments have been mainly made from stock.

WOODHULL MINE, Chester township, Morris county.

This is under the same management as the preceding, and was started anew in October last; 377 tons of ore were raised.

DICKERSON MINE, Mine Hill, Morris county.

Operated by the Musconetcong Iron Company. I. P. Pardee, Stanhope, superintendent.

Owing to a series of heavy caves, commencing in March, 1885, in the old workings, no mining has been done in the Big mine since that time. The new shaft which was begun in May, 1883, was finished in September, 1885, and is 575 feet deep.

A new tunnel, 350 feet long, has been driven in the hillside for the purpose of carrying out ore from the main shaft, which it meets 32 feet below the surface.

A new pumping engine, 30 inches by 48 inches, has been built, which is to raise 225 gallons per minute 1,000 feet. This engine also runs the air-compressor.

A new hoisting engine has also been put in with two drums 10 feet in diameter and 5 feet face. The cylinder is horizontal, 22 inches by 36 inches, and the whole is calculated to hoist 3 tons 500 feet per minute.

HOFF MINE, near Port Oram, Morris county.

Operated by Oram, Hance & Co., of Port Oram. Robert F. Oram, superintendent.

Only the "foot-wall vein" was worked during 1885, and about 5,000 tons were mined, but not all raised. There is one shaft on each of the two veins, and the "horse" between them is said to be of slight thickness at present. The shaft worked was sunk 30 feet, and drifts have been carried some distance from it on the vein.

DOLAND MINE, Mount Pleasant, Morris county.

Operated by Joseph Wharton. Cooke Straker, superintendent.

The work of the past year has been chiefly devoted to development, and but little ore has been raised. A new slope has been sunk to the depth of 170 feet and drifts run northeast 23 feet and southwest 62 feet. A new pump has been put in the old shaft 10 inches by 6 inches, and cars have been put in the new slope on the "hanging-wall vein," which is about 8 feet thick. The "foot-wall vein" is not now worked. The ore is said to contain 60 per cent. of metallic iron.

IRONDALE MINES, Randolph township, Morris county.

Owned by the New Jersey Iron Mining Company, and operated by the Thomas Iron Company. James Toutrin, superintendent.

No new developments have been made in shoot No. 13, the only one worked during 1885. The workings are now about 450 feet deep.

ORCHARD MINE, Port Oram, Morris county.

Owned by the J. Couper Lord estate. General J. S. Schultze, general manager; Joseph Richards, superintendent.

Nothing was done here except to ship away the stock left from 1884.

MEADOW MINE.

Owned and operated by the same estate as the preceding. But little progress was made during 1885.

MOUNT PLEASANT MINE, Mount Pleasant, Morris county.

Controlled by the same estate as the two preceding.

The length of the workings has not been materially increased during the past year. Mr. Richards informed me that there are 4 veins in all upon this property, two southeast of the main vein, 66 feet and 360 feet respectively, and one northwest, which is the Dolan or Hoff vein. The main vein is that of the Teabo mine. The ore body at present is about 5 feet thick. There are in all 3 shafts,

2 being now in operation. The northeastern one has been sunk about 20 feet during 1885. In February, 1885, the engine-houses were burned down and the machinery destroyed. The new machinery, however, is no larger or more powerful than that formerly used.

RICHARDS MINE, Mount Pleasant, Morris county.

Operated by the Thomas Iron Company. Reese Jenkins, superintendent.

During 1885 only the south or "hanging-wall vein" was worked. There are, in all, 4 openings, and ore is hoisted from shafts Nos. 1, 2 and 3. The vein has been worked for a distance of 2,300 feet. Shaft No. 2 reaches a depth of 340 feet below the surface. The amount of ore raised in 1885 was 57,833 tons.

An adit 467 feet long was driven to shaft No. 2 to carry off the water; it met the shaft about 57 feet below the surface.

Shaft No. 2 does not strike the vein until 167½ feet below the surface; from this point down it is a slope. Only steam pumps are in use. The ore is shipped to the Thomas Iron Company, at Hokendauqua, Hellertown, Chain Dam and Alburtis, Pa.

ALLEN MINE, Rockaway township, Morris county.

Owned by the New Jersey Iron Mining Company. L. C. Bierwirth, manager.

The work done here has consisted in drifting into the foot wall in search of ore. The undertaking was unsuccessful.

TEABO MINE, Rockaway township, Morris county.

Owned and operated by the Glendon Iron Company. George Richards, manager.

At this mine the two upper shoots have been worked this year in shaft No. 4.

An intermediate shaft is being sunk northeast of shaft No. 4 to reach the bottom of the first shoot from level No. 3, which is 430 feet below the surface.

A new hoisting engine has been put up on shaft No. 3, with 2 cylinders 14 inches by 18 inches; the drum is 6 feet in diameter and 5½ feet face. It is calculated to hoist 1½ tons at 350 feet per minute.

The following analysis of Teabo ore was made in 1876, at Lafayette College, Easton, Pa.:

	Sample No. 1.	Sample No. 2.
Silica	17.77	17.21
Magnetic oxide of iron	69.25	71.81
Sesquioxide of manganese	.26	.18
Alumina	4.48	4.02
Lime	3.40	2.22
Magnesia	1.98	2.34
Sulphur	.102	.01
Phosphoric acid	1.62	1.06
	98.862	98.85

MOUNT HOPE MINES, Rockaway township, Morris county.

Owned and operated by the Mount Hope Mining Company (Lackawanna Iron and Coal Company). Matson Williams, superintendent and manager.

During the past year work has been confined to the "tunnel mines" in the "jugular" vein. The tunnel cuts all five of the veins and terminates in the one mentioned. This has a maximum width of 25 feet, but has many pinches, a few of them reducing it to 18 inches.

It has been worked for a length of 390 feet northeast from the tunnel, and the bottom of the main shaft is 250 feet below the tunnel level. The total depth from the surface is about 550 feet.

The ore averages 60 per cent. of metallic iron, 1.9 per cent. of phosphorus and a trace of sulphur. The surface ore on the "Side Hill" vein averaged .35 per cent. of phosphorus, and at a depth of 300 feet was found to contain 1 per cent. This diminution of impurity at the surface is evidently due to the decomposition by weathering of the apatite or phosphate of lime which is intimately distributed through the ore in small granular crystals.

A vein of lean ore (25 per cent. metallic iron) quite free from phosphorus has been found between Mount Hope and White Meadow, at a depth of 100 feet; the bed is 3 feet thick.

West of the "jugular" vein a body of ore has been found nearly in the line of strike of the Hoff vein; it is, however, high in titanic acid.

The Mount Hope ores are all sold to the Thomas Iron Company.

WINTER'S MINE, Rockaway township, Morris county.

Leased by the Mutual Iron Company. J. L. Cunningham, agent and manager.

There are two openings which have been worked during 1885; one was sunk 75 feet and the other about 30 feet. From the former a drift was carried northeast about 30 feet. The ore-body in this shaft, which is known as the "Engine Shaft," is about 3 feet thick; in the other or "New Shaft," it is 10 feet thick. These openings are on different veins, the "New Shaft" being the more easterly. The ore is said to contain 65 per cent. of metallic iron, but no sulphur or phosphorus.

HOWELL TRACT MINES, near Charlotteburgh, Morris county.

Under the same management as the preceding.

There are four openings on this property which were worked during 1885, each of the two veins having two shafts on it. But little work was done here, and the out-put was small. The ore contains 55 per cent. metallic iron, and more sulphur and phosphorus than the preceding. Both of these mines were shut down at the end of the past year.

KITCHELL TRACT MINES, near Charlotteburgh, Morris county.

J. L. Cunningham, agent.

There are two beds of ore on this property, on one of which, the "Rich Vein," a shaft was sunk to the depth of 75 feet during 1885, its previous depth having been about 15 feet. Drifts have been carried from this shaft about 10 feet in each direction. There are also three slopes, one of which has been sunk about 35 feet. At the east end of the property is an open cut 40 feet deep. The ore here is 5 feet thick. The ore from the "Rich Vein" averages 65 per cent. of iron, and contains no sulphur; it is said to be a bessemer ore.

A small new hoisting engine was introduced here during the past year, and there is a prospect of considerable activity during 1886.

BEACH MINE, Rockaway township, Morris county.

Operated by the Andover Iron Company.

During the past year this mine has been operated in connection with the Lower Wood mine, at Hibernia, which adjoins it on the same vein.

HIBERNIA MINES, Rockaway township, Morris county.

The Lower Wood mine, under the same control as the above, was worked until the end of the year, when mining was suspended in

order to dispose of the large stock of ore on hand—45,000 tons. The ore raised from the Beach Mine is transported through a tunnel to the Lower Wood shaft, where it is hoisted to the surface. The total depth of the new slope is 550 feet, and the stopes have been driven on the vein about 200 feet farther northeast and 150 feet southwest.

The Glendon Iron Company controls the Glendon, Scott, De Camp and Upper Wood lots, of which only the three former were worked until their engine-houses were burned down. Since March 9th, 1885, no ore has been raised at the Glendon Shaft. The bottom of this is now 193 feet below the tunnel level, and the depths of the Scott and De Camp shafts are respectively 246 feet and 210 feet below the tunnel level.

The new ore dock, 1,624 feet long, is provided with three sets of screens which separate the dust and fine ore from the coarse before and after being broken, to the required size for shipment. About 22 to 25 per cent. is separated as *smalls*, and is shipped by itself to the furnaces for admixture in suitable proportions with the other ores.

BEACH GLEN MINES, Rockaway township, Morris county.

Owned by the J. Couper Lord estate. Gen. J. S. Schultze, manager; Joseph Richards, superintendent.

This mine has lain idle during the past year.

MUSCONETCONG BELT.

WEST END MINES, near Valley Station, Hunterdon county.

Owned and operated by the West End Iron Company. G. M. Miller, superintendent.

Work at the Turkey Hill mines was resumed July, 1885. There has been no increase in the depth of the old workings, but a new shaft was sunk 290 feet. The pitch of the vein is said to become steeper as the depth increases. The drifts were carried northeast 80 feet and 45 feet northwest.

At the Swayze mine the main shaft has been sunk about 50 feet, and the drifts have been extended about 60 feet northeast.

A new Ingersoll air-compressor, 18 inches by 30 inches, for 10 drills, has been put up.

HURD MINE, Hurdtown, Morris county.

Controlled by the Glendon Iron Company.

During 1885, the slope was sunk 150 feet on the vein. The average width of the ore-body is about 20 feet. An offset met during the past year, threw the vein into the hanging wall 12 feet.

An analysis of Hurd mine ore, made at Lafayette College, Easton, in 1875, gave the following results:

	Sample No. 1.		Sample No. 2.	
Protoxide of iron	26.65	Iron. 62.195	29.64	Iron. 66.63
Sesquioxide of iron	59.23		62.37	
Silica	7.90		3.81	
Sesquioxide of manganese	.21		.23	
Magnesia	.36		.25	
Phosphoric acid	.48		.44	
Sulphur	.06		.02	
Carbonate of lime	2.95		2.19	
Alumina	2.14		1.00	
	99.98		99.95	
Phosphorus	.209 per cent.		.192 per cent.	

FORD MINE, Jefferson township, Morris county.

Controlled by the Musconetcong Iron Company.

No mining has been done during 1885, owing to the depression in the iron market. New machinery has been erected at shaft No. 3, and the mine was pumped out in December. At present (January, 1886,) mining is going on.

SCOFIELD MINE, Jefferson township, Morris county.

Operated by the Crane Iron Company. David Jenkins, agent.

There is one shaft on this property 433 feet deep, which penetrates both shoots. The foot-wall of the old shoot dips southeast 80 degrees; that of the new shoot is vertical. The drifts have have been carried northeast 175 feet and 97 feet southwest. The ore contains 50 to 54 per cent. of iron and .9 per cent. sulphur. Phosphorus is said to be low. The ore-body is 18 feet thick at the bottom of the shaft.

OXFORD FURNACE MINES, Warren county.

Owned and operated by the Oxford Iron and Nail Company.

Slope No. 3 alone has been worked continuously during 1885, and

has been sunk about 35 feet; the ore-body increases in thickness as the depth increases, and is now about 3 feet thick.

The Washington Mine was worked for 15 days during the past year. An analysis of this ore, made in 1884, gave the following results:

Iron	63.19
Silica	7.985
Phosphorus	.615
Sulphur	1.68

All the ore from these mines is used at Oxford Furnace, which went into blast in December, and has produced 731 tons in 25 days.

PEQUEST BELT.

KISHPAUGH MINE, west of Danville, Warren county.

This property, owned and operated by A. Pardee, includes the former Cook farm, mentioned in previous reports. It has been in active operation during 1885. The new slope is 300 feet long and runs nearly parallel to slope No. 3 of the Crane Iron Company's old working. The drift running southwest from the bottom is 123 feet in length, and that running northeast is on the former Cook property, and about 75 feet long. Eighty thousand four hundred and thirty-four gross tons of ore were shipped to the Secaucus Iron Company. The average of recent analyses gives 55.91 per. cent. iron and .037 per cent. phosphorus.

OSMUN PLACE, Oxford township, Warren county.

Hartpence Brothers have sunk two shafts on this property and raised about 200 tons of ore during 1885. It contains about 1 per cent. manganese.

HEMATITE MINES.

The only deposit which has been worked to any extent in New Jersey during 1885, is that near Carpentersville, south of Pohatcong creek, and not far from the Delaware river. The bed lies between the blue Paleozoic limestone and the crystalline rock, and occurs for a considerable distance on both sides of the Delaware river.

The deposit is worked extensively on the property of Mr. Andrew Rapp, where one of the workings has been carried to the depth of 204 feet; the opening which is worked at present, is 160 feet deep, and the ore varies from 1 to 15 feet in thickness, being very unevenly distributed. It is said to be better at the level of the river. Analysis shows about 45 per cent. of iron and no sulphur or phosphorus.

The adjoining farms, northeast, are worked respectively by Cope Brothers and Ivy & Co.

All the ore is shipped to Glendon.

A deposit of hematite was opened during the past summer by the Middle Valley Iron Company. The amount of ore raised was small.

ZINC MINES.

At Mine Hill, Franklin Furnace, work has gone on throughout the past year in the Taylor mine, operated by the New Jersey Zinc and Iron Company, and on the property of C. W. Trotter. At the Trotter mine, of which Mr. J. H. Van Mater is superintendent, but little was done during the first three months. The extent of shaft-sinking during the year has been 50 feet in "No. 4" and 70 feet in the "Ding Dong" shaft. About 174 linear feet of drifting and cross-cutting was done during the year. The ore deposit has varied during the year from 2 feet to 30 feet in thickness. Some 13,000 tons of ore were raised, averaging 34.17 per cent. of zinc oxide.

At the Taylor mine, formerly known as the Buckwheat, extensive developments have been made and are now going on. The work is confined to the "back" or eastern vein, which, in the north chamber, is about 65 feet thick. The total amount of ore raised was 21,285 tons.

At Stirling Hill no mining has been done at either of the two mines since May 1st, the total shipments amounting to 9,443 tons.

GRAPHITE OR BLACK LEAD.

This useful mineral, which is so widely distributed through the crystalline rocks of New Jersey, in certain districts, is not at present being mined in any considerable quantity.

As already stated in Dr. N. L. Britton's article on the geology of the crystalline rocks in the present report, graphite is sparingly found throughout a long belt of quartz-feldspar and gneissoid rocks, on the east border of the Highlands, and occurs in appreciable quantity along the following lines:

1st. From Peapack northeasterly through Mendham and west of Morristown.

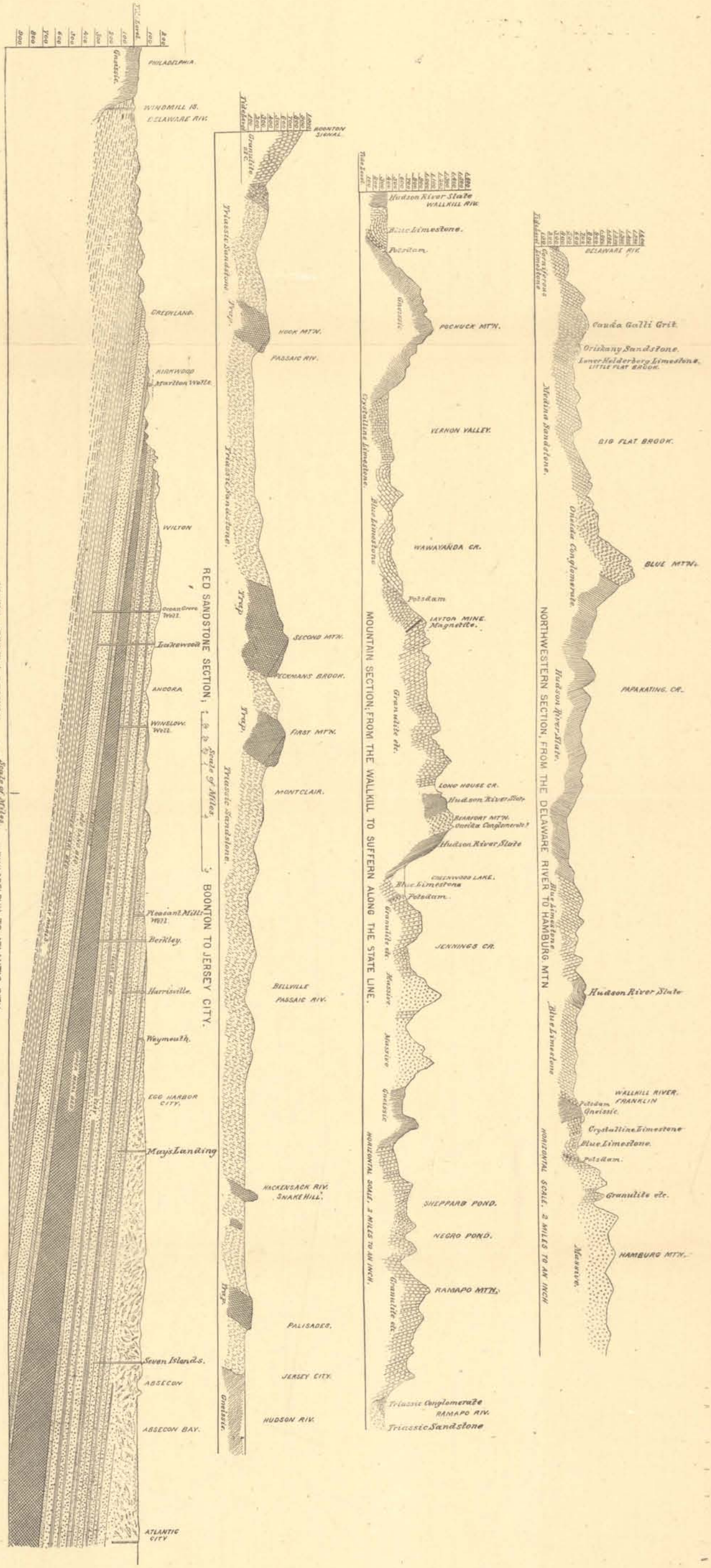
2d. From High Bridge northeasterly on a line passing near Fairmount, Pottersville and two miles east of Chester. On the continuation of this line graphite occurs at Bloomingdale.

Descriptions of these localities are to be found in the annual reports of 1868–'79–'80 and '83, consequently no space need be devoted to them here. At High Bridge and Bloomingdale only, have works been erected to concentrate and prepare the mineral for market. The former is no longer in operation. At the latter, during most of 1885, only the stock on the bank was treated, and but little rock was mined.

As yet no deposits of graphite in large masses have been discovered in New Jersey, and the material available is a rock containing a small percentage of graphite, which is crushed, sifted, and treated on a dressing table. At Bloomingdale, in 1879, a rock was being worked which carried 11.2 per cent. of graphite. The problems encountered in the working of these deposits are mainly dependent on the local conditions under which the mineral must be mined and concentrated, and the financial success of the undertaking depends largely on the expense of treatment.

At Ticonderoga, New York, a schist carrying 8 to 15 per cent. of black lead is very remunerative.

The white crystalline limestone of the Vernon Valley, which carries the zinc ores at Franklin and Ogdensburgh, contains, in places, quite an appreciable amount of graphite in small scales and crystals, but it is of no economic importance.


SOUTH JERSEY SECTION.
PHILADELPHIA TO ATLANTIC CITY.
Tide Level.
Granitic.
PHILADELPHIA.
WINDMILL IS.
DELAWARE RIV.
GREENLAND.
KIRKWOOD
Marston Wells.
WILTON
Ocean Grove Well.
Tuckerton
ANCORA
WINSLOW Well.
Pleasant Mills Well.
Berkley.
Harrisville.
Waymouth.
EGG HARBOR CITY.
Mays Landing
Seven Islands.
ABSECON
ABSECON BAY.
ATLANTIC CITY
RED SANDSTONE SECTION; BOONTON TO JERSEY CITY.
Tide Level.
Granite etc.
BOONTON SIGNAL.
Triassic Sandstone.
Trap.
HOOK MT'N.
PASSAIC RIV.
SECOND MT'N.
TEEKMANS BROOK.
FIRST MT'N.
MONTCLAIR.
BELLVILLE
PASSAIC RIV.
HACKENSACK RIV.
SNAKE HILL.
PALISADES.
JERSEY CITY.
HUDSON RIV.
Gneissic
MOUNTAIN SECTION; FROM THE WALLKILL TO SUFFERN ALONG THE STATE LINE.
Tide Level.
Hudson River Slate
WALLKILL RIV.
Blue Limestone.
Potsdam.
Gneissic
POCHUCK MT'N.
Crystalline Limestone.
VERNON VALLEY.
WAWAYANDA CR.
Potsdam
LAYTON MINE.
Magnetite.
Granulite etc.
LONG HOUSE CR.
Hudson River Slate
BEARFORT MT'N.
Oneida Conglomerate?
Hudson River Slate
GREENWOOD LAKE.
Blue Limestone
Potsdam.
Granulite etc.
JENNINGS CR.
Massive
Gneissic
RAMAPO MTN.
Granulite etc.
Triassic Conglomerate
RAMAPO RIV.
Triassic Sandstone
HORIZONTAL SCALE, 3 MILES TO AN INCH.
NORTHWESTERN SECTION, FROM THE DELAWARE RIVER TO HAMBURG MTN
Tide Level.
Limestone
Gneissic
DELAWARE RIV.
Cauda Galli Grit.
Oriskany Sandstone.
Lower Helderberg Limestone.
LITTLE FLAT BROOK.
Medina Sandstone.
BIG FLAT BROOK.
Oneida Conglomerate.
BLUE MT'N.
Hudson River Slate.
PAPAKATING CR.
Blue Limestone
Hudson River Slate
Blue Limestone
WALLKILL RIVER.
FRANKLIN
Potsdam.
Gneissic.
Crystalline Limestone
Blue Limestone.
Potsdam.
Granulite etc.
HAMBURG MT'N.
Massive.
HORIZONTAL SCALE, 2 MILES TO AN INCH.

WATER-SUPPLY,

FROM ARTESIAN OR OTHER BORED WELLS IN NEW JERSEY.

Wells which are bored or drilled into the earth and rock for obtaining a water-supply are frequently called artesian wells. The name is properly only applicable to those bored wells in which the water rises to the surface and flows over, like a spring. There are many bored wells, however, which do not flow, and yet they yield large quantities of water on being pumped, and the water in them is drawn from underneath strata which are impermeable to surface contamination. On this account, the term bored well will be used, and it refers to cases of such wells whether they are flowing or need to be pumped.

There is much inquiry made as to the probability of getting good supplies of water by boring. The question is one in which the answer must vary with the geological structure of the country where the boring is to be made. And as all portions of the State are interested in it, a pretty full statement of the differences of geological structure in various parts of the State is here made. An inspection of the geological map of New Jersey shows its different geological formations to occur in broad belts, crossing the State from northeast to southwest. Sections drawn across the State from northwest to southeast will cross all the geological formations, and when properly drawn, will show the peculiar rock structure of each.

To illustrate these peculiarities, four sections are here drawn:

1. THE NORTHWESTERN SECTION.—To show the limestones and slates which are the principal rocks beyond the Highlands.

2. THE MOUNTAIN SECTION.—To show the structure of the granitic and gneissic mountains and valleys.

3. THE RED SANDSTONE SECTION.—To show the red-sandstone and trap-rock structure, and its relations to the gneiss.

4. THE SOUTH JERSEY SECTION.—To show the fire-clays, marls and sandy clays of southern New Jersey.

1. *In the northwestern section* illustrations might be found of the true artesian wells. It is plain that if water should fall upon the

edges of the limestone beds on the higher borders of the valleys, and then sink down between the strata until it came under the middle portion, it would there be held down by the layers of solid rock, but if a boring were made in the lowest part of the valleys, and downwards through the rock until it reached the water-bearing layers, the water would rise in the bored hole and spout up to a height nearly equal to the elevation of the outcropping strata in which the water first entered. No bored wells are known to have been made in this part of the State, and while there is little doubt of their success, when properly made, it is most likely the water, though wholesome, would be hard and unfit for laundry or steam purposes.

2. *In the mountain section*, in the granitic rocks, there have been no wells bored on the section here shown, but they have been bored in similar rock in Jersey City, and one is now being bored in Perth Amboy, and many others have been bored in New York City and in Philadelphia. The gneissic and granitic rock is stratified, and only differs in structure from the other rocks in that its strata appear to be standing on their edges, and the divisional planes between the layers are almost perpendicular, so that if water is pumped out from the lower portions of the rock, rain or other water on the surface can descend freely between the layers to take its place. The structure is shown plainly on the mountain section, and also at the southeast end of the red-sandstone section, and the measure of success which has attended them, is here given. In April, 1825, Mr. Levi Disbrow bored a well in Jersey City, and his notes of it are as follows: "Level, 8 or 10 feet; begun to bore in a well 24 feet deep; water in it very brackish; Jersey City surrounded by salt water; granite from the commencement to the present depth, which is 208 feet; struck several veins of water after going 146 feet; by inserting a small pump 3 gallons a minute can be raised; the water runs over the tube 21 inches unaided by machinery; they are still boring; water excellent." This quality of water was usually found at first, but by continued pumping it became brackish.

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 8 inches, and in the lower 800 feet, 4 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° Fahr. 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 micaceous 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 eight-inch pipe down to the rock, below that the bore is $6\frac{1}{2}$ 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.

A well is now being bored at Perth Amboy for the purpose of getting a supply of water for the town. It is to be 12 inches in diameter in earth, and 8 inches in rock. It is located at the water-works engine-house, just north of Eagleswood, and about 28 feet above tide-level. The first 55 feet was in black clay, then some red and white clay, a little kaolin, an inch of white sand, and, at 61 feet, red-shale and sandstone. At 70 feet granitic or gneissic rock was struck, rather soft and crumbling at first, but becoming very hard at 85 feet, and in this the work continues to near 470 feet and no water.

"Holt's well, in New York, between Pearl and Water streets, near Fulton Market, extended 126 feet before striking rock, and continued into the rock 500 feet further, making a total depth of 626 feet. The rock is gneiss, with veins of quartz and granite. Two hundred feet of the upper part of the bore is a 3-inch hole, and the remainder $2\frac{1}{2}$-inch. The water obtained from this well was at first tolerably

good, and promised to be very serviceable, but since has very much deteriorated, and is now said to be even more saline than that of the neighboring river."—*Mather in 1843.*

"The celebrated well at the corner of Bleecker street and Broadway is 448 feet deep, 42 feet through stratified sands and gravel and 406 in solid rock, having the usual character of the rock of the island. The bore of the shaft is 7 inches diameter, and yields 120,000 gallons of water in 24 hours, according to the statement of Mr. Disbrow, who made the borings, and who also states that the water rose within 30 feet of the surface."—*Mather.*

Such wells are not true artesian wells in that the surface-water is not shut out by any impermeable stratum. And they have uniformly failed after long pumping. The New York Board of Health is said to have now forbidden the use of water from these wells for household purposes. The rock in Philadelphia is also gneiss. There are some bored wells in that city which are still in use, but they are unsafe for household use, and will necessarily soon be abandoned.

The water in these rocks, before being contaminated from the surface, is soft, pure and wholesome, but in all places where the surface over this rock is liable to accumulate filth or organic impurities, it will not be safe to bore wells for getting a supply of pure water.

3. *In the red-sandstone rock,* which covers so large a belt of country across New Jersey, bored wells have been put down in great numbers.

Mr. Disbrow, who began the boring of wells in this country, put down a number of wells in New Brunswick in 1824 and 1825. They were bored to various depths, one 175 feet, another 394 feet, another 176 feet, another 208 feet. They were lined with copper tubing 1½ inches in diameter. These were flowing wells, the water rising 2 or 3 feet above the surface, and discharging from a gallon and a half to two gallons a minute. Two of these wells are still flowing—one at the residence of the late Richard Johnson, Esq., and the other in a field on the southwest side of Easton avenue and not far from Mile run.

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.

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. The water is hard and unfit for washing, though it is not unwholesome for drinking; the impurities in it are mostly sulphate and carbonate of lime.

There is an artesian well at Loezer farm, a half mile east of Somerville, Somerset county, on Central Railroad of New Jersey. W. W. Merriam, Esq., has furnished the following account of it:

The well is located on land about 35 feet above the Raritan river, and 60 feet above tide-level. The work was done by Mr. Charles Spittlehouse, of Elizabeth. The bore was 6 inches in diameter, and the well 149 feet deep. The red sandstone rock comes within 18 inches or 2 feet of the surface; an iron pipe, 20 feet long, was driven into the bore and fitted so closely that no trouble was experienced from surface-water.

In boring, the water was struck at 13 feet, and a limited supply was found. This water rose to within 6 feet of the surface. It continued at this height till a depth of 65 feet was reached, when it fell to 32 feet, and there remained. At 75 feet something like iron ore was struck, and not a foot was made per day. The red shale rock was found all the way down to the bottom at 149 feet.

Upon testing the yield of water, it was found easy to lower it to 75 feet, below which it never fell, though always supplying the pump to its fullest capacity. The working cylinder of the pump is placed 100 feet down. This cylinder is of heavy brass, 3 inches in diameter, inside measure, with a 16-inch stroke, and has solid ball valves.

The first test of the well was 4 continuous hours, then a rest of 1 hour, and then another 4 hours' continuous work, without any signs of diminution in the supply of good water. One hundred barrels of water have been pumped from it in from $2\frac{1}{2}$ to 3 hours. The

quality of the water is excellent, and gives entire satisfaction for all household purposes, and for watering stock.

An examination of the water by Professors Austen and Wilber, showed it to contain 23.9 grains of solid matter to the gallon, mostly salts of lime and magnesia. It is free from organic matter, and, though scarcely to be called a soft water, it is safe and wholesome.

In Plainfield and its vicinity, a large number of wells have been bored for a few feet into the red sandstone which underlies the sandy earth of that town. The water in them does not differ materially from that in the common dug wells, and they are so shallow that they are necessarily liable to surface contamination when they have been drawn upon for large quantities.

Many bored wells have been put down in Elizabeth and places adjacent, perhaps, as many as 75, by Mr. Charles Spittlehouse, of that place. The wells pass through gravel, sand and clay for depths varying from 5 to 75 feet, underneath which is red sandstone, and the boring for them is continued until a satisfactory supply is reached, which has rarely failed at depths from 50 to 200 feet down.

There are reports of two deep wells near the shore of Staten Island sound, one of 344 feet and another of 1,200 feet, which have been unsuccessful.

In Newark several wells have been bored to a considerable depth in the sandstone, and these have yielded large quantities of water.

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 55½°. It yields 500 gallons a minute, or 720,000 gallons a day, 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. 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.

The well at 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, 124 grains of solid matter, mostly sulphates of lime, magnesia and soda.

The well of Messrs. Lister Brothers, at their works on the bank of the Passaic, in Newark, is 8 inches in diameter and 615 feet deep. It was sunk 110 feet in earth and 505 feet in the red sandstone rock. The surface is but a few feet above tide-level, 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 degrees. An analysis of the water showed it to contain 152 grains of solid matter to the gallon, consisting almost entirely of sulphates of lime, magnesia and soda. The well was bored in 1879, when the above analysis was made. Another analysis, made in 1882, yielded of solid matter 152 grains. Another analysis, made in 1884, showed the water to still contain 149 grains of solid matter, so that after several years of pumping and taking out this enormous quantity of water, it is still unchanged and unfit for drinking or for making steam. It is used for rinsing and for cooling purposes.

The deepest boring in the State is the well of the Passaic Rolling Mill Company, at Paterson. Its depth is 2,100 feet, and, excepting 6 feet of earth at the top, it 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 17 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 8-inch bore, and was cased with a 6-inch tube down to 1,120 feet, and the bore from that down to 2,100 feet was 4½ 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 tubing was drawn out of the well and the bore was stopped by a seed-bag below 900 feet. The water rose to within 17 feet of the top. By putting down a pump 40 feet into the well it has been made to yield 100 gallons of water a minute for 5 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):

Magnesia	2.15 grains.
Lime	3.71 "
Soda, with very little potash	1.15 "
Chlorine	1.08 "
Sulphuric acid	.55 "
Carbonic acid, not weighed	

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

Carbonate of magnesia	4.51 grains.
Carbonate of lime	5.95 "
Common salt	1.78 "
Carbonate of soda	.37 "
Sulphate of lime	.93 "
Total	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, or 360,000 gallons a day, 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."

The Burton Brewing Company's well, at Paterson, is 204 feet deep and 4-inch bore. The depth to the rock is 18 feet. The water contains about 12 grains of solid matter to one gallon of water. About 40,000 gallons a day are pumped without perceptibly lowering the surface in the well. The quality of the water is excellent.

At Kingsland's paper mills, Franklin, a well has been bored and lined with a 10-inch tube for 45 feet through the earth, and a bore of 8 inches in the red sandstone rock for 355 feet more. The water rises within 30 feet of the surface. It has been pumped continuously for 14 hours, discharging 125 gallons a minute and lowering the sur-

face of the water only 10 feet. This is at the rate of 180,000 gallons a day. The water is satisfactory in quality. The well was bored by Daniel Dull, of New York.

In Jersey City, the westerly part of which is underlaid by red sandstone, a boring of small diameter was made about 1842 by Mr. Andrew Clerke, in the marsh at the corner of Montgomery and Henderson streets. Here the red sandstone was met 15 feet below the surface and was penetrated to the depth of 200 feet, when a stratum of very hard rock of a whitish appearance was encountered, and the work was 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.

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 30 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° Fahr. 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 Limbech & 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° Fahr. 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.

The Orange Water Company, organized to furnish water to East

Orange and Bloomfield, draws its supply of water from near the great Boiling spring, which marks the junction of Newark city with the townships of East Orange and Bloomfield. This spring has long been noted for its abundant and equable flow of water at all seasons. J. M. Randall, Esq., vice-president of the Orange Water Company, informs us that three measurements of the flow of water from the boiling spring, made at different times within the last three years, have shown it to yield from 270,000 to 300,000 gallons a day. On the northwest side of this spring is the broad and shallow valley of 150 acres or more, in which the works of the company are situated. This valley or swale has always been too wet to invite clearing, and it is still in forest. Its surface is quite even, and there are no gravel hills within it. The upper layer of earth in this area is black, and made up of muck for from 1 to 5 feet down. Underneath this is a layer of sandy clay from 6 to 17 feet thick; quite uniform in composition, though it has a few scattering bowlders in it, and it is quite impenetrable to water. This material lies directly on the red sandstone rock of the country.

Wherever this layer of sandy clay is dug or bored through down to the rock, a flowing stream of water rises, and in a tube it will rise from 2 to 4 feet above the natural surface of the ground.

The first wells, Nos. 1, 2 and 3, were bored wells.

No. 1 has a 6-inch bore, and is 86 feet deep, 78 feet of which is in sandstone rock. Well No. 2 has a 6-inch bore, and is 90 feet deep, 81 feet of which is in sandstone rock. Well No. 3 has a 6-inch bore, and is 102 feet deep; 91 feet in sandstone rock.

Each of the above wells will yield 250,000 gallons of water in 24 hours, and not draw the water down more than 25 feet below the surface of the ground.

They are situated almost in a line, No. 2 being 170 feet from No. 1, and No. 3 is 240 feet from No. 2.

Wells Nos. 1 and 2 are a little affected by each other in the amount of water they yield, but not enough to interfere with the above-given estimated daily yield. No. 3 does not appear to be at all affected by pumping from the others.

Well No. 4 was next sunk near a large spring. It was sunk 12 feet into the solid rock, and then lined with a heavy stone and brick wall, cemented and carried up to a height of 5 or 6 feet above the surface. It is 25 feet in its inside diameter, roofed over and filled with clear and pure water.

The water rises from the joints in the rock. These joints are nearly vertical, and traverse the rock at intervals of from 1½ feet to 3 feet. It required powerful pumping apparatus to keep the well clear while it was being sunk, and when done and the pump stopped working, the water rose very fast.

The	1st	foot	filled	in	7 minutes.
"	2d	"	"		9 "
"	3d	"	"		11 "
"	4th	"	"		12 "
"	5th	"	"		14 "
"	6th	"	"		15 "
"	7th	"	"		17 "
"	8th	"	"		18 "
"	9th	"	"		21 "
"	10th	"	"		25 "
"	11th	"	"		29 "
"	12th	"	"		36 "
"	13th	"	"		49 "
"	14th	"	"		72 "
"	15th	"	"		115 "

A foot of this well holds 3,682 gallons of water, and if the pump were driven fast enough to keep the water down to 2½ feet in depth, it would supply more than 500,000 gallons a day.

Well No. 5 is located where there was formerly a spring, about 500 feet away from No. 4, and is 50 feet inside diameter, and is dug about 14 feet below the natural surface; 6 feet of this depth is in rock, and the remainder in earth. The water rises about 3 feet above the surface. In digging the well, when near the bottom, the contractor had to pump 1,250,000 gallons of water per day, to keep the work clear. And when the pump was stopped and the water allowed to accumulate,

The	1st	foot	filled	in	18 minutes.
"	2d	"	"		26 "
"	3d	"	"		30 "
"	4th	"	"		46 "
"	5th	"	"		55 "

A foot in depth of this well holds 14,728 gallons, and if, by pumping, the water was kept down to a depth of 2½ feet, the well would supply daily more than 750,000 gallons. It has been drawn from since June, 1884, for the supply of the two towns of Bloomfield and East Orange, to the amount of from 150,000 to 300,000 gallons

daily, without lowering the well so as to stop its overflow. While sinking this well the whole supply, amounting to about 200,000 gallons daily, was drawn from well No. 4. The latter well was slightly affected in its level, perhaps to the amount of 2 feet, while the other was being dug and walled up. The work of completing the walls and getting them thoroughly cemented and solid, required that the water should be kept out for the whole of that time, which was 40 days. In all that time the water in well No. 4 was at least 11 feet above that in well No. 5.

The flow of water from the rock in this locality is most remarkable, and is unexampled in our red sandstone regions. The quality of the water, both in the deep and shallow wells, is given in the following analyses:

ANALYSIS OF WATER FROM WELL NO. 1.

Total solids, grains per gallon		12.8000
Chlorine, as chlorides, grains per gallon	2.2422	
Sulphuric acid, as sulphates, grains per gallon	0.3666	
Silica, grains per gallon	0.9098	
Iron and alumina, grains per gallon	0.0233	
Lime, grains per gallon	2.1461	
Magnesia, grains per gallon	0.3965	
Free ammonia	.....	
Albuminoid ammonia	.....	
		6.0845
Alkalis and undetermined matter		5.7155

*Hardness, grains per gallon, as calcium carbonate, 4.99.

ANALYSIS OF WATER FROM WELL NO. 2.

Total solids, grains per gallon		12.1184
Chlorine, as chlorides, grains per gallon	1.1955	
Sulphuric acid, as sulphates, grains per gallon	0.3091	
Silica, grains per gallon	0.5948	
Iron and alumina, grains per gallon	0.0233	
Lime, grains per gallon	3.7907	
Magnesia, grains per gallon	0.6531	
Free ammonia	.....	
Albuminoid ammonia	.....	
		6.5665
Alkalis and undetermined matter		5.5519

*Hardness, as calcium carbonate, 4.5779.

*Water containing only from 6 to 9 grains of calcium carbonate per gallon, is *soft water.*

ANALYSIS OF WATER FROM WELL NO. 5.

Total solids, grains per gallon		9.838
Chlorine, as chlorides, grains per gallon	0.857	
Sulphuric acid, as sulphates, grains per gallon	0.379	
Silica, grains per gallon	1.230	
Iron and alumina, grains per gallon	0.046	
Lime, grains per gallon	2.209	
Magnesia, grains per gallon	0.712	
Soda, grains per gallon	1.936	
Potash, grains per gallon	0.227	
		7.596
Volatile matter, grains per gallon		2.242

Hardness, equivalent to calcium carbonate, grains per gallon, 5.091.

WELLS IN TRAP ROCK.

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° Fahr. 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.

The well of Mr. S. R. Parkhurst, on Mt. Prospect, Montclair, was started in trap rock, with a bore of 7¾ inches. At the depth of 90 feet sandstone was struck, and the boring was continued in that 420 feet, making the well 510 feet deep. The water rises in it to within 70 feet of the surface. It will yield 45 gallons a minute without being at all lowered by pumping. The water is said to be soft, and it is liked for household purposes.

From these trials of bored wells, it will be seen that it is uncertain whether a flow of water can be obtained from wells bored in the red sandstone. It is uncertain, too, whether the quality of water which the wells yield will be fit for domestic purposes, on account of its hardness. The strata are not all water-bearing. In some of the wells, strata which yield no water are driven into for many feet,

sometimes several hundred feet. The rock is traversed by nearly vertical joints, in two directions, which are nearly at right angles to each other, and some water may undoubtedly pass through them. From the structure (see section 3) it will be seen that surface-water may find its way down, as that below is drawn out by pumping. The water in shallow wells is specially liable to be contaminated by surface-water which is in the close vicinity of the well. The dip of the rock is from 8° to 12° towards the northwest, so that the distance it must run to reach the well is easily calculated.

4. *The South Jersey section* shows a succession of beds of clay and sand, of greensand marls and of sandy clays, all descending gently towards the southeast. These beds are of different thicknesses, from a few inches to a hundred feet or more, and, while many of them are quite impermeable to water, they are separated from each other by layers of sand, some fine and others coarser, and of thicknesses from the fraction of an inch to several feet. Water moves in these sandy layers with more or less facility as the sand is coarser or finer. The descent of these beds and layers towards the southeast is at the most only about 40 feet to a mile, so that if water is drawn from a well 400 feet deep, that water must have entered from the surface at least 10 miles to the northwest, if the surface is level. It will readily be perceived that the water from wells bored in these beds is not exposed to contamination from the surface near or surrounding them. Wells in some situations flow above the surface, while in others the water does not rise so high.

It will be most convenient to arrange the wells of this section in three divisions:

1. Those in the belt of clay and sand which is immediately southeast of the line which separates it from the red sandstone, and which may be drawn from Staten Island sound, north of Woodbridge, to the Delaware, at Trenton, and on in the same line down that river to near Salem. This belt is from 5 to 10 miles wide. A number of wells have been bored in it, but most of them have not yielded any large supply of water.

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 its excavated portion.

Perth Amboy is near the junction of the Cretaceous and Triassic rocks, and also near the underlying gneissic rock from which both of the others were originally derived and which is the line of division between them where it comes to the surface. The well now being bored at this place was begun in the clay and sand and was sunk through that and also through the red sandstone, and is now in gneiss.

At Sayre & Fisher's brickyards, on the bank of the Raritan, two wells of 2½ inches diameter and 80 feet deep, furnish an abundant supply of water. The material passed through was clay, till near the bottom, when sand and gravel were reached, and the water. The water is soft and does not corrode steam boilers, though it contains a little iron, probably a carbonate.

A deep well was bored in this clay and sand belt by Mr. C. S. Bucklin, at Matawan. The boring, lined with an 8-inch pipe, passed through about 100 feet of bluish clay with marl grains and then fine sand and an abundance of water. But this was not available on account of the sand following the water up into the tube. The boring was continued in this white sand, meeting occasional layers of clay which were 2 or 3 inches thick. The boring was continued to the depth of 264 feet without finding gravel or sand coarse enough to keep the lower end of the pipe clear, and the work was suspended.

There is said to be a flowing well at Port Monmouth, near the terminus of the New Jersey Southern Railway. It is over 100 feet deep, and yields a small supply of good water.

At the State Reform School, at Jamesburg, a well was bored to a depth of 481 feet and lined with a tube 8 inches in diameter for 285 feet and 6 inches for the remaining depth. It passed through numerous strata of clay and sand, and some water was found at a depth of 110 feet and at 202 feet, but it did not flow to the surface, and it is not known how much it would have yielded. The water was soft and slightly chalybeate. It would be a wholesome water for drinking, and the small amount of iron in it would not be troublesome for most domestic uses, but it was not suitable for laundry purposes and has not been tried any further.

At Columbus, Burlington county, on the stock farm of P. Lorillard, Esq, there is a well bored through strata of clay and sand for 356 feet. A fair supply of good water was obtained, which rose to within 45 feet of the surface of the ground. The water is since said to be a little sulphurous. A pump worked by 4 men could not lower the water in the well. Another well on the same farm is 156 feet

deep, its flow is about 10 gallons a minute, which has to be raised 30 feet. It is slightly sulphurous, but is liked and thought to be decidedly wholesome.

A well at the residence of Charles S. Taylor, Esq., near Burlington, was sunk 200 feet in these beds of sand and clay, but no good water was found.

The well at Cooper Hospital, Camden, has recently been sunk and a supply of water obtained at a depth of 129 feet. It is a 6-inch pipe, and the water rises in it to within 16 feet of the surface. It is not yet in regular use, but some partial trials indicate a daily supply of 25,000 gallons. The water has been analyzed and the following is reported as the amount and composition of its solid matter, in a gallon:

Sulphate of lime	1.76
Carbonate of lime	0.77
Carbonate of magnesia	0.83
Chloride of sodium	0.30
Sesqui-oxide of iron and alumina	0.07
Silicia	0.54
Organic and volatile matter	0.46
Total solids per gallon	4.73

It is a soft and good water.

In sinking the well, the boring passed through

Sand and top soil	4 feet.
Moulding clay and sand	6 "
White gravel (water)	2 "
Sand	8 "
Soft clay	6 "
Soft iron stone	2 "
Potters' clay	2 "
Black clay and mud, with pieces of wood	4 "
Soft pink clay	6 "
White sand, white gravel (large stone)	28 "
White gravel	10 "
Red gravel	2 "
Yellow gravel and sand (water)	15 "
White sand and gravel	25 "
Red gravel, with 3 inches white clay	3 "
Red gravel with 1 or 2 inches white clay	3 "
White gravel	3 "
Total depth	129 feet.

At the works of the Esterbrook Steel Pen Co., on Cooper street, Camden, a well has been bored which is supplying large quantities of water. It is about 175 yards from the Delaware river, and on ground about 5 feet above high-water. It is 66½ feet deep and lined with a 6-inch pipe. The water stands 5 or 6 feet below the surface. It has yielded 40,000 gallons in 10 hours. The water was at first clear, but now carries some fine, filmy particles of clay.

The materials passed through were:

Muck and some gravel	20	feet.
Gray mud	3	"
Sand	2	"
Potters' clay	5	"
Yellow sand	3	"
Coarse gravel, with some yellow sand	27	"
Fine, smooth yellow clay	2	"
Coarse sand, with green specks, resembling marl	4½	"

2. The portion of section 4 which contains the greensand marls, represents the outcropping edge of those beds and shows them extending out towards the southeast, probably under the ocean, though at a great depth, as they descend about 38 feet in a mile. The outcropping edge is in a belt, 10 or 15 miles wide, and having the clay and sand beds to the northwest of and under them, and the sandy clays to the southeast and overlying them. It will be seen from the section that the beds slope very gently and evenly, and that their outcrop is far to the northwest of where deep wells are bored. It yields excellent water in bored wells.

At Red Bank a boring was made to reach the sand under the Lower Marl bed and ascertain how much water could be obtained from it. It was known to be the stratum from which the wells at Asbury Park, Ocean Grove and Ocean Beach get their supply of water. And the boring was to test the question whether the stratum would yield good water there in sufficient quantity to supply the town. The marl stratum is about 30 feet below tide-level, and the surface where the well was tried is about the same height above that level. The boring was continued through the marl, and the water was found at a depth of between 80 and 90 feet. The well, which was in earthy material, was lined with an eight-inch tube. On pumping, it was found to yield about 40,000 gallons a day. The water rises within 6 to 8 feet of the surface, but does not overflow. A second

well was bored and lined with a six-inch tube. It was put down to a depth of 90 feet, but appeared to yield no water. After several ineffectual trials the tube was raised a few feet and the water rose in it the same as in the other well. The tube had been driven through the water-bearing sand into the underlying clay, and in that way the water had been shut out. This is an oversight which has frequently been the cause of failures in boring artesian wells.

The supply of water of good quality from this stratum of sand being assured, the water commissioners next examined the question as to the best method of getting the quantity needed for the wants of the town; whether by sinking a number of tubes at some distance from each other, and connecting all of them with a centrally located pump, or to dig a very large open well and pump from that. The conclusion reached is best given in the following report, communicated by William S. Sneden, Esq., one of the commissioners, and their secretary:

"As you remember, we found the water-bearing sand as you had predicted, directly under the marl stratum, at a depth of 66 to 69 feet below the surface. This gives the elevation of the sand, say 35 feet below ordinary tide.

"Our engineers, Messrs. Wilson Brothers & Co., of Philadelphia, advised the construction of an open well, 15 feet in diameter, sunk to the water-bearing sand, anticipating a larger supply of water from the increased area, and giving a larger volume in store to pump from after the pumping machinery should be at rest, as at night, in case of fires. The well has been completed, but it was thought advisable to stop sinking the main wall of the well when it reached within 10 feet of the sand, to secure a solid foundation on the marl. From that point 5 large cast-iron pipes, 36 inches in diameter, were put down through the 10 feet of marl to the water-bearing sand. A bed of concrete, 3 feet thick, made of English Portland cement, sand and broken stone, surrounds the upper or bell-end of the pipes, and extends under the curb of the main well walls, making a tight floor, allowing the water to come through the cast-iron pipes without contact with the marl. The walls of the well, 20 inches thick, laid in Portland cement mortar, were built on a shoe or curb of boiler iron and white oak, 26 inches deep, tapering to a cutting edge at the bottom. As the material was excavated and hoisted out, and the walls sunk, additional brick work was added, until the depth of 56 feet was reached. A pulsometer capable of discharging 500 gallons per minute, supplied with steam from a 25 horse-power boiler, kept the water down. Marl was found at 29 feet, at 40 feet, and on to 48 feet large lumps of hard marl and rock were encountered; and from 48 to 52 feet the excavation was

through a hard, seamy marl, closely compacted with shells, specimens of which I send you.

"At a depth of 42 feet, after the lumpy stratum was struck, a large spring burst in, flowing at the rate of 100 gallons per minute, and at the same time, the water in the artesian wells (100 feet off) lowered some 25 feet. This spring kept with us through the shelly marl, and worked its way down under the curb after the dry, ordinary marl had been reached. After we had sunk the cast-iron pipes in the bottom, and the water began to flow through them, the spring gradually lessened.

"It is evident that this water must have worked up through some 'pocket' of the seamy marl which must have extended down through the otherwise impervious marl to the sand, and, running through this pocket, squeezed its way horizontally to the opening we had made. While we were pumping 100 to 125 gallons per minute out of the well at 50 feet below the surface, and the water in the artesian pipes standing at, say 45 feet, or but 5 feet higher, the surface-water stood at its normal height, in the vicinity, which was from 6 to 8 feet below the surface.

"The water now comes in our completed well at the rate of about 250,000 gallons per day, rising to a point within 12 feet of the surface of the ground.

"The pumps are to be vertical, the steam end at the top of the well, with the water cylinders 30 feet below, so that, with 20 feet suction, the maximum flow can be availed of.

"We constructed a reservoir on the hill, just east of the town, at an altitude of 145 feet above tide, with a capacity of 900,000 gallons. Our whole works, when complete, with 3 miles of mains now laid, will cost about $45,000."

The water from the well is clear and free from any organic matter. Its reaction is slightly alkaline. Three different samples of the water gave, in solid matter per gallon, 6.8 grains, 6.9 grains, and 5.6 grains. It contains a mere trace of iron, and the solid matter is mostly carbonate and sulphate of lime. The water is soft and fit for all household purposes, and for making steam. Its purity is unquestioned.

Mr. Sneden says no perceptible difference has yet been observed in the flow of water in the well, though he thinks the maximum head is not as high by 3 or 4 feet as it was when the trial wells were first bored in 1884.

At Ocean Grove, in Monmouth county, is a flowing well, yielding a daily supply of 60,000 or 70,000 gallons of sparkling, pure and wholesome water. It is the first deep well which has been bored into the water-bearing cretaceous strata of New Jersey, and its suc-

cess gives assurance that all our seaside resorts can obtain a like supply of water of unexceptional quality by opening wells into these strata.

This well was bored for the Ocean Grove Association by Mr. H. C. Safford, of Brooklyn, N. Y. The well, for about 50 feet down, was lined with a 6-inch iron tube, but from that on down to the depth of 382 feet it was bored without tubing. The material in which the well is bored is all earthy, and not rock, with a possible exception of two layers, each a few inches in thickness, which the workmen thought hard enough to be called stone.

But little water was met until a depth of 382 feet was reached, when the water rose to a height of 18 or 20 feet above the surface. At this depth a 4-inch tube was put in the well and properly set, so as to hinder any loss by leakage around the tube, and also to shut out any surface-water that might otherwise find its way down the outside of the tube.

When the tube was fixed in its place the drill was again put down, the sand and earth was stirred for 38 feet further, and several cubic yards of sand were taken out. The water, in this way, was much increased in quantity, and it rose to a height of 28 feet above the surface.

The water which flows from the well has a temperature of 60° Fahr., is clear and colorless, and contains 8.5 cubic inches of carbonic acid per gallon. An analysis of the water, made by Professor F. A. Wilber, shows it to contain 8.19 grains of solid matter in 1 gallon.

At Asbury Park, Mr. Uriah White has sunk an artesian well which sends up a fine flow of pure water. The well is located on Mr. White's lot, about 300 feet from the depot, and 3,276 feet northeast from the Ocean Grove well. This distance, however, is oblique to the line of dip, and by making proper allowance for this oblique measurement it is found that it is only 2,216 feet farther up on the sloping stratum than the former well is. As the dip of the stratum is near 37 feet per mile, the well at Asbury Park should not be as deep as that at Ocean Grove by 16 feet; and, further, as the ground at the latter is 4 feet higher than at the former, it follows the measurements taken from the surface at Asbury Park well should be 20 feet less than those at the Ocean Beach well.

The well is lined with an 8-inch wrought-iron pipe to the depth of 372 feet, and is bored 21 feet in the earth beyond the tubing.

It yields an abundant supply of water—considerably more than it did when it was first bored. A late trial of its yield, by a fire engine, showed it to be capable of supplying 95,000 gallons of water in 24 hours.

A second well was bored there by Mr. White. The pipe in it is down 393 feet, and the drill has been sunk to 448 feet. The flow of water, as far as tested, is about 20 gallons a minute. Its temperature is 60° Fahr.

At Asbury Park and Ocean Grove there have been a number more of artesian wells put down during the past year. They get the supply of water from the stratum of sand underlying the lower marl bed. Considerable variation is found in the quantity supplied by the different wells, and much interest is felt, lest the large number of wells should diminish the flow from those first bored. The layer of sand from which the water is drawn varies from 3 to 20 feet in thickness.

At Key East, just north of Shark river, there are two artesian wells, bored by Kisner & Bennett, of Ocean Beach, both of which yield an abundant supply of pure water. That at the Avon hotel flows into the building, and is distributed by pipes. It has a 3-inch bore, is 430 feet deep, and a test of it gave 52 gallons a minute.

The artesian well at Ocean Beach, Monmouth county, is on the property of Mr. Eben C. Jayne, at the corner of Ocean and Sixth avenues. The well is about 400 feet from the ocean, has a total depth of 485 feet, its wrought-iron casing pipe 471 feet, and a diameter of 3 inches. It was put down in the spring of 1884, by the Southwark Foundry and Machine Company, of Philadelphia, two months time being occupied in the work, and the cost a little over $1,100.

Soon after completion, the flow of water at the surface level, and by actual measurement, was 25 gallons a minute, or 36,000 gallons a day. The pressure was sufficient to cause it to rise vertically 34 feet above the ground, and about 50 feet above low-water mark of the ocean. No measurement of the daily yield has since been made, but it was immediately connected with the supply pipes of three large cottages, and has continuously afforded not only an ample supply for them, but also a surplus equal to the supply of many more, should it be required.

In quality the water is clear, colorless, pleasant to the taste, perfectly wholesome and suitable for drinking and for culinary and

household purposes, although a little hard and containing a trace of iron. Coming from such a great depth, from under a series of clay beds, and from such a distance inland, it is entirely free from any and all surface contaminations, a great desideratum sanitarily.

A second well at Ocean Beach, between Second and Third avenues, and one block from the ocean, and only a few hundred feet from the former, was bored in 1885, and is 480 feet deep, with a 3-inch pipe, and flows at the surface 50 gallons a minute.

At Spring Lake there is another artesian well, 465 feet deep, which supplies the Essex and Sussex Hotel and two other dwellings, and there is enough water for several other dwellings still.

At Lakewood an artesian well has been bored for the purpose of getting a supply of unquestionably pure water for the Laurel Hotel. It has been sunk through the Middle and Lower Marl beds, and the water-bearing stratum of sand has been found at the depth of 475 feet from the surface. The well is upon ground 50 feet above tide-level, and the water rises in a tube about 17 feet above the surface. It was hardly to be expected that the water would rise to the level of the ground here, and the quantity which flows is 3½ gallons per minute; by pumping, 12 gallons per minute have been obtained. The water is clear and sparkling, and the analysis shows it to be of good quality and entirely free from any suspicion of contamination by organic or other surface impurities. It contains 8.87 grains of solid matter per gallon of water.

At Greenwich, in Cumberland county, Job Bacon, Esq., bored a well 690 feet deep. It is lined with a 4-inch pipe for 200 feet down, and a 2½-inch pipe the remaining 490 feet. The Middle Marl bed, with its characteristic fossils and its greensand, was passed at 550 feet, and the Lower Marl bed, with its equally characteristic fossils and greensand, was passed at 650 feet, but no layer of open water-bearing sand was found under the latter bed, and the boring is suspended for the present.

At Marlton, in Burlington county, an artesian well has been bored for Charles B. Chew, Esq., by Mr. Goldsmith Wilmot, of Haddonfield. The well is 86 feet deep and with a bore of 5⅝ inches, and has been sunk through the Middle Marl bed and down into a sandy layer, in which the well ends. Unfortunately the notes in relation to the successive layers of materials passed through are lost. In general, however, they may be described as follows:

Loam and gravel, to the marl	20 feet.
Black marl	6 "
Greensand marl	15–20 "
Chocolate marl	6 "
Thin stony crust, 2 inches.	
Chocolate marl	6–7 "
Thin stony crust.	
Hard black sand, which gradually grew lighter until it became white.	
About 2 or 3 feet from the bottom, struck a very hard rock, or bowlder, and drove the casing through it.	
Total depth	86 feet.

The water rose to within 24 feet of the surface. The well was then tested with a pump, driven by a steam engine, and the water was not lowered an inch, after running the pump steadily for 8 hours. The quality of the water is good; its temperature is 53½ degrees.

At the farm of Benjamin Cooper, two miles east of Marlton, in Burlington county, an artesian well has been sunk which supplies a large quantity of unexceptionably good water. It is located over the Middle Marl bed and the water is evidently drawn from a sand bed underneath that bed of marl. The materials passed through, as reported by Mr. Cooper, are:

Upper soil	28 feet.
Ironstone (sand and oxide of iron)	3 "
Greensand marl	1 foot.
Ironstone	1 "
Greensand marl, black and chocolate marl, no accurate account of each kept	19 feet.
Clean black sand, with white specks	14 "
Stopped in open, coarse sand with belemnites	4 "
Whole depth	70 feet.

The well was tubed with a 6-inch pipe, and the water rose in it to within 5 feet 7 inches of the surface, and remained at that point until the water was pumped freely, after which it rose to 3 feet 10 inches from the surface. The water is clear, soft, and of excellent quality for all household purposes. Its temperature is 54°. Mr. Cooper has erected over the well a 12-foot iron turbine wind-mill. After running the pump for 3 days, with a good wind during the day, at no

time was the water lowered more than 3 inches, though the pump was showing a steady inch stream.

The above two wells are all that we have records of which draw their supply from the sand under the Middle Marl bed.

A well some 4 or 5 miles southeast of Marlton is 316 feet deep and yielding a satisfactory supply of water by pumping. It probably goes through the Middle Marl bed, but no definite information has been obtained in regard to the material it passes through.

Berkeley Arms artesian well. This well is located on the beach, opposite the mouth of the Toms river, and was bored to get a supply of pure water for the house. It was sunk down through various strata of sand and clay, and at about 450 feet a stratum of greensand was met. After passing through this, water was found at the depth of 475 feet. This greensand is probably the *upper layer of the Upper Marl bed,* as the Lower Marl bed, with its usual dip, would not be met at a depth much less than 900 feet, while the upper layer of the Upper Marl bed, with its more gentle dip, should be at about the depth at which it was met in sinking this well. It is a matter of much interest to know that there is a stratum of water-bearing sand under the Upper Marl bed, as it is met with under the beaches, and can be reached at much less depth than the Lower Marl bed, under which is the water-bearing stratum of sand from which the wells at Red Bank, Asbury Park, Ocean Grove, Ocean Beach and Lakewood get their supply.

The water in the well at Berkeley rises to the surface but does not flow. When pumped it yields 60 gallons per minute without lowering more than 25 feet.

ANALYSIS OF BERKELEY ARMS WELL-WATER, BY AUSTEN AND WILBER.

Sodium chloride, grains per gallon	0.769
Sodium sulphate, grains per gallon	0.764
Sodium carbonate, grains per gallon	6.619
Potassium sulphate, grains per gallon	0.635
Calcium bi-carbonate, grains per gallon	1.300
Magnesium, grains per gallon	0.571
Silica, grains per gallon	1.032
Sesqui-oxide of iron and alumina, grains per gallon	0.052
Total solids, grains per gallon	11.742

The water is pure and wholesome; is remarkable for the quantity of carbonate of soda found in it.

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 analysis of the water of this well, as made for the report in 1868, is here given in grains per gallon:

Silica	.816
Chlorine	.012
Sulphuric acid	.157
Carbonic acid	3.030
Peroxide of iron	.175
Lime	1.177
Magnesia	.460
Potash	.583
Soda	3.230
Solid matter in one gallon of water	9.640

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

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.

The two wells last described draw their supply from a bed of sand

underneath the Upper Marl bed. They are remarkable for containing so much alkaline carbonates.

3. In the *sandy clay* of the third division of this section there are water-bearing layers of sand between the clay strata, and several artesian wells have been successfully bored in it. These strata overlie the beds of greensand marl, and are of considerable thickness along the southeastern border of the State. Wells bored in this will, of course, be much shallower than would those in the same locality if bored down to and through the marl beds, and as far as at present known the water is of equally good quality.

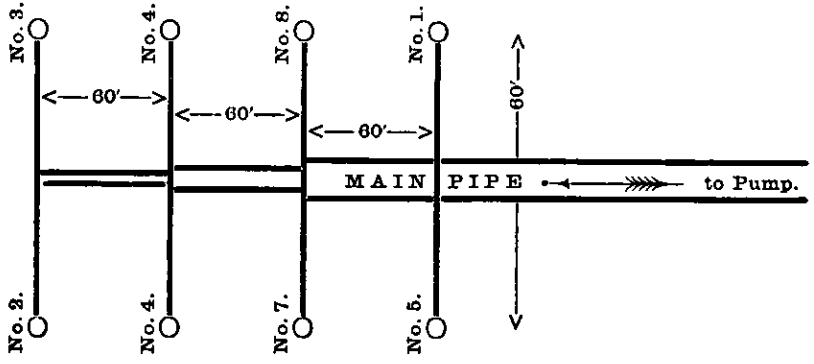
Well at Harrisville, Burlington county. This well was bored by R. C. Harris, Esq., in 1866, to get a supply of water that could be used in a steam boiler without corroding it. The bore was sunk to a depth of 306 feet and lined with a 6-inch tube. Gravel, blue and gray clay were passed through until a depth of 180 feet was reached; mud, sand and what appeared to be decayed wood was also encountered. Further on a gravelly bed was found, and water suddenly spouted up, reaching to the top of the tubing, 8 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 [sulphate of] iron very strongly. The project was then abandoned. This was evidently a mistake—a good well could have been had at 180 feet. And if an examination for water at greater depth were desirable, it could have been made by driving down the boring tools without sinking the lining tube until the expected deeper supply was found.

A well is being bored on one of the Seven islands, near Little Egg Harbor inlet, for Joseph Wharton, of Philadelphia, by Joseph H. Moore. It is down 335 feet, of which 279 feet is in sand like that of the beaches, and below this, 5 feet of dark-blue tough clay, then 1 foot of pebbly sand, and then clay with similar streaks of sand quite to the bottom. At this depth there is difficulty with the lining pipes, and fear that they are broken. The pipe is full of water, and there appears to be plenty of it, but it is brackish.

Wells at Pleasant Mills, Atlantic county, described by W. E. Farrell, Esq.

"In 1873 we sunk a 3-inch well for pure water. After going

through about 40 feet of yellow and white sand and pebbles, we came upon a bed or stratum of tough, hard, dry blue and blue-black clay. This blue clay was about 8 feet thick. As soon as this stratum of clay was passed the water burst through and rose in the pipe to the height of 13 feet above the level of the ground. The water was very black at first, being mixed with fine black sand and *smooth* pieces of blue clay, which came up with the water in flat, round, smooth pieces, from $\frac{1}{2}$ to 3 inches in diameter, and from $\frac{1}{4}$ to $\frac{1}{2}$ inch thick. In about three days the well cleared, and, having thrown out about sand enough to form an excavation at the bottom of the pipe of about 10x10x6 feet, the sand ceased to rise. The volume was found to be 124 gallons a minute, on a *level* with the ground. When the pipe was raised the *natural* flow was diminished until, at 13 feet 4 inches above the level of the ground, the water stopped rising in the pipes and stood still, neither falling nor rising. In 1880 we determined to sink another well (3-inch) about 200 feet from the first (sunk in 1873). The level of the ground was, say, 2 feet lower than well No. 1. At about the same distance down we struck the same water, going through the same stratum. This seemed to give the same quality of water, which is very clear, brilliant, sparkling, and 55° temperature. We then put down 6 other wells, 60 feet apart. The water in all is the same, and reached through the same stratum, and we could tell within a foot when we would strike water. The inside of the pipe, when in the clay, was very dry, until within 1 inch of the under side of the blue clay stratum. As soon as this was penetrated the water would rush up and boil over the top of the pipe with a force due to its 13-feet head. We have 8 wells, 60 feet apart, thus:



"The well No. 1, we supposed, gave 124 gallons a minute. No. 2 the same (we supposed, as it was not measured). We sunk the other 6, and the yield from all (8) is now but 300 gallons a minute. We notice that all the wells (before being piped and so closed in) were quite sensitive to each other; that is, if No. 1 was closed, No. 2 would show an increased flow. When 2 or more would be closed with a plug driven in the top of the pipe, those remaining open would show increased flow of water. And if *any* one of the seven were opened the others would show a *diminished* flow, which clearly proved the entire 8 wells were in the same water stratum. The water is very pure, as per accompanying chemical analysis, which shows 28.41 grains to the gallon of solid mater. Two analyses of the water were made, one in 1873, and one in 1876; they were both alike. The water, on being exposed to the air, the oxygen of the air attacks the iron in the water, and oxide of iron is thrown down as an iron rust.

"It works well in steam boilers, leaving no incrustation or scale, and no acids to eat or corrode the inside of the boilers, which the surface-water did. The surface-water from the pine and cedar swamps was so destructive to our boilers that in ten years a new boiler was entirely ruined and rendered unsafe through corrosion. The *surface*-water attacking the boiler plates at the rivet holes and seams, and eating large holes or pits in the iron plates, which have the effect of 'honeycomb.'

"The question is, will *more* wells give more water, or have these wells tapped the *whole* stream.

"We notice another peculiar feature. We pump this water into a 60,000-gallon tank with a *rotary* fan-pump, which runs at 200 revolutions a minute. This throws the water 25 feet *above* the ground, but when the pump is *stopped*, as on a Sunday, the tank then being full, the water will run *back* through the pump and into the wells until the water in the tank is down to the *natural head* of the wells, showing that while deep wells will *yield* water, the water-bearing stratum will also take *more water* if the head is higher than the natural head, and water is so given to this water-bearing stratum, as in this case."

Since the above report was written, we learn from Mr. Farrell that other wells have been sunk, making 14 in all. A settling-pond of 3 acres is also being constructed, in which to allow the iron to settle to the bottom of the pond, so that clear water may be drawn off from the surface for bleaching paper stock.

The 14 wells seem to have the same head of 14 feet 6 inches above tide-water.

He says: "We found a pine tree 38 feet below the surface, fresh and sound, and chips cut from it by the tools were the same as if cut from a growing tree; also shells and sound and green pine cones at 36 feet in another well.

A well was bored for Mr. Charles G. Rockwood, on Mechesataukin creek, about 4 miles from Atsion and 5 or 6 northwest of Pleasant Mills. It was sunk to the depth of 158 feet, through beds of sandy clay and sand, but no satisfactory supply of water was got.

At Mays Landing Water Power Company's works, in Atlantic county, two artesian wells have been sunk, and they are furnishing a moderate supply of pure water through a 2½-inch tube. They are in ground which is about 8 feet above high-water. From Mr. Charles Mason, superintendent of the works, it is learned that the first well was sunk for

15 or 20 feet, through coarse gravel.
40 feet, through quick-sand.
30 feet, through beach sand and layers of clay, perhaps 1 foot thick.
5 or 6 feet, fine black or blue tough clay without water. First water found under this.
40 feet of glass sand and no clay.
10 feet in sand; no increase of water.

150 feet, total depth.

The tube was driven by a sledge for 15 or 20 feet, then by steam 60 feet further, and the remainder was washed out by water under pressure. With the conveniences there, the extra cost of putting down the well was not more than $90.

It yielded about 12 gallons a minute for a week, and then gradually fell to 7 gallons a minute, at which it still continues.

The second well was stopped at 130 feet on account of meeting logs. It passes through the same kind of material as the other, and yields 3 or 4 gallons a minute. The temperature of the water is 57°.

These wells are on the bank of Great Egg Harbor river, a stream which has an abundant flow of soft water, and which, though a little brown in color, would seem to be pure enough for all purposes, but it

corrodes steam boilers rapidly. The following is an analysis of the water from the river :

ANALYSIS OF GREAT EGG HARBOR RIVER WATER.

A gallon of the water, which is 58,372 grains, on being evaporated down to dryness, at a temperature of 110°, left of solid matter..... 1.89 grains.
It contains of sesqui-oxide of iron, per gallon..... 0.17 "
It contains of sulphuric acid, per gallon..... 0.15 "

The water contains much organic matter. A part, at least, of the iron is present in the ferrous state, and it is this salt which gives the corrosive property to the water when used in a steam boiler.

ANALYSIS OF THE ARTESIAN WELL-WATER AT MAYS LANDING.

A gallon of this water, on being evaporated at a temperature of 110°, left of solid matter, 7.69 grains.
Of sesqui-oxide of iron—only a trace.
Of sulphuric acid—none.

The water is slightly alkaline, and does not produce any ill effect in steam boilers. Mr. Mason, the superintendent, reports in June, 1885, that the flow from the wells has increased by perhaps one-third.

At Weymouth, in Atlantic county, 5½ miles northwest of Mays Landing, and on Great Egg Harbor river, the same corroding effect of the river water on boilers is suffered. Boilers in which this water was used needed repairs every six months. Two artesian wells have been sunk there to procure water which would not injure the iron boilers. The first well was bored under the new paper mill, in 1877, and is altogether successful.

In this well a 4-inch pipe was sunk. It is 42 feet deep. It flows over at the surface of the ground, and yields 70 gallons per minute.

The second well has been bored since at the old mill, and on lower ground. A 5-inch pipe was used. It was first sunk to the depth of 47 feet, but was drawn back to 38 feet. It has a uniform flow of 52 gallons per minute. The water is taken at the surface of the ground, but a trial was made by connecting the pipe with a 2-inch pipe, when the water rose to a height of 8 or 10 feet above the surface.

The materials passed through in boring the second well—

2½ feet of old cinders.
3 feet of yellow sand.
2½ feet of coarse quick-sand.
1 foot of stony crust.
6–8 feet of coarse sand and a little gravel.
1½–2 feet of clay.
12 feet of sand.
5–6 feet of clay.
9 feet of sand.
clay.

The water-bearing stratum of sand is probably the same with that met at Mays Landing, and the difference in depth of the wells at the two places is due to the stratum dipping towards the southeast. We have not the elevation of the ground above tide-water at Weymouth, but if it is assumed to be 25 feet, it would leave the stratum only about 15 feet below tide-level, while at Mays Landing it is 120 feet, and the stratum should descend 105 feet in the 6½ miles between the two places. This is 16 feet per mile, and is very nearly correct.

A deep well is now being bored at Cape May Point. It is down 456 feet. The first 270 feet were in beach sand, when thin beds of clay began to be found in the sand; from 320 to 360 feet, many broken shells were met, apparently of the common species now in the bay. The sand, with occasional lumps of clay, still continues. There appears to be a good supply of fresh water, but the boring is continued with hope of finding gravel or coarse sand sufficient to keep the lower end of the pipe clear.

The interest which attaches to these wells in the sandy clay will be appreciated when it is considered how large the area is which is underlaid by these water-bearing strata.

The permanence of the supply from these wells is a matter which will suggest itself to any who consider the important uses they serve. The quantity of water included in these thin but widely extended beds of sand must be very large. It takes time for its movement, and only experience can tell what may be its limit of flow in quantity or time.

DRAINAGE.

The projects for drainage which have required the attention of the Survey, are still the subject of investigation. The drainage of the Great Meadows on the Pequest has been very successful. Enormous crops are grown on the portions which have been cleared off and tilled, and the land is proving itself to be the best in the county.

The drainage of Passaic valley, above Little Falls, for sanitary as well as for agricultural improvement, has now been a subject of discussion for more than a hundred years. Plans for executing the works were matured several years ago, but on account of financial difficulties they have been delayed. It is hoped that the business prospects of the country are now so much improved that work upon the improvement can be begun this year. Its effect must be to bring tracts of from 10,000 to 15,000 acres of land into productive and regular use, and to remove a discreditable and insalubrious feature from what may be otherwise one of the most attractive portions of New Jersey.

The drowned lands of Sussex are also requiring a thorough system of drainage. For this we are necessarily dependent upon the action of New York authorities, as the outlet for waters of freshets is within that State. There is reason to expect that some action will soon be taken there in which we can coöperate, and so secure the reclamation of this rich and valuable tract of land.

FORESTRY.

There still remains a considerable portion of the State in forest. A large part of this is land unsuitable for cultivation and more valuable for raising timber than for any other purpose. In Northern New Jersey the prevailing timber is chestnut, and this, in the Highlands, usually attains a size suitable for railroad ties or telegraph poles, in from 25 to 35 years. A young growth therefore rapidly increases in value since there is a steady and convenient market for these products. Two-thirds of the whole forest area of the State consists of pines and cedar swamp, so prevalent in Southern New Jersey. The former is used to some extent for lumber and lath, but much the larger part for firewood or charcoal; the latter is a valuable timber, and is mostly made into shingles, strips or siding. After the timber is cut the swamp is allowed to grow up again, and in a few years becomes valuable. There is more profit to be derived from timber culture in the State than is generally supposed, and the million and a half acres of land unsuitable for cultivation, may yet be made to yield a considerable revenue when our people come to give more attention to forestry.

The new topographical survey is supplying more exact information as to the forest area of the State than has yet been accessible, but this survey is not yet complete. Another year, however, will suffice to furnish accurate forest maps of all the State south of the Raritan river, and of a considerable portion of Northern New Jersey. Enough has already been ascertained to make a close estimate possible. In the following statistics the results of this survey and of the tenth census of the United States have been compared and utilized. The following table exhibits the percentage of upland remaining in forest on each geological belt of the State, since this is found to be the most natural division of the State, the geological formation having a decided effect on the area in forest. This effect has been modified by glacial action, however, and on the same formation more timber is found on the glaciated portion than elsewhere, hence the division of the formations into northeast and southwest in the table:

Paleozoic formation (Kittatinny valley and mountain)	55 per cent.
Archaean Highlands, northeast part	80 "
Archaean Highlands, southwest part	40 "
Triassic, red sandstone plain, northeast part	50 "
Triassic, red sandstone plain, southwest part	25 "
Cretaceous, clay and marl country	20–40 "
Tertiary, pine plains, Ocean, Burlington and Atlantic counties	92 "
Tertiary, all other parts	65 "

A careful estimate of the actual acreage of forest in the State makes the total

Equal	2,330,000 acres.
Census of 1880 gives improved land	2,097,719 "
Area of tide-marsh equals	295,474 "
Leaving for wet-meadow, barrens and land used for residences in cities, etc	125,876 "
Total area of State	4,849,069 "
Of the above forest area the amount included in farms is	708,092 "

Of this area of 2,330,000 acres, a large portion is destined to remain permanently in forest. That of the paleozoic and archaean formations lies principally on rocky and untillable ground. That of the triassic formation is mostly included in farms, and will decrease somewhat. That of the cretaceous formation is also largely included in farms, but much of it lies on gravelly and stony hill-tops, or other untillable areas. It will also decrease slightly. The largest decrease will be in the pine forests, which cover 1,485,290 acres. Of this area, probably one-half will eventually be cultivated.

It will probably be conducive to the best interests of the State to leave at least one and a half million acres permanently devoted to forestry. The following table exhibits the increase of improved land since 1850, and the decrease of land in farms since 1860, in acres:

	1850.	1860.	1870.	1880.
Total land in farms	2,752,946	2,983,525	2,989,511	2,929,773
Improved land in farms	1,767,991	1,942,281	1,978,067	2,097,719

Decrease in land in farms (1860 to 1880)	53,752
Increase in improved land (1860 to 1880)	155,438

A closer examination of the census returns shows that the land allowed to grow up again in forest, or used for city and village sites, amounts to 61,032 acres in the counties of Bergen, Essex, Hudson, Mercer, Passaic and Union, which counties show a decrease in the amount of improved land. The amount of land cleared and improved is therefore not less than 216,470 acres for the period of 1860 to 1880. This is certainly a small area, but a glance at the amounts of improved land in the above table shows that the rate for the last decade was greater than for the previous one, and as attention is again turning to improvement of the pine lands, it will probably be still greater for the next. The greatest inroads into the forest have been made in that portion of the pines which lies in the counties of Monmouth, Atlantic, Gloucester, Cumberland, Salem and Cape May.

The fact that there has been a decrease in the total land in farms, with an increase in improved land since 1860, is explained by a fact noticeable to any one who has traveled over the mountainous districts or through the pine country; it is probably due to the abandonment of unproductive farms, which contained a large amount of unimproved land. Many such farms have been allowed to fall back into forest, and the result will eventually be a benefit to the State; there is much land still undeveloped which is more suitable for cultivation, while this is worth more as forest.

While the acreage of forest has slowly decreased, this is not the case with the products of the forest, as a glance at the following table of lumber production will show:

	1880.	1870.	1860.	1850.
Total value of products.....	$1,627,640	$2,745,317	$1,602,319	$1,123,052
Lumber, number of feet.....	109,679,000	101,829,000		
Lath, number..	8,948,000	3,167,000		
Shingles, number.....	10,717,000	3,624,000		
Capital employed.....	$1,657,395	$2,238,900		
Wages paid.....	$179,693	$369,835		
Hands employed.....	768	1,145		

The shrinkage in value of products between 1870 and 1880, while the amount of products increased, was due to a falling off in prices. In the whole United States, in the same period, while the production increased 42 per cent. for lumber and 70 per cent. for shingles, the value of products increased only 11 per cent. The State is thirty-second in value of lumber products.

The above, however, does not fully represent the value of the forest products of the State, for the census shows the following consumption of wood which is supplied by the forests of the State:

	Cords.	Value.
Fuel for domestic consumption	642,598	$2,787,216
Fuel for brick and tile manufacture	14,683	55,722
Fuel for glass manufacture	29,144	110,747
Total	686,425	$2,953,685
This, added to the above value of lumber products, amounting to		1,627,640
Gives a grand total of		$4,581,325

Yet this has not included the fuel sold outside of the State, in the neighboring large cities and to brick and tile works; nor does it take account of the production of railroad ties, telegraph and telephone poles and fencing, which is considerable. The value of the annual product of our forests cannot be less than $5,000,000, even in their present neglected condition, and the experience of European countries teaches that proper attention to timber culture would give as a result not less than double this amount.

It seems scarcely necessary to speak of the markets for our timber, as they are generally supposed to be ample, yet the fuel market, on which the pine forests have largely depended, has recently suffered a depression, and to show that this must of necessity be temporary, we have only to point to the above table, which shows a consumption of 686,425 cords of fuel within the State; to the brick and tile industries of Rockland, Kings and Richmond counties, New York, and of the vicinity of Philadelphia, and to the consumption of domestic fuel by the two great cities, all of which must make a permanent and accessible market for fully 1,500,000 cords of fuel, or one cord per acre annually for the whole pine forest of the State, which is all that it will produce in its present condition.

Chestnut, oak, locust and other timber suitable for construction, has everywhere a good market close at hand in the demand for railroad ties, telegraph and telephone poles.

Excepting, perhaps, the case of cedar swamps, the possibility of growing timber with profit seems to have been overlooked, yet cases are not uncommon, throughout the State, where nature has insisted on growing timber in the face of all obstacles, and has yielded large

returns on the capital invested; and, no doubt, with a little attention to pruning and cutting out surplus growth, some protection to the young growth (now very generally allowed to be browsed off or trampled down by cattle, by which practice the yield of chestnut, etc., is very much reduced), and proper precaution to prevent fires, would result in handsome profits from land now allowed to go to waste.

At a moderate estimate, 1,000,000 ties are annually consumed by the railroads of the State for construction and renewal. At 50 cents each the value of these would be $500,000. Here is a market which lies at our very doors, and should be wholly supplied with chestnut timber from the untillable land of Northern New Jersey.

The value of chestnut timber in the Highlands and Kittatinny valley, depends much on the quality of the soil and the location. The stump land sells at from $1 to $5 per acre; a growth of 30 years at from $10 to $30; of 50 years, from $25 to $50; but in many instances good growths, accessible to markets, have sold at figures 3 or 4 fold greater than the above. The time required to grow railroad ties and telegraph poles is from 25 to 40 years, and will probably average 30 years. Chestnut grows naturally and brings the quickest and best returns, although oak is more valuable when grown.

The possibility of growing locust timber on the 250,000 acres of waste land of the cretaceous formation, is fully shown by Professor John C. Smock, in an article on the subject in the report of the State Board of Agriculture for 1874. He estimates that it is possible to raise on good land, a crop of 30 years' growth worth $3,000 per acre; and states that returns at the rate of $2,000 per acre, are not uncommon in Monmouth county. An ample market always awaits this valuable timber, and its cultivation should be encouraged, for it may properly take the place of other crops and prove more profitable, even on some of the land now cultivated. In this connection it may be well to call attention to the fact, that when timber culture has been placed on a secure footing, and becomes a recognized occupation, it will not be necessary to wait the full period of growth in order to realize a profit, for the value of the forest will become commensurate with its age and growth.

The growing of cedar timber is generally recognized as profitable. The value of stump land is from $5 to $10; of 20 years' growth of

timber, from $5 to $50; of 35 years' growth, from $15 to $200; of 50 years' growth, $75 to $400. Location and the size of timber having much to do with the price. A swamp of 70 years' growth sold recently for $800 per acre.

The common pine attains a size suitable for fire-wood in from 15 to 20 years, and it is commonly estimated that it will produce as many cords per acre as it has been years in growing. The present value of pine wood per cord, standing, ranges from $0.75 to $1.50, and $1.00 is probably a fair estimate of the average. When the timber becomes larger its value per cord increases, as it then finds a market for lumber and lath, for piling and other purposes. The following figures are from estimates of men familiar with the pine forests in various sections, and the wide range is due to difference in accessibility to market and in producing powers of the land. Value of pine stump land per acre, $0.10 to $5.00 (this does not include the figures from localities where the land has a value of from $10 to $25 for cultivation); of 30 years' growth of timber, $5 to $25; of 50 years' growth, $10 to $100. Taking figures pertaining to the average of the better two-thirds of pine land as a guide, the present conditions would give about the following results in raising pine of 30 years' growth:

Cost of stump land, per 100 acres	$250
Taxes on average value, 30 years	448
Policing and protection, 30 years	120
Interest, at 6 per cent.	450
Total expenditure	$1,268
Value of a 30 years' growth, for 100 acres	$2,500
Value of stump land	250
Total value	$2,750
Profit	$1,482

The interest on annually-paid expenses is supposed to be offset by increase in value of stump land.

It is not to be supposed that proper protection and attention will not greatly increase the above profit. These figures represent the present values, depreciated by the results of neglect and the uncertainty and loss caused by fires.

Great advantages would accrue to the State should timber culture be successfully inaugurated. The solution of the water-supply prob-

lems, which become yearly more important and serious, would be materially aided by the preservation and regulation of the flow of the fine streams of the Archæan Highlands, and in this way, also, the many valuable water-powers of the State would be improved; the healthful climatic conditions of Southern New Jersey, an element which has been largely conducive to the development of that section, may be unfavorably affected should the destruction of the pine forests by fire and neglect continue; but perhaps a more direct advantage would be the yielding of a profit by over two millions of acres of land, now almost non-producing.

FOREST FIRES.

The greatest destroyer of the forest and the worst enemy of the forester is fire. The disastrous effects of forest fires are felt throughout the United States, and our State is among those suffering most severely. These fires occur to some extent throughout Northern New Jersey, but usually on rather limited areas, not often exceeding 3 or 4 square miles, but the most serious trouble is in the pine forest of the southern part. Any one who has witnessed a fire under full headway in this country must have been impressed with its grandeur, its irresistible fury and its disastrous effects. A few notes of remarkable fires are at hand. In 1866 a fire burned over 10,000 acres, extending 7 miles inland from Tuckerton and West Creek. In 1870–71 nearly the whole wooded portion of Bass River township, Burlington county, was burned over. In 1871 two fires in Ocean county burned over 30,000 acres. In 1872 a fire burned over from 15 to 20 square miles, worth before the fire from $10 to $30 per acre, and after from $2 to $4. In a paper on forest fires, by Mr. Charles E. Elmer, in the Report of State Board of Agriculture for 1874, he says of the year 1872: "To assume that 100,000 acres have been burned over, at a money loss in timber of $1,000,000, would surely be within the bounds of truth." From the census of 1880, we have for that year an area burned over of 71,074 acres, with an estimated loss of $252,240, which is certainly a very moderate estimate and can scarcely include any allowance for loss of cedar swamps. During the past summer some very large fires occurred in the district under survey, and the areas covered were noted by the topographers. One burned over an area of 60 square miles, near Atsion, in Burlington

county; another, near Friendship, in the same county, covered 10 square miles; and another, in Ocean county, burned over not less than 75 square miles north of Barnegat. The total of these three fires is therefore 145 square miles, but several other fires occurred farther south in the State, the extent of which was not observed. It may be safely estimated that the whole area burned over this year has reached 200 square miles or 128,000 acres. A large amount of cedar swamp was destroyed by these fires, and $10 per acre would not more than cover the direct damage to timber, making the loss for this year $1,128,000, nearly equal to the total value of the annual lumber production of the State. On the whole, the loss in timber from forest fires in the State, on a low estimate has averaged $1,000,000 per year for the last 15 or 20 years. The loss is much more than the mere value of the wood, however. The soil is so impoverished by these periodical burnings, which deprive it of all vegetable matter, that its capacity for producing timber is much diminished. There is also a great depreciation in the value of the land, because of the danger of fires, whether it be as timber land or for occupation and improvement, and a considerable damage is done to the many valuable cranberry bogs which are scattered through the forest, not to speak of the danger to buildings, habitations, and even to human life.

The causes of these fires are various; those given for the 54 fires of the census year are as follows: Clearing land, 7; locomotives, 28; hunters, 6; malice, 7; coal-pits, 6. It will be noticed that more than half were caused by railroads. Neither of the two great fires of this year were caused by locomotives; that at Barnegat starting 6 or 7 miles from any railroad, and that at Atsion in a meadow, also far from a railroad, either from the carelessness of hunters or berry-pickers, or through malice. Mr. Elmer attributes many of the fires to carelessness in clearing up land. Many fires no doubt start from coalings, and it is common to hear the belief expressed that some of these are started intentionally, in order to keep the coalers and wood-choppers at work, since timber burned over must be cut at once, whereas it would otherwise be left to grow and increase in value. Those caused through malice often are the result of chastising, or holding under surveillance, of timber thieves, by no means uncommon in the pine forests. Of the various causes, the most frequent one is the one which is apparently most easily prevented, although it is not unlikely that the damage from this source is somewhat overrated, for

these fires are soonest detected and checked. Some railroads, notably the West Jersey, and Delaware, Lackawanna and Western, have already taken the matter in hand. The plan followed, and apparently with success, is to clear away all timber for a width of 100 feet on each side of the track, to plow a furrow or two close to the outer edge of this space and then fire the space in the fall, and keep it mowed and cleared, if necessary, through the summer. Were this plan adopted by all railroads, and the engines furnished with suitable spark arresters, danger from this source would disappear, as would the constant suits for damages, which probably are much more expensive than the remedy. The other causes are apparently to be prevented only by establishing a forest police, but the danger of fire spreading over such a great extent of territory might be lessened by less expensive means. The pine forest is traversed by numerous roads, which are used as a means of access to the timber, or of passing through the forest to the various settlements. Most of these roads are at present only just wide enough to allow a wagon to pass through, not unfrequently by grazing the trunks of the trees on either side. It is invariably the practice when a fire is to be fought, to make a stand along one of these roads and, by firing back, to stop its progress by depriving it of food. Not unfrequently, narrow as they are, these roads alone stop the progress of the flames. It seems, then, that it would be feasible to have all these roads recorded as regularly-laid highways, with a uniform width of four rods, and to clear away all timber and brush for this width, and fire the space in the autumn, annually. It is believed that this would create a gap which the flames would rarely leap, and that they would usually be confined to a few hundred acres at most. Probably about two acres to a hundred would have to be cut off in this way, to protect the rest, and in case it was seen that, because of high winds, the flames would leap this barrier, it could be rendered effectual by a little back firing. If this could be supplemented by a forest police of perhaps one mounted man to each 30,000 acres, making the whole annual cost not more than four cents per acre, much would be accomplished toward preventing forest fires, which now cause an average loss of 67 cents per acre for the whole of the pine country. But it must also be remembered that a large amount is now annually expended in fruitlessly fighting fires, after they have become irresistible from the extent of their front.

Some legislation imposing proper penalties for careless use of fire in

camps, clearings, or coalings, would be necessary. Stringent laws of this kind exist in some European countries and in Canada. The effect of an efficient forest police on depredations of timber thieves will be most salutary, and the increase in the value of timber lands that would arise from increased security, even though otherwise unimproved, would pay the expenses of the plan. It is most probable that the railroads would readily coöperate in any plan to increase the security of the forests, as they might otherwise be held strictly accountable for all damage done by them.

In Northern New Jersey the expense of keeping clear avenues through the forests would not be necessary, but it would probably be best to double the police force because of the larger population. If the railroads used proper precautions the police would be needed in but a few of the townships of this part of the State, as the areas in danger from fires are not large.

There seems to be no imminent danger of the evils usually attributed to stripping the country of forests in this State if fires and wasteful practices can be prevented. As soon as a crop of timber is gathered nature sets about reforesting the denuded area. No planting is needed, only a little protection and care, and in from twelve to fifteen years a young forest has again appeared to take the place of the old one; as the cutting is usually done on limited areas at a time the timber is scarcely missed.

IV.

HISTORICAL NOTES ON THE GEOLOGICAL SURVEYS OF NEW JERSEY.

New Jersey was first settled for its agricultural capabilities, and farming was its leading industry, until some time within the last half century. Its mineral riches were, however, of such importance, as to be thought worthy of public assistance for their development at a very early day. Col. Lewis Morris located himself at Tinton Falls, in Monmouth county, and purchased 3,900 acres of land there, proposing to establish iron-works at that place. As early as the 6th of April, 1676, the Legislature voted that "as touching Col. Morris' request, the Deputies are willing the lands and works belonging properly to the iron works, shall or may be rate free for seven years, excepting in extraordinary cases, as war or the like." The grant from the Proprietors of East Jersey was a perpetual lease, with a payment of a half-penny an acre yearly, on 3,540 acres. This lease allowed him and his associates to dig for iron or any other minerals, in any part lying between the Raritan river and the Whale pond (Lib. I., p. 155, E. J. Records). The works were carried on here for a number of years, and were probably supplied with stock from the bog ores which were found in various places near by, and from the woods. Private enterprise was sufficient to extend this work further, and forges were in operation at Spotswood, in Middlesex, and at Imlaystown, in Monmouth, very early after the year 1700, probably working upon bog ores such as are still to be found in those places. And as soon as the Indian title to the lands in Morris and Hunterdon counties was extinguished, which was from 1712 to 1715, settlers entered upon them for the purpose of working the rich magnetic iron ores which abound in the hills of those counties, and forges were soon in operation and turning out good bar iron. The forge in Whippany, Morris county, was in operation as early as 1716, and others were established

farther in the newly-acquired lands, from time to time, as roads were opened, and ore was found, till they dotted the whole of the region in which those ores occur. The blast furnace at Oxford, in Warren county, was established in 1745. Others were built at later periods. The demands for ore to supply these various works stimulated the searches for them, and the whole iron ore district was pretty fully explored. Openings were made wherever there were any indications of ore, and now there is scarcely a tract to be found where diggings have not been carried on in the search for new beds of ore. These searches were made at the expense of land-owners and other interested parties. And their effect was seen in the construction of new works for reducing of ore to metallic iron. It is stated by Tench Coxe, that in 1784 there were eight blast furnaces and seventy-nine forges.* In Gordon's History of New Jersey,† written in 1831, he states there were then 12 blast furnaces and 108 forges, which yearly produced 1,671 tons pig-iron, 5,615 tons of castings and 3,000 tons of bar-iron.

The copper mines at Belleville were discovered early, and were worked by Arent Schuyler in 1719. Mines at New Brunswick were worked by Elias Boudinot in 1751, and those at Somerville, Flemington, and other places at a much later date.

The zinc mines at Franklin and Ogdensburgh, in Sussex county, were discovered early, Maclure having sent specimens to France for analysis in 1811, and public attention was called to them by Dr. Bruce, of New York, in his American Journal of Mineralogy, which was published in 1814. In Jour. Acad. Nat. Sciences, Vol. II., p. 277, is a very full and accurate paper on the Geology and Mineralogy of Franklin, in Sussex county, by L. Vanuxem and Wm. H. Keating, dated August 6th, 1822. It treated of the zinc ores. Many unsuccessful attempts were made to work them before 1830.

The greensand marls, which have been such a source of agricultural wealth to the State, were not generally known before 1840. Single cases of its use were known at the beginning of the century. In the Memoirs of the Philadelphia Society for the Promotion of Agriculture, there are several articles on the use of marls, written in 1815—one by Mark Reeves, of Evesham; one by Dr. George Holcombe, of Allentown; one by George Craft, near Woodbury, and one by Paul Cooper, of Woodbury; and an analysis of the marl, by Henry Seybert, in 1822.

*Hist. iron manufacture, p. 72.

†Page 38.

Dr. S. G. Morton's descriptions of the organic remains found in the marl were published from 1830–1834, and can be found in the Am. Journal of Science, or in his Synopsis of Organic Remains.

Mr. Pierce, who wrote for the Am. Journal of Science in 1823, says: "Six years ago but one or two small beds of marl were known, but marl is now extensively used and highly esteemed." It is also mentioned by Gordon, in his History of New Jersey, 1833, as being of much value, and of great promise in the future.

These early attempts to develop the natural resources of the State were productive of much benefit to the people interested, though no systematic attempts were made to study the geological structure of the country, or to collect, arrange and publish for the common good, the facts which were distributed among many individuals.

At the session of the Legislature in October, 1832, Governor Peter D. Vroom in his message said: "In viewing the different improvements now going forward in our State there is cause for gratulation and pride. Each one within the sphere of its influence will produce new incentives to industry, and discover new avenues to prosperity and comfort. Taken in connection they will have a tendency to retain and increase our population and draw forth and distribute the resources of the State which are just beginning to develop themselves. When the different parts of the country shall be connected together with water or other easy communication,* our limestone districts will scatter their treasures to parts where they are needed in fertilizing the soil, and the value of our iron regions will be greatly increased. Many of our mountains and valleys abound with hidden wealth, which must soon be brought to light, and I have no doubt that if a geological survey of our State, or parts of it, could be made, even upon a limited scale, it would result in most valuable discoveries."

No action was taken upon this portion of Governor Vroom's message. But in his message to the Legislature, on the 30th of October, 1834, he alludes to the subject again and says: "I am induced to believe that such a [geological] survey would lead to the discovery of valuable mineral and metallic resources. A small appropriation will be sufficient to commence with, and I think it due

*The Camden and Amboy Railroad was then laid only from Bordentown to Hightstown, and the Delaware and Raritan Canal was being constructed, though the work was much delayed by the sickness among the workmen. The Morris Canal, begun in 1825, was completed in 1831.

to the State, as well as to the age in which we live, that a commencement be made."

The Committee of the Assembly, through its chairman, William Marshall, of Hunterdon, reported favorably upon this portion of the Governor's message, saying such a survey "would tend to develop still further the wealth and resources of the State. It would have a tendency to advance the progress of science, to exalt the character of New Jersey, and to promote the growth and prosperity of her agricultural and manufacturing industry." And they further reported the following bill:

"To provide for a geological and mineralogical survey of the State of New Jersey.

"That the Governor, or person administering the government of this State, be and he is hereby empowered to employ some suitable and scientific person or persons to make a geological and mineralogical survey of the State, and make a report thereon to the next session of the Legislature, and that he be authorized to draw upon the Treasurer for any sum not exceeding in the whole one thousand dollars, in order to defray the expenses of the same."

This bill was passed February 26th, 1835.

Under this act Henry D. Rogers, professor of geology in the University of Pennsylvania, received the appointment to make the proposed survey. He entered at once upon the work and evidently prosecuted it with a systematic plan and enthusiastic earnestness. His report was presented to Governor Vroom, 16th of February, 1836. It is entitled "Report on the Geological Survey of the State of New Jersey," and is an octavo of 174 pages, illustrated by a large plate of five sections across the State. A map is also mentioned as accompanying the report, but it probably was not published at that time.

The plan which he adopted for the year's work was to "lay down upon the map of the State (Gordon's) a series of straight lines, five in number, so drawn as to cross, nearly at the same angle, all the various formations. The regions adjacent to these lines, embracing a width of several miles on both sides of each, were then selected for more particular and detailed examination; and the extent and boundaries of the several formations, as far as determinable, were delineated upon these portions of the map.

"The five geological sections or profiles thus surveyed embrace all the strata, and afford a general insight into the principal features of the stratification, of the State."

The five profiles laid down and studied were:

"First, a line of country extending across Bergen and Sussex counties, from the vicinity of Fort Lee, on the Hudson river, to near Dingman's Ferry, on the Delaware.

"Secondly, a tract stretching from the sea-shore, in Monmouth, to the Water Gap of the Delaware, in Warren.

"Thirdly, a tract extending from the bend of the Delaware, at Easton, parallel with the general course of the river to Trenton, and thence prolonged to the sea-shore, south of Barnegat.

"Fourthly, a section across Gloucester, reaching from the Delaware river, at Camden, to the sea-shore, near Leeds' Point.

"Fifthly, a tract traversing Salem, Cumberland, and Cape May counties, from the Delaware to the sea-coast."

This clear and easily understood plan of work was carried out, and

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NOTE.—Prof. Henry Darwin Rogers, the first State Geologist of New Jersey, was born in Philadelphia, August 1st, 1808. He was educated in Baltimore, and Williamsburg, Virginia. In his twenty-second year he was elected Professor of Chemistry and Natural Philosophy, in Dickinson College, Carlisle, Pa. He went to England, in 1831, and studied chemistry in the laboratory of Dr. Edward Turner, and attended the lectures of De La Beche on Geology. He returned to Philadelphia in 1833. In the winter of 1833–4 he delivered lectures on geology in Philadelphia, and in 1835 the University of Pennsylvania elected him Professor of Geology and Mineralogy. And the same year the Governor of New Jersey appointed him to make a geological and mineralogical survey of that State. His first report was made in 1836, and his final report in 1840.

In 1836 Prof. Rogers was appointed Geologist of Pennsylvania. He made six annual reports on the progress of the survey of that State, when the work was suspended. It was resumed in 1851, and continued through 1852, '53 and '54. And his final report, in two large quarto volumes, was published in 1858.

In 1858 he was appointed Requis Professor of Natural History in the University of Glasgow, and transferred his residence to that city. He remained in the discharge of his duties there till 1866—his health had been failing for some time—and in that year some obscure disorder of the brain was developed, and terminated his life on the 29th of May.

He was a man of great ability, and of very attractive powers of speaking, and held a prominent place among the geologists of the world. His works on geology are admirably arranged and presented, and his generalizations are remarkably clear and well sustained.*

*For biographical notices of Prof. Rogers and his three brothers, see Dr. Ruschenberger's sketch in Proc. Am. Phil. Soc., Vol. XXIII., pp. 104-146.

has furnished the basis for all the geological investigations which have since been made in the State.

In addition to studies made of the geology of the State, as shown along these lines, much attention was given to the occurrence and description of the useful minerals found in different parts of the State. "This was done more especially in the survey made of the *greensand or marl formation,* passing through Monmouth, Burlington, Gloucester and Salem counties."

This report was received with great satisfaction by the Legislature and by the people, and a further appropriation of $2,000 was made for continuing the survey.

At the end of the year 1836 a very short report upon the progress of the survey was made to Governor Vroom by Prof. Rogers. It was presented to the Legislature by Governor Philemon Dickerson, January 3d, 1837, with the recommendation that a further appropriation be made for continuing the survey another year, and, in accordance with this, an appropriation of $2,000 was made.

The report for 1837 covers but two octavo pages. It was presented as a separate document, and also as a document accompanying Governor Dickerson's message. It is entitled "A Sketch of what has been achieved towards the Geological Survey of New Jersey during the past year." The general plan sketched in the report of the preceding year was followed, but the investigations "have been conducted with an eye to more system and greater scientific accuracy. In place of *crossing* the strata, as hitherto, in certain lines, with a view to detect their more obvious contents and relative situation, they have this year been traced, also, *longitudinally,* in order to delineate on the map, with precision, their true boundaries, and to behold throughout their entire area every modification their rocks or mineral deposits might present."

The larger portion of the work was given to the survey of the portion of the State between the Blue Mountain on the northwest, and the greensand marl formation on the southeast. Considerable chemical work was done, and many specimens were collected "to form a cabinet for the better elucidation of the final report and geological map."

October 26th, 1837, Governor Dickerson, in his message, says that he is "authorized by Prof. Rogers to say that no further appropriations will be required, but in order to finish his survey and make a

report in manner satisfactory to himself and useful to the public, further time will be required." *

October, 1838, Prof. Rogers made a short report to Governor William Pennington, in which he says that all the field work is done except two or three small neighborhoods, but that the chemical work will not all be done till in the winter. He also notices the different subjects he has under investigation, and finally states that he cannot complete the printing of the final report for the present Legislature.

In 1840 Governor Pennington announced in his annual message that Prof. Rogers' final report was printed.

This report is entitled "Description of the Geology of the State of New Jersey: being a Final Report, by Henry D. Rogers, State Geologist." It is an octavo volume of 301 pages, with a geological map of the State, on a scale of six miles to one inch; and a plate containing two sections across the State—one from New York to the Delaware river at Dingman's Ferry, and the other from the Atlantic ocean at Long Beach to the Delaware Water Gap.

The report, though without index or table of contents, is carefully planned, and is written in a clear and flowing style, so that it is read with interest even by those least familiar with scientific geology. It consists of an INTRODUCTION of 6 pages, in which the physical features of the State are well presented and described. The geology of the State is described in two PARTS, one of which is north of a line drawn across the State from the Raritan, a little below New Brunswick, to the Delaware, a little below Trenton. The Northern Division, or Part I., occupies the report from page 9 to page 175, and the Southern Division, or Part II., the remainder to page 301.

In the Northern Division he classes the rocks in three groups, enumerating them in the order of the period of their formation. They are:

"*First.* A group of *primary rocks*, confined to the Highlands and the vicinity of Trenton.

"*Secondly.* A group of *older secondary strata*, confined to the northwestern portions of Sussex and Warren counties, from the base of the Highlands to the Delaware river, and to most of the regular valleys between the primary ridges of the Highlands.

"*Thirdly.* A group of *middle secondary strata*, lying in the broad

* Prof. Rogers' time was largely occupied in the Geological Survey of Pennsylvania from early in 1836 to 1842.

belt of country between the southeastern foot of the Highlands and the boundary connecting Trenton and New Brunswick, including, also, the red shale, red sandstone and conglomerate rocks of the Green-Pond mountain. With the above third group are connected the *trap rocks*, which are confined almost exclusively to the region of the middle secondary formation, just referred to."

In each of these divisions the report takes up the rocks which occur in it, describes them, gives the geological structure of the group, then refers to the economical geology, giving account of the iron ores and iron mines of the first, of the limestones and slates in the second, and to the trap rocks and the copper ores in the third. There are many chemical analyses of the iron ores and of limestones, and much effort is shown to make the results of the survey useful to the people of the State.

In Part II., the Southern Division of the State is described under five divisions, viz.:

"*First.* A group of *sands* and *clays* of several colors and of somewhat variable constitution, but frequently of extreme whiteness and remarkable purity. Among these occur beds of pure potter's clay. This division rests along its northwest margin," etc.

"*Second.* A somewhat mixed group, consisting of beds almost wholly composed of *greensand* in a loose granular condition, alternating with and occasionally replaced by layers of a blue, sandy, micaceous clay. This is the 'greensand formation,' properly so called," etc.

"*Third.* Immediately overlying the greensand formation, near its southeastern border, we find several limited exposures of a yellowish granular limestone of rather crystalline structure and frequently siliceous composition," etc.

"*Fourth.* A yellow, very ferruginous, coarse sand, containing sometimes a small proportion of the green mineral," etc.

"*Fifth.* Resting upon the former and constituting the highest ascertained member of the upper secondary series in the State, there occurs a coarse, brown, ferruginous sandstone, sometimes passing into a conglomerate," etc.

The whole of these he designates as the *greensand series.*

Each of these is described in succession, and every effort is made to make its location and mode of occurrence understood. This is specially true of the marl formation, on account of its usefulness in

agriculture. He took great pains to get representative specimens from all parts of the marl region, analyzed them, and then discussed at length the fertilizing qualities of the marl, and described its remarkable effects upon the sandy and exhausted soils of the country. The earnestness and enthusiasm he shows in his description of the marl and its effects upon farm products, was an attractive feature of the report.

In the message of Governor Rodman M. Price, dated January 17th, 1854, he says: "It is reported that valuable mineral deposits are frequently discovered by foreigners, and lands purchased from our landholders at nominal prices. A thorough geological survey of the State would doubtless discover mineral deposits to the advantage of our citizens and prevent the speculation now practiced upon them, and increase the value of taxable property beyond the cost of the survey and promote the great interest of agriculture. Fifteen years ago a survey was made which does not meet the progress of scientific discovery. The benefits and practical returns from that survey greatly increased our agricultural productions. The value of marl previous to the survey was unknown, and its use as a fertilizer has greatly enhanced the value of lands. It is thought other natural fertilizers, veins of phosphate of lime, are known to exist; vast beds of peat and muck, which, if properly composted, would be of great value to our farmers and which a survey would develop, and the State be benefited by the increased wealth of its citizens and value of its lands. I express the hope that a geological survey may be ordered, if a suitable person can be found to perform the service."

In accordance with this recommendation, the following law was passed on the 2d of March of that year, viz.:

"AN ACT to cause a geological survey.

"1. BE IT ENACTED *by the Senate and General Assembly of the State of New Jersey*, That the governor of this state be and is hereby authorized to employ some competent person or persons to make a geological survey of the state.

"2. *And be it enacted*, That the person or persons who may be employed by the governor as aforesaid shall have the right, without molestation or hindrance, to enter upon any lands within this state, not doing any unnecessary damage thereto, with such others as assistants as he or they may deem necessary, to make the required investigations and to effect the objects of said survey.

"3. *And be it enacted,* That it shall be the duty of the person or persons so employed as the surveyor or surveyors, to make an accurate, thorough and complete geological survey of the state; which survey shall be made and described in sections of one township each, accompanied by proper maps, diagrams, profiles and references, with a full scientific and practical description of the rocks, minerals, ores, sands, clays, marls, peat, fossils, soils and other substances, with a detailed and alphabetical list of the principal localities of rocks, minerals, ores, sands, clays, marls, peat, fossils, soils and other substances, which may be valuable to the people, in the several townships of this state.

"4. *And be it enacted,* That the governor of this state shall have a general supervision of said survey, the power to employ such person or persons as aforesaid to make said survey, and to discharge and dismiss them as he may think right and proper to further and secure the object of this act; to stipulate and agree with said person or persons so employed, in regard to their compensation, allowance for stationery used, the completion of said survey in manner aforesaid, at the earliest period for the publishing of the work and securing the copyright of the same to the state, and further, to cause a report of the progress of the work to the legislature of this state at the annual meeting thereof until the same be completed and finished; and the governor of this state for the time being is hereby authorized, by his draft in favor of such person or persons as may be employed as aforesaid, to draw on the treasurer of this state for such sum or sums of money as may be necessary from time to time to pay such persons employed as aforesaid; *provided,* the several sums so drawn for shall not exceed the whole amount hereinafter appropriated for the said survey; and the said treasurer is hereby authorized to pay, out of any moneys not otherwise appropriated, for the purpose and in manner aforesaid, any sum not exceeding four thousand dollars.

"5. *And be it enacted,* That it shall be the duty of the governor to require of the surveyor or surveyors aforesaid to collect specimens of the different minerals, rocks, fossils, marls, clays, sands, peats, and of such valuable substances as may be found in the state, to be disposed of in such manner as the legislature may hereafter direct; and also to collect specimens of such substances as may be valuable and peculiar to each county, to be disposed of in such manner as the board of freeholders of the counties where collected shall direct.

"6. *And be it enacted,* That when the survey of a county shall be completed in manner aforesaid, it shall be the duty of the governor to require the same to be published and bound in a strong and substantial manner; and as the survey of the state shall progress by counties, published and bound as aforesaid, it shall be the duty of the treasurer to distribute duplicate copies of the same to each of the county clerks, to be by them preserved and kept for the free use and benefit of the people of said counties.

"Approved March 2d, 1854."

Under this act the survey was organized in the summer of 1854, by the following appointments:

Dr. WM. KITCHELL, Superintendent and State Geologist, taking charge of the Geological Survey of the Northern Division of the State.

Prof. GEO. H. COOK, Assistant Geologist, in charge of the Geological Survey of the Southern Division.

Dr. HENRY WURTZ, Chemist and Mineralogist.

Gen. EGBERT L. VIELE, Topographical Engineer, to conduct the Topographical Survey.

These officers all entered upon their duties at once, and the results of the season's work were given in a report to the Governor at the end of the year. The first report is an octavo of 103 pages, and contains short statements of the work begun in each department, and is illustrated by a plate of scenery on the Delaware, figures of some instruments used, a plate of sections showing the structure and relations of the three marl beds, and an illustrative triangulation map.

In the Northern Division geological work was begun by making

NOTE.—Dr. William Kitchell, the second State Geologist of New Jersey, was born at East Madison, Morris county, New Jersey, April 21st, 1827. He entered Rutgers College, at New Brunswick, and remained there as a student in the Freshman and Sophomore classes, through the years 1845–6 and 1846–7. He left college to take up the study of medicine, and attended lectures at the University of New York. He did not engage in the practice of his profession, but became a teacher of Natural Sciences and a Professor in the Newark Institute. In 1850 (?) he went to Europe and studied in the Mining School at Freiberg, in Germany. After his return home he was appointed State Geologist. This was in the Spring of 1854. He continued in charge of the State Survey through the years 1854, 1855 and 1856, when the work was closed on account of the failure of appropriations. He made annual reports to the Legislature for each of those years, and had commenced a system of elaborate and detailed surveys of the mining industries of the State, but, unfortunately, the work had to be left unfinished. In 1861 he, in connection with G. M. Hopkins, C.E., published a good geographical map of the State on a scale of 2½ miles to an inch.

Dr. Kitchell died of some acute disease December 29th, 1861. He was an earnest worker in science and its applications to the useful arts. He had made a special study of mining and metallurgy, and his plans comprehended important and useful work for the people of the State. It is greatly to be regretted that he could not carry out his work to its completion, and to meet the high hopes which were centered in him.

detailed surveys, measurements and other examinations of the iron and zinc mines, and of calcareous marl beds.

In the Southern Division the geological structure of the greensand marl beds was the principal subject of examination, and the location, dip and strike of the three greater divisions were plainly made out and described.

The Chemical and Mineralogical work was begun with a careful and exhaustive examination of the calcareous marls of Northern New Jersey.

The Topographical Survey was begun in Sussex county by the work of two parties with plane-tables and a triangulation party. Much of the county was gone over in that year, and a county map was well advanced.

The work of this season of 1854 was highly satisfactory, and a further appropriation of $20,000 was made for carrying on the survey as it had been begun.

In 1855 active work was prosecuted throughout the entire year, and at its close a report upon the work done was submitted to the Governor. This report is an octavo of viii and 248 pages, with an outline map of the State on a scale of $\frac{1}{400000}$, on which the triangulation projected for the northern portion of the State wa laid down; a large map and profile of the Hibernia iron mine, and numerous illustrations of scenery, of geological formations, and of mines and mining machinery.

In the Topographical Department, General Viele reports that the triangulation has been begun at 25 stations, and 460 observations have been made. Plane-table parties were put in each of the counties of Sussex, Morris, Salem, Monmouth, Hudson, Warren, Cape May, Cumberland and Atlantic. The surveys of Sussex and Cape May were completed and the maps drawn, and good progress had been made in several other of the counties.

In the Southern Division geological work was continued in tracing out and describing the subdivisions of the greensand marl beds and the Cumberland marls, in studying the geological structure of the beds of fire and potters' clay, and the geology of the formations on the seashore and on Delaware bay, with the evidences of recent change and subsidence. Chemical examinations of the marls, clays and other substances were given, with much matter relating to the agriculture of the country.

In the Northern Division a detailed statement of the physical geography of the country was given, with its mountains, valleys, lakes, rivers, and then a resume of its geology, its rocks, minerals and ores. Numerous local details of mines are also given, and with it the work of Mr. Wurtz is included, where the latter describes minutely the composition of the rocks in the mine walls, and the ores themselves.

This report was received with much interest, and was printed and widely circulated. The appropriation of $25,000 was made at the beginning of the year for the work of 1856, and for the expenses of engraving the maps of Sussex and Cape May, and printing 1,000 copies of the report and map of Sussex, and 500 copies of the report and map of Cape May. Provision was also made for the distribution of copies to various bodies of persons, amounting to 200 or more, and the rest were to be sold at $3.00 a copy for that of Sussex, and $2.00 for that of Cape May.

It was early found, however, that the State funds were not available for the sum appropriated, and the work was greatly diminished in its extent, and some portions entirely suspended. The limited amount of work which was done, was by those in the service who were willing to go on at their own charge, and trust to the succeeding Legislature to provide the means for reimbursing them.

The report for the year 1856 was made to Governor Price at the close of his term of office.

This report was printed as an octavo of 79 pages, and contains an account of the work done in the Geology of the Northern and Southern Divisions of the State, and in its Topographical Survey. It was also accompanied by a Catalogue of Plants of Monmouth and Ocean counties, by Dr. P. D. Knieskern, of Shark River.

Dr. Kitchell reported that detailed surveys of the geology, scientific and economic, were about completed for the counties of Sussex and Morris, and were considerably advanced in Essex and Hudson counties. He wrote out a fuller account than had been given before of the magnetic iron ores and their occurrence and distribution in the rocks, and in the use of the magnetic needle in searching for new beds of that mineral; he also wrote upon the methods and economy of working the ores.

In the Southern Division the assistant in charge reported that the geology of the county of Cape May was completed and the report and map published. The county of Monmouth had been nearly all

surveyed, and a considerable portion of Cumberland, and that much of the chemical work connected with the analysis of soils, marls and other fertilizers was done. The report also contained a full statement of the agriculture of that portion of the State, the opportunities offered for its further development, and the natural advantages furnished for its profitable pursuit.

It was the plan of the survey to publish its results, in county reports, each of which was to be accompanied by a topographic map of the county. The county of Cape May, in the Southern Division, was the only county report that was completed and published. It is a large octavo of 208 pages, and contains a folded map of the county on a scale of $\frac{1}{60000}$. It also contains numerous illustrative views and sections. The geology is very simple, only the quaternary to be found in the county, and the surface so uniformly level that there is not an elevation 40 feet above the sea in it. Its sandy and gravelly loams, its salt marshes, and its sand beaches are described, and the wear of its shores, and the changes of level, for which it furnishes remarkable proofs, are treated at length. Its climate and its agricultural resources are given, and lists of animals, birds, fishes, flowering plants and algæ are also published; and a sketch of the early history of the county of Cape May, by Dr. Maurice Beesley, is included in it.

General Viele reported for the Topographical Department that work on a diminished scale had been vigorously prosecuted, though under discouraging circumstances, during the year, and that the following was a summary of the work thus far accomplished:

County of Cape May.—Survey completed, map drawn, engraved and published.

County of Sussex.—Survey completed, map drawn and partly engraved.

County of Monmouth.—Survey completed and map drawn.

County of Morris.—Survey nearly completed and map partly drawn (could have been completed in about three weeks).

County of Warren.—More than half surveyed.

County of Salem.—Half surveyed.

County of Cumberland.—Half surveyed.

County of Hudson.—This county could have been completed in four weeks, with the aid (which had been offered) of the New York Harbor Commissioners' work.

The work was not resumed in 1857. The property, unfinished records, surveys and notes were collected together and all liabilities discharged. The sum expended during the year 1856 was $16,902.69.

Much good work had been done, and it was a great disappointment to many that it was suspended and the half-finished work left in such condition that it was liable to be entirely lost.

In 1860, the State Agricultural Society, in consideration of the agricultural and other interests of the State, secured the passage of a law by which Dr. Kitchell was allowed the free use of the property, surveys, maps, notes and results of the late Geological Survey, and authorized to complete and publish the report of the survey in one book, and the survey to be shown in one map of not less than three miles to an inch, and to be done at his own cost, and without charge or expense to the State. Under this authority, Dr. Kitchell, in connection with G. M. Hopkins, C.E., prepared and published a good geographical map of New Jersey, on a scale of two-and-a-half miles to one inch.

The death of Dr. Kitchell, in 1861, before he had written out any full account of the geology of the State or of those mining interests in which he was so heartily engaged, closed the hopes of friends of the Survey in that direction.

In 1863 the State Agricultural Society obtained the passage of a law authorizing its officers to receive the State property which had been in possession of Dr. Kitchell, and transfer it to Professor George H. Cook or some other suitable person, in order to complete the survey, as proposed in the original engagement with Dr. Kitchell.

During the season of 1863, a section across the State, from the Atlantic shore at Shark River inlet to the Delaware Water Gap, was carefully studied and drawn, and a short report was prepared by Professor Cook on the State surveys, as made by Professor Rogers and Dr. Kitchell, and the benefits derived from them. This report he was invited to read before the Senate and the Assembly in their regular sessions. In it was said that "the importance of having the geological survey so executed and published that all our citizens may understand the geology of the State, can hardly be overestimated. To the practical man it is of the first importance *to know* that the materials of the globe are not jumbled together in a confused mass, where any particular substance can only be found by chance, but that there is an orderly arrangement of them, and each is to be found in its

appropriate place. The soils upon each rock formation have their peculiar characteristics, and the farmer who wishes to devote himself to dairying, to the raising of stock, of grass, of grain, of fruits, or of garden vegetables, will look for the rock formation and soil upon which his special product is most profitably raised. Our iron need only be looked for in one kind of rock, and that rock is confined to a particular district of country. The limestones are all in regular layers, traversing the country in a northeast and southwest direction, and never in any other. Our greensand marls are only found in one favored portion of the State. The fire-clays are only in one belt of country, which crosses the middle of the State from northeast to southwest. It would be worse than useless to look for magnetic iron in Southern New Jersey, marl in the northern part of the State, or coal-beds anywhere within our bounds. It is only by surveys of this kind, carefully carried out over the whole country, faithfully described and illustrated, and the results brought within the reach of all our citizens, that we can fully and profitably make this arrangement known and appreciated. Our abundant but undeveloped resources require from the State this kind of survey and publication."

Following the reading of this report, the bill for the completion of the Geological Survey was prepared, passed by both houses and signed by the Governor, the Hon. Joel Parker. It is as follows:

"AN ACT to complete the geological survey of the state."

"WHEREAS, The senate and general assembly of the state, by an act passed March second, eighteen hundred and fifty-four, authorized a geological survey of the state to be made, which survey was subsequently suspended by the state; *and whereas*, the state agricultural society, under the authority granted to it by the act of February twenty-fifth, eighteen hundred and sixty-three, has shown a laudable zeal in continuing the said survey; *and whereas*, it appears by the report of Robert C. Bacot and Jacob Herbert (committee of the legislature), made March eleventh, eighteen hundred and fifty-seven, that of the former appropriations made by the state there was, at that date, an unexpended balance amounting to eight thousand and ninety-seven dollars and thirty-one cents, which balance still remains to the credit of that account; *and whereas*, it is the duty of the state to develop and render available to the fullest extent the facts relative to its great natural resources, as also of its agricultural, mining, mechanical and other industrial interests; therefore,

"1. BE IT ENACTED *by the Senate and General Assembly of the State of New Jersey*, That the duty of completing the said survey be

and is hereby resumed by the state, said survey to be completed within a period not to exceed four years, and at an expense not to exceed the sum of twenty thousand dollars, aside from the cost of publication, and all laws conferring on the state agricultural society authority to continue the survey, or transferring to it the state property used by the survey, be and the same are hereby repealed.

"2. *And be it enacted*, That the sum of twenty thousand dollars, of which the unexpended balance of former appropriations shall be part, be and is hereby appropriated to carry out the provisions of this act.

"3. *And be it enacted*, That the appointment of George H. Cook, by the state agricultural society, is approved of, and that the said George H. Cook is hereby appointed state geologist, with authority to receive from the state agricultural society the state property used by the survey, and employ, control and use the same; to employ such assistant or assistants as shall seem to him necessary for the proper prosecution of the survey; and it shall be lawful for the said George H. Cook and the person or persons employed by him, to enter, without molestation, upon any lands in this state which he or they may deem necessary to further the object of the said survey; and it shall be the duty of the state geologist, on or before the first day of January of each year, to furnish to the president of a board of managers (hereinafter to be created) a detailed statement of his expenditures, with the vouchers therefor, and also a report of his operations for the preceding year.

"4. *And be it enacted*, That to promote the objects which this act has in view, there shall be a board of managers of the same, to consist of eleven members, one of whom shall be the governor of the state, who also shall be president of the board, and two members from each of the five congressional districts of the state; and the state geologist shall make his annual report to the president, who shall appoint from the members of the board a committee to examine the annual accounts of expenditure, and the president shall submit the same and all matters pertaining to the survey at the first following session of the legislature; and it shall be lawful for the president and board of managers, or a majority of them, to make yearly agreements with the state geologist as to his own and the salaries of his assistant or assistants, but such temporary assistance as may be needed, the purchase of the necessary implements and materials, the means necessary for transportation and all other incidental expenses shall be under the control of the state geologist; and it shall be the duty of the members of the board, in addition to those already specified, to furnish from time to time to the state geologist, any and all information which will contribute to the more full and complete development of the facts relating to the agricultural, mining, mechanical and other industrial interests of the state.

"5. *And be it enacted*, That the governor of the state is hereby

authorized, by his draft in favor of the state geologist, to draw on the treasurer of the state for such sum or sums of money as may be called for by the state geologist; *provided*, the several sums so called for shall not in any one year exceed the one-fourth part of the appropriation made in section two of this act, to wit: twenty thousand dollars.

"6. *And be it enacted*, That it shall be lawful for the state geologist to take from the first yearly installment a sum not to exceed five hundred dollars to reimburse himself for the expenses incurred in prosecuting the survey the past year.

"7. *And be it enacted*, That the board created by this act shall be a committee of publication, with authority to print and publish the annual and final reports of the state geologist, and also to direct the distribution of suites of the geological, mineralogical and other specimens collected in the survey, to such literary, scientific and other institutions as will best conduce to the interests of the citizens of the state.

"8. *And be it enacted*, That the following named persons are hereby appointed and shall constitute the board of managers of the geological survey of the state, viz.: president, Joel Parker; managers, David Potter, of Cumberland; Andrew K. Hay, of Camden, in the first district; William Parry, of Burlington; John A. Roebling, of Mercer, in the second district; Isaac R. Cornell, of Somerset; Henry Aitkin, of Union, in the third district; Abraham S. Hewitt, of Passaic, Andrew B. Cobb, of Morris, in the fourth district; William M. Force, of Essex; J. R. Wortendyke, of Hudson, in the fifth district; and power is hereby given to the said board, or a majority of them, to fill any vacancies which may occur.

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

"Approved March 30, 1864."

Under this act work in the survey was resumed with the purpose of collecting together all that could be found relating to the geology and natural resources of the State in the four years allotted to the work, and to prepare and put these in such form as might be most useful and acceptable to the people. Short pamphlet reports of the condition and progress of the survey were made every year to the Governor. That of 1864 contains 24 pages, with a colored geological map and a profile of the rocks of the State, each in an octavo page. The report of 1865 contains only 12 pages; the one of 1866 has 27 pages, and that of 1867 has 28 pages. The matter in these, however, is all reproduced in the Geology of New Jersey, which was printed in 1868, and is the only report of that year.

The organization of the Survey for those years was—

George H. Cook, State Geologist.

John C. Smock, Assistant Geologist.

Major T. B. Brooks was engaged in topographic and magnetic surveys of iron mines and iron-ore lands in 1864.

Dr. David Murray was engaged in preparing projection for a new map of the State, and in collating and revising in the field the materials for such a map in 1864–5.

Dr. Charles C. Abbott voluntarily devoted himself to the preparation of catalogues of the vertebrate animals of the State during the years 1864–5–6–7.

G. M. Hopkins, C.E., compiled the maps for the use of the Survey and for publication, using such material as was available from former surveys and from old maps. He also surveyed and drew a topographic map of about 80 square miles of the district of Morris county in which the largest iron mines are located. His work was done in 1865–6–7.

Edwin H. Bogardus was employed as chemist through the years 1866–7.

Francis C. Van Dyck was engaged in chemical researches during part of the year 1866–7.

Paul Cook was occupied in tracing lines of magnetic attraction and beds of iron ore in 1866–67.

Lines of magnetic attraction were also traced by John Hance and others.

The work of the four years was completed as prepared, and at an expense within the appropriation made for it. The report, however, was not ready for publication, and the section requiring its completion in four years was repealed March 24th, 1868.

The year 1868 was devoted to the preparation of the general report.

This report, which was entitled "The Geology of New Jersey," and made to Governor Marcus L. Ward, is an octavo of xxiv and 899 pages, and is illustrated by numerous explanatory sections and sketches, and is accompanied by a portfolio of 8 maps.

In this report was brought together the work of all those who have been engaged, with recognition of their services; the geographical material which could be made available; the systematic geology of the State as given in four divisions, viz., the Azoic and Paleozoic, Triassic, Cretaceous, Tertiary and Recent Formations; Historic

Geology, Economic Geology, Fertilizers, Building Materials, Ores, Manufacturers' Materials and Useful Products; and in an appendix are given a List of Invertebate Fossils, by T. A. Conrad; Lists of Extinct Mammalia and Reptilia, by E. D. Cope; Lists of Minerals, by Rev. E. Seymour; Lists of Vertebrate Animals, by Dr. C. C. Abbott, and Lists of Elevations in New Jersey, from various sources.

The four general maps were on a scale of two miles to an inch and covered the whole State, following the four divisions mentioned above. The map of a group of iron mines in Morris county was drawn to a scale of three inches to a mile. Those of the zinc mines of Sussex county, of the Oxford iron mines and of the Ringwood iron mines on a scale of eight inches to one mile.

Two thousand copies of the report and maps were printed and mostly distributed gratuitously, a few only being sold at the cost of publication.

This report presented the resources of the State in detail, and was intended to give them in such words and such order that they could be made use of for practical purposes, and it cited facts to prove that the principle which had been followed in authorizing the surveys, and widely publishing their results, had been profitable to the State.

A supplement to the "Act to complete the geological survey of the state" was passed April 1st, 1869, in which the survey was authorized to be continued for a further period of four years, with an annual appropriation of a sum not to exceed five thousand dollars.

AN ANNUAL REPORT FOR 1869 was made to Governor Theo. F. Randolph. It is an octavo of 57 pages, and contains: A map of the tide marshes on Newark bay and the Passaic and Hackensack, on a scale of two inches to a mile, with the depth in feet of the marsh-mud; a map of the tide marshes on the Delaware, in Salem county, on a scale of two miles to an inch, with the depth in feet of the marsh-mud; a map of the Passaic river, between Little Falls and Chatham, with its branches, the Rockaway and Whippany, scale two inches to a mile; profiles of the Passaic river, from Little Falls to Chatham, and its branches, the Rockaway and Whippany, horizontal scale two inches to one mile, vertical scale one inch to forty feet.

Mr. E. H. Bogardus was engaged during the year in chemical work. Prof. E. A. Bowser made the surveys for the maps with reports upon them. The work of the survey was arranged under the following heads:

1. Fertilizers found in the State, and the means of making them more quickly and generally useful.
2. On the tide marshes and tracts of land subject to protracted freshets. [Plans for drainage were prepared.]
3. On the soils of the State, their origin, chemical and physical properties and distribution, and suggestions for their most productive management.
4. On the iron and zinc ores of the State.
5. Additions to the Scientific and Economic Geology of the State.

The topics above mentioned have been continued in successive years, and have been the beginning of valuable and lasting improvements.

THE REPORT FOR 1870 was made to Governor Randolph, and is an octavo of 75 pages, and contains a profile of the Passaic river from Chatham to Millington, on a scale of two inches to a mile; a map of the Great Meadows in Warren county, scale two inches to a mile; a profile of the Pequest river through the Great Meadows, horizontal scale two inches to a mile, vertical scale 40 feet to an inch; and a plate showing the arrangement of Hoffman's perpetual-burning brick-kiln.

The assistance of Mr. Bogardus and Prof. Bowser in the work of the Survey was continued, and the State Geologist spent some time in Europe, visiting reclaimed marsh lands in England and Holland, and in visiting mines in Norway, Sweden, Germany and England. The material is arranged under the same heads as in 1869; plans for the drainage of the flowed lands on the Passaic and the Pequest were prepared; and the results of the drainage works in Europe were reported upon.

THE REPORT FOR 1871 was made to Governor Randolph, in an octavo of 46 pages, and contains a map of the Drowned Lands on the Wallkill river and its branches, in Sussex county, New Jersey, and Orange county, New York, on a scale of one inch to a mile, and a profile of the Wallkill river, from Lawrence's Bridge, in Sussex county, New Jersey, to the mouth of the canal, near Hampton, in Orange county, New York; horizontal scale one inch to a mile, vertical scale 20 feet to an inch.

Prof. Smock resumed his connection with the Survey in June of this year.

Mr. Bogardus continued his work in the laboratory as chemist.

Prof. Bowser continued work on surveys.

Geo. W. Howell, C.E., also did work on surveys.

The passage of a law by the Legislature at its session in the beginning of 1871, entitled "An act to provide for the drainage of lands," required the managers of the Geological Survey, when petitioned, to prepare maps and plans for drainage works, and, under this act, maps and plans were prepared for the lands on the Passaic and Pequest, and the preparatory notices, &c., were given for the appointment of commissioners to execute the plans.

Much attention was also given to the agricultural and mining interests of the State, and to their progressive development and improvement.

THE ANNUAL REPORT FOR 1872 was made to Governor Joel Parker, in an octavo volume of 44 pages. The work of the Survey was continued, with the assistance of Prof. Smock, Assistant Geologist; Prof. Bowser, as surveyor, and Mr. Bogardus, as chemist. The projects for the drainage of wet and flowed lands occupied much attention and labor, and their importance to the State was strongly presented. The geological location and relations of the iron mines was presented, and modes of searching for and opening new mines were described. The condition of the business of producing and marketing the products of quarries, mines and soils was presented at length and discussed. In the agricultural interest of the State the announcement was made of the organization of a State Board of Agriculture, and the question is proposed as to the transfer of those matters relating to agriculture, from the Geological Survey to this new Board.

The Legislature, at the session of 1872, passed an act continuing the appropriation of $5,000 a year for the Geological Survey for a further period of four years.

THE ANNUAL REPORT OF THE STATE GEOLOGIST FOR THE YEAR 1873 was made to Govornor Parker, and printed in an octavo of 128 pages, and accompanied by a geological map of Northern New Jersey, showing the iron ore and limestone districts; scale, 2 miles to 1 inch.

The working force in the Survey was continued the same as in 1872. In addition to the miscellaneous work of furnishing information upon the numerous subjects and interests which come within the special work of the Survey, the drainage works on the Pequest were begun; the resurvey of the northern boundary line was begun, and some work was done in Warren county in surveying and leveling for the purpose of making a topographic map of the county, in which the elevation and outline of the hills and mountains and the lines of

drainage would be accurately shown by means of contour lines. In this report, too, the mines of magnetic iron ore are named in detail with descriptive notes, and the attempt is made to arrange them in geological order, as they appear in somewhat parallel belts or ranges which cross the State in a northeast and southwest direction. Two hundred and twenty-three mines were included in this list. A description was also given of the methods of searching for iron ores by the miners' compass, which was accompanied by two small maps of actual surveys to illustrate the method. The references are also given to the growing industries of lime burning, marl producing, plumbago mining, &c.

THE REPORT FOR 1874 was made to Governor Parker, in an octavo of 116 pages, and was accompanied by a map of the northern boundary of the State, to illustrate the survey of that line. It is drawn on a scale of one inch to a mile.

The work of the Survey was continued by the aid of the same assistants as for the two preceding years, and the further assistance of James K. Barton, who assisted in Prof. Bowser's surveys, and began the topographic survey of the Middlesex clay beds.

The resurvey of the northern boundary furnishes remarkable illustrations of the errors of compass surveys. The line was run in 1774. It is marked by mile monuments, of which there are 48. The line was run by the surveyor's compass, and was intended to be straight, but there are no three monuments of the boundary which are in the same straight line; there are great crooks in some parts of it, and the whole is south of the straight line; in the middle it is nearly a half-mile too far south.

The drainage works on the Pequest are in progress. Special mention is made of the mines of hematite, of copper, and of zinc, and of the methods of searching for hematite. The fire and potters' clays of Middlesex are here given, with their chemical composition, and, for the first time, the geological position and subdivisions of the several beds of clay, sand, kaolin, &c., are laid down with definiteness. The question of water-supply for the towns and cities of the State was also presented in this report.

THE ANNUAL REPORT FOR 1875 was made to Governor Joseph D. Bedle, in a report of 41 pages octavo, and an outline map of the State, on a scale of $\frac{1}{250,000}$, in which was shown the triangulation proposed and partly executed by the U. S. Coast Survey, to furnish a basis for

accurate maps. The U. S. Coast Survey was authorized, in 1871, to determine triangulation points in each State in the Union which shall make requisite provision for its own geological survey. Under this act, the Coast Survey, in 1873, determined the latitude and longitude of *Tri-States-Rock*, which marks the western end of the boundary between New York and New Jersey, and also the northern end of the boundary between New Jersey and Pennsylvania. In the spring of 1875, Prof. Bowser was appointed assistant in the Coast Survey service, with the duty of conducting and extending the triangulation over New Jersey. This appointment he still holds, in 1885.

The other assistants continued in the service of the Survey, and, in addition, Ed. A. Reiley and Robert A. Meeker assisted Prof. Smock in collecting geological specimens and minerals for the Centennial Exposition, in Philadelphia. Much time was taken up with this work of collecting specimens. The survey of the clay district of Middlesex county was completed in its field work, the drainage work on the Pequest was continued, the question of water-supply was again brought forward and examined further, and much miscellaneous work was done in the laboratory to furnish information upon the subjects in charge of the Survey.

The Legislature of 1876 made a further appropriation of $8,000 a year for five years more.

THE ANNUAL REPORT FOR 1876 was made to Gov. Bedle in an octavo of 56 pages, which was accompanied by a map of the Passaic water-shed on a scale of two miles to an inch.

The assistants of last year were continued and George W. Howell, C.E., William E. King and William F. Gregory, surveyors, were employed in surveyings for projects of water-supply in the area drained by the Passaic and its branches. Wm. R. Whitehead and Geo. McC. Taylor surveyed and mapped the Bear Swamp near Trenton, in preparation for its drainage.

The Centennial Exhibit, at Philadelphia, was arranged and catalogued, and a highly satisfactory display was made of the agricultural and mineral products of the State, and of the means provided to make these products known to all our citizens. The catalogue is an octavo of 111 pages, and contains lists of forest trees, soils, rocks, minerals, building stones, ores, marls, lime, clay and miscellaneous products.

The subject of water-supply from the basin of the Passaic above

Little Falls, was presented in much detail, and clearly showed a source of supply sufficient for Jersey City, Newark and neighboring cities and towns, that was pure and wholesome,—sufficient for the largest population—and capable of being secured at a moderate cost.

THE REPORT FOR 1877 is an octavo of 56 pages, with a one-page map of New Jersey on which the area covered by the glacial drift, together with its southern limit, is plainly marked. It was made to Governor Bedle. The Geologist was assisted in the work of the survey by Messrs. Smock, Bogardus and G. W. Howell. Prof. Bowser continued in the triangulation of the State at the expense of the U. S. Coast Survey.

A large part of the work of the year was given to a study of the fire and potters' clays, both in the laboratory and the furnace. The locating and tracing out of the southern margin of the northern glacial drift was done this year, and the line was traced across New Jersey, as shown on the map, and the examinations extended east across Long Island in its length, and in Pennsylvania westward to Berwick on the Susquehanna. The clear definition of this southern margin was recognized in the spring of 1877, and the record of it was given in a paper presented to the Society of Mining Engineers at their meeting at Wilkesbarre, in May of that year, and is published in Vol. VI., p. 467, of the transactions of the society. The work of drainage of the Great Meadows was continued, and testimony is printed in regard to the sanitary condition of the country surrounding them. The topographic survey of the country between Orange Mountain and the Hudson was begun this year by Mr. Geo. W. Howell. The surveys were taken so as to construct a map of the whole country and to put on it contour lines, so that an inspection of it will enable one to see the form and elevation of the hills, and the depth, direction and drainage of the valleys. It was the beginning of a survey which is still continued and is intended to cover the whole State.

At the beginning of the year 1878 was published the "Report on the Clay Deposits of Woodbridge, South Amboy, and other places in New Jersey, together with their uses for Fire-Brick, Pottery, &c." This was an octavo of viii and 381 pages, and was accompanied by a topographical map of the clay district on a scale of three inches to one mile, and by one large general section, showing the clay beds and clay pits, with their proper location and elevation. The map was the

first of those which have been prepared by the Survey with contour lines of elevation upon it. This report contained a very full account of the three most characteristically marked beds of fire-clay, and the single bed of stone-ware clay. By the numerous openings which had been made, and the contour lines upon the map, it was possible to trace out the outcroppings of these several beds upon the uneven surface of the district, and to give most valuable information to those seeking for locations upon which to make new openings.

The assistants engaged in this work were Prof. John C. Smock, in the geology; Edwin H. Bogardus, in the laboratory, and James K. Barton, C.E., in surveying and drawing the map.

The chemical examinations of the fire-clays showed them to be composed of silicate of alumina of almost unequaled purity, and possessing remarkable power to resist the action of intense heat.

The history and statistics of the working of these beds of fire-clay show that their extraordinary development and use has been attained since the year 1840, and that it possesses excellences which will cause it to continue and increase in these respects for a long time to come.

THE ANNUAL REPORT FOR 1878 was made to Governor George B. McClellan, in an octavo volume of 131 pages, and a map of the State on a scale of six miles to the inch, and colored to show its surface geology.

The corps of assistants remained the same as last year. The topographical surveys were continued by Mr. Howell, and extended nearly far enough to get the material from which the map of Northern New Jersey was afterwards drawn. Prof. Smock traced out the varieties of soil in the southern division of the State, and examined the numerous openings which have been made for clay and for glass-sand. Much time was given to collecting facts in relation to the glacial drift which covers so much of the northern part of the State, and tracing out minutely its southern limiting boundary. Mr. Bogardus examined a great many soils and determined their chemical composition. The miscellaneous work and correspondence of the office increases every year, as the resources of the State come to be better known.

THE ANNUAL REPORT FOR 1879 was made to Governor McClellan, and is an octavo of 199 pages, accompanied by a map of the State on a scale of six miles to the inch, which is colored to show its economic geology. The report, in addition to the usual matter, gives special information in regard to the iron mines and their working, with maps

of magnetic surveys, prosecuted in the search for new or undiscovered beds of ores, and full accounts of the soils of the State, with analyses showing their composition; and a lengthy list of bored and dug wells in various parts of the State and their geological relations, together with some account of the success which has attended the efforts to get a water-supply from them. A list of the blast furnaces in the State is also given, and as complete a list as possible of the forges which have been in operation in New Jersey at various times.

The Legislature of 1880 made an appropriation of $8,000 a year for five years more. The assistants engaged this year were Professor J. C. Smock, Assistant Geologist; E. H. Bogardus, chemist; C. C. Vermeule, topographer and surveyor. Geo. W. Howell, C.E., and Prof. E. A. Bowser, were employed a part of the year in topographic and geodetic work.

THE ANNUAL REPORT FOR 1880 was made to Governor McClellan, and is an octavo of 220 pages, with a geographical map of the State, on a scale of six miles to an inch, entitled "A Map of Progress." An important part of the report is on the glacial drift and its distribution over the northern part of the State. A few new mines of iron ore are described; a long series of experiments upon the refractory properties of the fire-clays of New Jersey, in comparison with those from other well-known localities, with their results, are given; and in the appendix there is given a series of tables upon the climatology of the State.

The assistants engaged in the work were Prof. J. C. Smock, Assistant Geologist; Edwin H. Bogardus, chemist; C. C. Vermeule, topographer and surveyor. N. L. Britton was engaged in preparing a list of the plants growing wild in the State. Prof. J. S. Newberry has in hand the description of the fossil plants and fishes of the Triassic sandstone and the plants of the Cretaceous formation. And Prof. R. P. Whitfield has begun the drawing and description of the invertebrate fossils of the Cretaceous and Tertiary formations.

THE ANNUAL REPORT FOR 1881 was made to Governor Geo. C. Ludlow in an octavo of 88 and 107 and xiv pages. The principal topics treated of are the topographic survey, in which 1,260 square miles are now surveyed and mapped with contour lines. Record of a series of bench-marks made on a line across the State from Sandy Hook to Easton, in Pennsylvania, all referred to the mean level of the ocean at the former place. These benches were made by the U.

S. Coast and Geodetic Survey. Notes of change in the level of the sea and land in recent times, description of quarries and building stones found in New Jersey, and an appendix containing carefully digested records and tables upon the climatology of the State, by Prof. J. C. Smock.

Prof. Smock, Assistant Geologist, was employed. Mr. Bogardus, chemist, closed his work in April. Mr. Vermeule, with several assistants, continued the topographic survey. Dr. Britton completed a preliminary catalogue of plants, which was printed, and Profs. Newberry and Whitfield continued their work upon paleontology.

THE ANNUAL REPORT FOR 1882 was made to Governor Ludlow, in an octavo of 191 pages, and was accompanied by a geological map of the State, on the scale of six miles to an inch. The *topographical map of a part of Northern New Jersey*, was published this year. It is on a scale of one mile to an inch, and includes 847 square miles. The greater portion of the appropriation was expended in carrying forward the topographical surveys, and the whole area surveyed at the close of this year was 1,740 square miles. A lengthy account was given of the characteristic features of the red sandstone and trap-rocks of the Triassic age, and some account of the igneous rocks in the Kittatinny valley, in Sussex county; a few new iron mines were described, and new developments and uses for the plastic clays were noticed; sea-shore changes were recorded, and a list of the new settlements along the seaside was given. The agricultural development of Southern New Jersey was also given a prominent place. The subject of public water-supply occupied 78 pages of the work; the pollution of many present sources, and their dangerous qualities, the sources of better supply from lakes, ponds, streams, springs, artesian wells, driven wells and dug wells, and rain-water cisterns, were presented, and a list given of the water-works already in operation in the State. The geological structure of Southern New Jersey was described; the strong probability of getting a supply of good water from artesian wells bored along the sea-shore was pointed out, and lines were drawn across the State maps to indicate the depth at which water-bearing strata would probably be met.

The assistants employed were the same as at the close of last year.

THE ANNUAL REPORT FOR 1883 was made to Governor Ludlow, in an octavo of 188 pages. The Topographic Survey occupied the first place in it. The total area surveyed was then 2,856 square miles;

1,893 square miles had been mapped, and 1,691 square miles had been engraved, on a scale of one mile to an inch. The matured plan for making the maps so as to cover the whole State was given; it required 17 maps, each 24 by 34 inches, and maps Nos. 3 and 4 were nearly ready for distribution. The geology of southern New Jersey was again referred to, with a notice of some better observations on the dip of the strata, and it was announced that in accordance with the suggestions made in the report of the preceding year two artesian wells had been bored, the first at Ocean Grove, and the second at Asbury Park, and that both were successful, the water in them spouting up some 20 or 30 feet above the surface. Some observations upon faults in the red sandstone were recorded. The description of the Archæan rocks was given at some length, with examples of different kinds of rock, their strike and dip, and of pinches, folds, flexures and fractures found in it. A full list of all the iron mines in the State was given, with references to descriptions in further reports. Some account is also given of explorations for iron ore by means of the diamond drill, and by the miner's compass. Various matters connected with economic geology are also treated of.

The assistants employed are still the same as those of the two preceding years.

THE ANNUAL REPORT FOR 1884 was made to Governor Leon Abbett in an octavo of 168 pages. The Topographic Survey is reported to have extended over 4,438 square miles, and 2,910 square miles are mapped and ready for engraving. Maps 3, 4 and 7 are done, and 2, 6 and 16 were to be printed very soon. Sections were also given to show the stratification of various deposits beneath the surface, and extending out under the ocean. The geological age of the Green-Pond mountain range has been a subject of question ever since its first examination by Prof. Rogers. This year's work has determined the rocks to be Silurian, and in their newer parts, perhaps, Devonian. Some further examinations were made upon the geological structure of the Archæan rocks. In addition to the record of dips, strikes and kinds of rock, it was noticed that considerable belts of the rocks in the mountain ridges were massive and unstratified. A full record of the iron mining industry was also made. A history was also given of the drainage of the Great Meadows in Warren county, including the plan, the effects, the crops in them, the litigation and the total expenses. An account was given of the successful

boring of a number of artesian wells in the Cretaceous and Tertiary strata of Southern New Jersey. The results of the surveys by the State Water-Supply Commission were also given, and an article on the chemical *purification* of water by alum, by Prof. P. T. Austin.

The assistants were continued the same as in former years, but the pay and expenses of Mr. Vermeule and his assistants in the topographic survey were, after the 15th of July, borne by the United States Geological Survey, Major J. W. Powell, director. The work is conducted by the same persons in the same way, and by the same methods and instruments as before. The United States Geological Survey gets the maps made, by this means, for its general United States map. The State of New Jersey only pays for copying the maps and field-book notes, for its own records, and has the remaining part of its appropriation for its proper geological work.

The Legislature of 1885 made a further appropriation of $8,000 a year, for 5 years, for completing the geological survey.

THE ANNUAL REPORT FOR 1885 is made to Governor Abbett in the usual form. It is accompanied by several geological sections to illustrate the Archæan and the Quatenary Geology, and to show the relations of artesian wells to geological structure; and by maps, to show the changes which have taken place in the location and outline of the beaches since the first surveys were made. The geodetic work has been completed upon 2 primary stations, and nearly finished on a third one, and observations have been completed on 27 tertiary points, and the work on the whole State approaches completion. The topographic survey now covers 5,828 square miles, and 475 square miles additional have been partially surveyed. In addition to maps 2, 3, 4, 6, 7 and 16, which were issued last year, maps 1, 9, 13 and 17 are engraved and ready to be printed, and the mapping of 8, 11 and 12 is in progress. The study of the geology of the Highlands, with their Archæan rocks and their iron ores, is now begun with the aid of the topographic maps, and several sections across them have already been studied. The study of the detailed geology of the Quaternary formations along the seashore has also been begun, with the purpose of making the full and final report upon them. The demand for fuller information in regard to artesian wells has been answered in an account of the wells bored in the different geological formations of the State, with illustrations of geological structure and of the success which has attended such bored

wells in the different sections of the State. Various minor particulars of theoretical and economic geology are also treated of, and a historical sketch of the 3 geological surveys of the State, and their influence upon its prosperity, is also given.

The assistants in the survey have been Dr. N. L. Britton and Mr. F. J. H. Merrill, in the department of geology; Mr. C. C. Vermeule has had charge of the topographic surveys, with several assistants, and Prof. Edward A. Bowser has conducted the geodetic work.

DIRECTION AND CONTROL OF THE SURVEY.

The Board of Managers of the Survey was named in the act of the Legislature of 1864. It consists of the Governor of the State, who is *ex-officio* President of the Board, and of two members from each Congressional district. The first members were named in the act, and vacancies in the Board are filled by the remaining members. The original members were: General David Potter and Hon. Andrew K. Hay, from the First district; William Parry and John A. Roebling, from the Second district; Isaac R. Cornell and Henry Aitkin, from the Third district; Hon. Andrew B. Cobb and Hon. Abram S. Hewitt, of the Fourth district; and William M. Force and J. R. Wortendyke, from the Fifth district. The vacancy caused by the death of General Potter, in 1865, was filled by the appointment of Hon. Mr. Matlack, of Woodbury; and on his decease, in 1867, by Charles E. Elmer. S. T. Scranton was appointed to fill the place of J. R. Cornell, who had removed from the State in 1866. Hon. H. S. Little was appointed in 1869, to fill the vacancy caused by the death of John A. Roebling. Hon. Jos. P. Bradley was appointed in 1869 to fill the vacancy caused by the death of Mr. Wortendyke. Thos. T. Kinney was appointed in 1870 to fill the vacancy caused by the removal of Judge Bradley from the State. Hon. Aug. W. Cutler was appointed in 1872 to fill the place left vacant by the death of Judge Cobb. Benj. Ayerigg was appointed in 1874 to fill the vacancy caused by the removal of Hon. A. S. Hewitt from the State. In 1875 the State was divided into seven Congressional districts, which made necessary the appointment of four new members, viz.: Dr. John Vought, of the Third district; Hon. Thos. Lawrence, of the Fourth district, and Benj. G. Clark and Wm. W. Shippen, of the Seventh district. Hon. Clement H. Sinnickson was appointed in 1881 to fill

the place vacated by the death of Mr. Hay. Wm. H. Hendrickson was appointed in 1882 to fill the vacancy caused by the death of Dr. Vought. George Richards was appointed in 1885 to fill the vacancy caused by the resignation of Col. Ayerigg. Rev. Samuel B. Dod was appointed in 1885 to fill the vacancy caused by the death of Mr. Shippen; and Lebbeus B. Ward, C.E., was appointed in 1885 to fill the place left vacant by Mr. Clark. Wm. M. Force, of Newark, is secretary of the Board.

OFFICERS OF THE SURVEY.

Geo. H. Cook was appointed State Geologist by the law originating the Survey. John C. Smock has been Assistant Geologist from 1864 to 1869, and again from 1871 to the beginning of 1885. Mr. C. C. Vermeule has had charge of the Topographical Survey from 1879, and still continues in the work. Numerous other worthy assistants have been engaged in the work for longer or shorter times, and their names are given in full in the reports for the years in which they were employed.

PUBLICATIONS.

The Board of Managers is by law a board of publication, with authority to draw from the State treasury such sums as may be needed to pay the expenses incurred in printing and publishing the reports and maps presented by the Geologist. This authority was exercised in the publication of the Geology of New Jersey in 1868, and in engraving and printing maps, and also in some expenses of distribution, but most of the printing is done by order of the Legislature, by the State Printer, and the expense is a part of the charge for public printing. Some monographs, like those containing the fossils of the Cretaceous and Tertiary periods, are of general interest and will be engraved and published at the expense of the U. S. Geological Survey, and the New Jersey Survey gets such copies as may be ordered for it at the cost of paper, printing and binding.

DISTRIBUTION.

The Board of Managers of the Geological Survey are authorized to distribute the results of the Survey, its reports, maps and collections,

and some attempts were made to sell the publications at the cost of paper and printing. But the Legislature, in assuming the publication of the reports as a part of the State printing, have also the right to a free distribution of them among their constituents, which right is exercised liberally. This, of course, prevents all sales, and nothing has been attempted in that way for several years. The result is a wide distribution among the people of the State. The expense of this has not been felt as a burden, and the educating influence of the publication, or, as it may be called, *advertising* the resources of the State, has been attended by the happiest effects upon the material interests of the State, as will appear farther in the statements of its development and growth.

The editions of the annual reports have varied from 3,000 to 8,000 copies each, and the final reports and maps have been printed in editions of from 1,000 to 2,000 copies each.

COLLECTIONS.

An excellent collection of the minerals, fossils, building stones, rocks, woods, and everything to represent the natural products of the State, was placed in a museum in the State House, at Trenton. The best of these specimens had been lent to the New Orleans Exposition, in 1884. The fire which burnt the State building in the winter of 1885, destroyed most of the specimens left. But space is left in the new building for a geological museum, and it is intended to make as full an exhibit of the natural products of the State as the means provided will allow. Suites of specimens, representing the rocks of the State, have been sent to the colleges, and a further distribution is still to be made.

METHODS.

The method pursued in the work of the Survey has been such as to keep its practical objects and applications prominently in view. Its systematic and theoretical prosecution has not been lost sight of, and while mining, quarrying and farming have held the foremost places for the people of the country, and water-supply, drainage, forestry, &c., have interested the people of the towns and cities, the structure of our marl and fire-clay beds, the changes of our shore, the limitations of our glacial deposits have been facts added to geological

science, and the geological structure of the country has been a constant subject of study, though no attempts have been made to force conclusions as long as further points of inquiry or investigation remained unsettled. The accumulation of facts bearing upon geological science has been steadily continued, and as fast as unquestionable evidence can be found, conclusions will be announced. It has been the practice to publish the work done, fully, and at the earliest possible time, and with such illustrations as may be needed, to make it instructive to the people of the State who read it.

TOPOGRAPHICAL SURVEYING.

The need of topographical surveys is sometimes looked on as recent, and a demand created by our advanced civilization, but while it is true that topographical surveying as we know it to-day, is almost a new science, the need of it has been felt since very early times.

The rapid development of the last century has nevertheless rendered indispensable what had long been regarded as a luxury, and all Europe has bestirred itself to supply the want. From the wealthiest to the poorest; from the little principalities to the great Russian empire; all the nations of Europe are either now engaged in prosecuting or have just completed extensive and costly topographical surveys of their territory, as well for a measure of defense as of promotion of improvements and discoveries. These European surveys range in cost from $200 per square mile in England to $6 or $7 in Russia.

The United States, although not usually deficient in enterprise, is very much behind other nations in this matter, and thus far the cartography of even important and populous sections of the country is lamentably deficient. The cause of this is not difficult to trace. Here the governments, both State and national, which alone can prosecute a work of so great magnitude and of indirect benefit, so far as individuals are concerned, are in the hands of the whole people, who ultimately direct all expenditure. In every community there are a large number who do not use maps and, naturally, have no conception of their value to those who do. The proportion of this class is increased in the United States from the fact that the people have never had accurate maps, and have, therefore, had no opportunity to learn their uses. Just here it may be noted that those States which are foremost to-day in the movement for accurate topographical surveys are those

which have had the best maps in the past, and have felt their educating influences. New Jersey has the honor to lead the States, the present survey, now nearing completion, having been begun in 1877, and she is followed by Massachusetts in 1884. No other States have successfully inaugurated, as yet, a thorough topographical survey of a character suited to the present needs of the Eastern States.

The first map of New Jersey, embracing the whole State, was probably that published by Adrian Van der Donck in his "Description of New Netherlands as it now is," in 1656. This map was subsequently referred to as Vischer's map by the commissioners appointed in 1769 to settle the disputes as to the boundary between New Jersey and New York. Its errors of location range as high as 21 miles, of distance 100 per cent. It was probably used by the Duke of York in 1664 in describing the bounds of the province, and its errors led to a misunderstanding of that description which involved the colonies of New Jersey and New York in disputes which lasted nearly a century. It is also probable that to it was due the unequal division of the province into East and West Jersey, which also gave use to long disputes between the proprietors of the two divisions.

A map was published in 1749, on a scale of about 15 miles to one inch, which is one of the earliest printed in this country, and is a considerable advance on anything which had preceded it. It is entitled "A map of PENNSYLVANIA, NEW JERSEY, NEW YORK and the THREE DELAWARE COUNTIES, by Lewis Evans, MDCCXLIX."

The next map was made by Bernard Ratzer, Lieutenant in the 60th Regiment, R. A., in 1769, to assist in settling the disputes caused by the first. It is a great improvement on the previous one, but still very incomplete.

All later maps have used two surveys, which had been made up to this time and were regarded as official. These were Lawrence's survey of the East and West Jersey line, of 1743, crossing the State for a distance of 120 miles and giving much useful information as to the topography, but having errors as great as 25 per cent. in some places in chaining, and of three miles in a total distance of seven miles in "triangulating" across Little Egg Harbor Bay; and the survey of the New York line in 1774, the position of the ends of which were determined with remarkable accuracy by Rittenhouse, of Philadelphia, but the line itself was surveyed with the old surveyors'

compass, and instead of being, as intended, a straight line, it approximates a rhumb line, but as no precautions were taken to eliminate the effects of local attraction it is very crooked. The divergence from a straight line amounts to 2,415 feet at Greenwood lake, and in consequence all maps made since have been erroneous by half a mile in the location of the lake and surrounding localities. The errors of chaining amount to 12 per cent. in places.

The map of 1777, entitled "THE PROVINCE OF NEW JERSEY, Divided into EAST and WEST, commonly called THE JERSEYS," published in London, December, 1777, drawn from the survey of 1769, and from another map of the northern part, in possession of the Earl of Dunmore, by Gerard Banker, scale about seven miles to one inch, familiar to all from its reprint, issued in the Centennial year, 1876, was a decided step in advance, and, although it has errors of location, amounting, in one extreme case, to twelve miles, it represents much detail and the relative positions of the various settlements, with the leading highways, and must have been of great service to the British army. It was made by the English and published in London, compiled, no doubt, from the material which Ratzer used in the previously-mentioned New York and New Jersey boundary map, with some other military and property maps of limited districts. About this time, the British officers prepared several of these military charts, covering small areas, particularly in the vicinity of New York harbor.

Our Legislature first recognized the importance of good maps in 1822, when a loan of $1,000 was made to Thomas Gordon, a surveyor conversant with the State and with existing surveys, "to enable him to obtain additional surveys, for the purpose of making a State map." Gordon's bond was afterward canceled, and 125 copies of the map subscribed for, and still later the Governor was authorized to subscribe for 125 copies more, at $1,000. Its title is, "A Map of NEW JERSEY, with part of the Adjoining States, compiled under the patronage of the Legislature of said State, by Thomas Gordon. 1828." Scale, three miles to one inch. The map was largely compiled from existing records, but some field-work must have been done, for the greatest error in latitude is but three-quarters of a mile, and in longitude five-eighths of a mile, for all places of importance. Considering the means at hand, the work was very creditably performed, and this map continued to be the only authority as to the surface

features and areas of the State until 1858. It was the basis for the geological survey by Prof. Henry Rogers, in 1836–40.

In 1854 the State began a systematic triangulation and topographical survey, which was actively prosecuted until 1856, when, the treasury having become depleted, the work was suspended.

A map of New Jersey on a scale of 2½ miles to 1 inch was published in 1860. It was compiled from all the materials available in the United States Coast Survey publications, and in the manuscript maps and records of the Geological Survey of 1854–6. The work was done by G. M. Hopkins, C.E., under the direction of Dr. William Kitchell, Superintendent of the Geological Survey, and was published by them, the State giving the use of the maps and records of all surveys made. This is an excellent map and greatly in advance of all which precede it.

The Geological Survey was resumed in 1864, and as it was found impossible to proceed without better maps, a compilation was again resorted to, but this time with increased materials to work with. The available material was found to be:

(1) A triangulation by the United States Coast Survey. The main chain of primary triangles crossed the State from northeast to southwest its entire length, and a tertiary system had been run down the Atlantic coast and up Delaware bay to Trenton.

(2) Plane-table sheets of the United States Coast Survey, extending along the entire eastern side of the State, and up Delaware bay and river to Lambertville, in a belt from 2 to 4 miles wide.

(3) Plane-table sheets of the State Survey of 1854–56, covering some 2,000 square miles of the interior.

(4) County and city maps, and various other local surveys, not entirely reliable but answering a fairly good purpose when adjusted to the foregoing work, and reduced to the small scale of 2 miles to an inch.

The result of this work was a map which, while necessarily deficient in many respects, was nevertheless a decided advance over the average State map, and has answered a very useful purpose during a period of rapid development. No doubt it was an educating influence which led up to the present undertaking.

In 1877 it was found that the geological work could proceed no farther without more satisfactory topographical delineation, and as

population was becoming dense, public works were being projected and undertaken on a rapidly-increasing scale, and questions affecting important interests, which could only be satisfactorily settled by such a survey, were constantly arising; a new and complete topographical survey was then undertaken. The coöperation of the Coast Survey was secured and the triangulation was proceeded with by that organization in advance of the topography. It was at first supposed that enough good surveys existed to allow a considerable part of the State to be compiled, but as the survey proceeded it became evident that but little really existed which could be used without affecting the accuracy of the work to a degree incommensurate with the slight saving effected thereby. It was decided to make use of only the following material:

(1) The triangulation of the U. S. Coast and Geodetic Survey, still being prosecuted in advance of the topography.

(2) Plane-table sheets of the same survey, covering about 440 square miles of the coast from the head of Barnegat bay to Townsend's inlet, and the shore line of Delaware bay and river, from Cape May to Camden.

(3) Some recent surveys of cities and towns, giving the street lines, and some of the better class of railroad surveys for alignment of roads.

Excepting the above, all of which has been carefully revised and improved, an entirely new and complete survey has been made. The triangulation has been extended by filling in the larger gaps, a total of 105 stations having thus far been located by the topographical survey.

From what has been said it may be readily seen why the maps of the State have been unreliable and insufficient. It is simply because no actual survey has ever been made. Originally compiled from disconnected, inharmonious and largely unreliable sources, they have been copied and recopied, a certain class of errors being each time increased, and many important details being necessarily omitted because no surveys including them were at hand.

Yet the condition of the maps of this State is much better than that of most of the other States. If the location of the Delaware river, the line between New Jersey and Pennsylvania, is erroneous to the extent of a mile in some places on our maps, much greater errors must exist in the maps of Pennsylvania, for the compilation there has been adjusted to our map of 1868, which was regarded an excep-

tionally reliable authority, and in New York also the only existing maps are unofficial compilations, which have been shown by the State Survey to be very erroneous.

But in the United States the topographer is beset with other difficulties than those of topography. The first question which must usually be confronted is that of cost. It must be known approximately what degree of expenditure will best meet the case in hand. On the one hand he has the scientific world, which knows well that an expenditure of $50 per square mile would be wise and profitable, but usually on the other hand he knows that no such expense will be practicable, and if attempted will only result in failure. He must therefore ascertain what rate of expenditure will be practicable and will give results sufficient for the end desired. This question of cost determines the methods which should be used, and in fact the whole plan of work, and the cost can only be fixed by deciding beforehand the material to be represented, and the limit of accuracy necessary to be attained in representation. Thus we come to the plan of the survey.

The selection of material to be represented, accuracy required and the scale of the map are interdependent. It will sometimes be necessary to fix the scale of the plot first, as, when it is desirable to represent a certain amount of country on a single sheet or in a single atlas, too large a scale will make a work so unwieldy as to impair its usefulness. On the present survey it was determined that a scale of three inches to a mile would be suitable for the original plot, and a scale of one inch to a mile for the printed map for general use. By choosing a large scale for plotting the notes and then reducing this plot by photography, increased accuracy is attained, and the original is also available for use for special maps of important districts on a larger scale when required.

The scales which give a simple relation between inches and miles seem the best for general use, for they give the larger units, in which approximate measures are always desired, directly; and it should always be remembered that, on account of the varying condition of the paper, the more exact measurements, which are desired in smaller units, should never be taken from a map by means of a detached scale, but by the scale engraved on the map. No matter what the scale of the map may be, this engraved scale may always be drawn to give any unit desired, as feet or yards. For this reason it seems ob-

jectionable to resort to scales of feet to the inch, etc., and compel the ordinary observer to divide by 5,280 to obtain his approximate measures in miles, since there is no offsetting advantage reaped by the exact measurer.

It might seem best to fix the limit of accuracy of location to be attained, and select material to be represented, and then choose that scale for the map which will be just sufficient to exhibit the results. This is not always practicable, however, and especially when the cost is limited the reverse course seems as good. It is usually as well to have the scale for plotting rather in excess of the requirements of accuracy as greater ease in plotting will result. The hundredth of an inch is about the smallest distance which can be realized in ordinary plotting; now on a scale of 1 inch to a mile this will represent 53 feet; of 2 inches to a mile, 26 feet, and of 3 inches to a mile, 18 feet. It is therefore useless to locate any portion of the topography more exact than within about 20 feet for a 3-inch scale, or about 30 feet for a 2-inch scale, but if the latter be adopted as the limit of accuracy desired, it will still be best to choose a scale of 3 inches to a mile, for then the desired accuracy can be attained by plotting to the closest fiftieth of an inch, and the draughtsman will be able to proceed more rapidly and easier.

Now in the field surveys there is often a misapprehension of what constitutes true accuracy. The survey cannot cover every one of the myriads of topographical lines with an actual traverse. The magnitude of such an undertaking is not generally understood. In the case of the present survey of New Jersey, the surveys of road-lines alone now aggregate a length of 13,000 miles, and the lines of levels about 14,000 miles, with over 600 miles more of transit lines for topography, not to speak of the many thousand miles of streams, swamp-lines and other detail traced up with the pocket compass. It may therefore be accepted as a fact, that a certain number of stations will be determined within the limits of accuracy and the intermediate detail sketched in by eye, or by pacing. A survey, then, which locates 2 stations to a square mile, within an error of 1 foot, leaving all the intermediate detail to be sketched, while it may lay claim to accuracy, and, no doubt, be allowed to be remarkably accurate by the inexperienced, is really much less accurate than one which locates 20 stations on the same area with a possible error of 30 feet. Instances are know where surveys have been made by locating

a small number of points with the precision which could by no means be realized in plotting them, and then, the means available having been nearly expended in reaching this useless refinement, the details were filled in about these points by compiling from inferior and untrustworthy maps, or by sketching. This faulty distribution of work is by no means uncommon in topography. The other question, as to what material should be represented, is also important in determining the cost. With a fixed limit to the cost of a survey, it will be found impossible to show all details of topography, nor should it be attempted to show too much, for by sacrificing the less important matter increased accuracy may be secured in delineating the remainder. Again it is easy to overcrowd maps with detail and thereby obscure important material and impair the usefulness of the work.

In the present work the material selected as most useful and sufficient for ordinary purposes, is highways and streets, railroads, streams and waterways, swamps and marshes, timber, mines, quarries, clay and marl pits, political divisions and contour lines to accurately determine the shape of the surface and its elevation.

Having determined the scale of the map, and thereby the accuracy necessary to be realized, we proceed to a choice of methods. It is believed to be a mistake to assume that because a method has shown itself to be well suited to a survey, to cost $50 per square mile, or even $20, it is equally applicable to one to cost but $5 or $10, or that any one method of surveying will prove efficient in all kinds of topography. The methods most in use are the plane-table method, the transit and chain, or compass and chain method, now nearly obsolete; and the transit and telemeter, or "tachometric method." That most in favor of late appears to be the plane-table method, for an account of which the reader is referred to the excellent treatise on "The Plane-Table and its Uses in Topographical Surveying," published in the U. S. Coast Survey Report for 1865.

The special advantages claimed for it are (1) that it enables the topographer to dispense with taking notes. This, however, is not strictly true, and far from true, where the vertical element of the survey is important. (2) The map is made in the field while the ground is under the eye of the topographer. This is true to a very limited extent, and only in open country. (3) It dispenses with the errors incident to plotting in the office with protractors, as the angles are

laid down directly in the field. There is an element of truth in this, but there are few who will claim that, as a whole, the work can be more carefully plotted in the field, under exposure to heat and cold, sun and wind, than under the more favorable conditions existing in the office; and it seems almost certain that there can be no economy in plotting in the field, often while the entire party is kept waiting, and in the time when the heavier field rate of expenditure obtains.

The objections which have been decisive in choosing the methods for the Topographical Survey of New Jersey are (1), that it is essentially a fair-weather method, and great expense is incurred through loss of time when the party is in the field in this latitude. (2) It crowds the entire work of the year into about six months, since field-work and plotting are done simultaneously; and, therefore, to accomplish a given amount of work, the force must be doubled, and this increased force must be disbanded at the close of the working season, and another, probably untrained one, organized for the next year, a process fatal to that *esprit du corps* so essential to all good work.

For a reconnoissance of mountain country, to be plotted on a small scale, or for expensive detailed surveys of open country, such as the marshes of our coast, or some portions of Northern New Jersey, it may be an excellent method, but for general application to our topography it is wholly unsuited.

The tachometric method has been well described by Mr. George J. Specht, in Van Nostrand's Engineering Magazine, Vol. 22, p. 134, and useful tables have been computed from his formula by Mr. Arthur J. Winslow, of the Second Geological Survey of Pennsylvania, which are published in a convenient form in No. 77 of Van Nostrand's Science Series. A diagram by which distances and elevations may be readily obtained accompanies Mr. J. B. Johnson's Topographical Surveying.

This method has been used with great success for surveys of important rivers, the tide-marsh, bays, creeks, channels and beaches of the coast, and wherever great precision was required, or where the method most in use was not applicable. For these surveys the wires, which are movable, are set so that the outer ones cover 1 foot at a distance of 100 feet, and the central wire, the horizontal spider line of the transit, is set exactly midway between them. For the more important work the maximum range of sights on transit points is 1,300 feet, ordinary Philadelphia leveling rods, fitted with an extra

target at the foot, being used, and the targets being set to coincide with the outer wires, if too distant for the readings to be taken with the telescope from the face of the rod. For topographical stations, the errors of location of which will not be cumulative, the targets are set to coincide with one outer and the central wire, the possible range of sight being thereby increased to 2,600 feet, allowing a belt of country a mile in width to be worked up from a single transit line, with transit stations 1,300 feet apart. In this way it is possible to run the main traverse lines with an error not exceeding 1 in 800. The cost of this work diminishes with increase of range of sight. This may be secured by using longer rods, by using wires set closer than above, or what is the same thing, using the middle and one outer wire instead of the two outer wires in reading, but always at the expense of accuracy. The latter method has been adopted for work the importance of which would not warrant the use of the shorter sight, or where frequent checks could be secured by triangulation. The practice in such cases has been to read the distance with the lower and middle wires, and repeat with the middle and upper wires, the maximum length of sight being 2,600 feet, a 13-feet rod being used. The error by this method may reach 1 in 300. The cost of field-work, using the 1,300-feet sight, has been about $15 per square mile, against $10 with the 2,600-feet sight. It not unfrequently occurs that some local circumstances compel the use of the longer sight, as in rugged mountain topography, one such instance having occured in Northern New Jersey, where the sight had to be increased to a mile in order to make any progress whatever. In such cases, where great accuracy is required, it is necessary to throw a tertiary triangulation over the area, with stations at intervals of about 3 miles.

The organization of the party for stadia surveying depends on the length of sight employed. The most economical adjustment is that which keeps the transit observer wholly employed in instrumental work and in directing the movements of the party. That usually employed in this survey is a transit-man and two topographers, each accompanied by a staff-man. If the work is on the water, a boatman will be necessary, or, if in the woods, one or two axemen. Supposing the transit to occupy a station, the transit-man selects the point which appears to be most favorable for the next instrument station (on this selection success largely depends), and a topographer is sent off on either side to sketch the topography, until he comes to a point the

location of which is desired to check his sketch, when the staff-man obtains the reading, while the topographer proceeds with his sketch. As soon as the reading is obtained, the topographer can locate himself near enough for sketching purposes by taking the direction back to the transit with his pocket compass. He then proceeds, traveling over the ground and sketching details, for 300 or 400 yards, when he again obtains his location, and thus gradually works toward the point selected for the new instrument station. The first staff-man to reach this point takes the readings for the new station, the instrument moves up and the work proceeds. The stations being all shown on the sketches, these sketches are adjusted to the accurately plotted points in the office.

It has not been found that any increase of sight over 2,600 feet has improved the economy of the work, and greater sights should not be resorted to unless unavoidable.

The above method is one which is captivating in its theory and excellent in its practice when conditions of topography are favorable and when its cost is permissible. It is applicable wherever the plane-table method is applicable, excepting for rapid reconnoissance, and, in the writer's experience, has been found more economical. It gives more accurate results for elevations, and, where the vertical element of the survey is of importance, it should always take the place of the plane-table. It is, nevertheless, open to many of the same objections as the plane-table, in actual field-work. Its cost is too great.

From what has been said, it may be inferred that the New Jersey survey has not adhered rigidly to any one method. Each has been used in its place, where it was peculiarly adapted to the circumstances, but one method has been mainly in use, and has allowed the end to be attained by a moderate expenditure. This I shall proceed to describe, giving, first, a brief outline of the method as a whole, and then taking up the various parts in turn.

The aim has been to use the simplest of the standard forms of engineering instruments and the simplest methods, as far as possible. A few special forms have suggested themselves, however, and have been adopted in the interests of economy and accuracy, as the work proceeded.

THE METHOD.

The underlying principle of this method is division of labor rather than an attempt to complete the whole survey at one operation. Its

elasticity is such that it adapts itself equally well to the pine plains of Southern New Jersey or the wooded highlands of the north.

As already noted the principal triangulation is done in advance of the topography by the United States Coast and Geodetic Survey, but for the method in use it became necessary to increase the number of points by tertiary triangulation, gaps of over 20 miles being found sometimes in the older triangulation, while an average distance of five miles from point to point has been adopted as suitable for this method. This is done by the topographer in charge, independently of other work. The instrument used for angular measurements is an excellently graduated engineer's transit of the ordinary pattern. A side of one of the Coast Survey triangles, convenient to the area to be filled in, is chosen as a base and a series of triangles with sides from 5 to 20 miles in length are selected by reconnoissance. For stations, commanding hill-tops destitute of timber, church spires, towers and other structures are selected, since the building of observatories must be avoided as too expensive. When it is impossible to accomplish this an inexpensive scaffold in the form of a tripod is erected, but thus far this has been necessary in but two cases, and then the scaffolds (with signals) were erected twenty-five feet high at a cost of about $15 each. The instrument has been set up in a great many church spires, on house roofs and like structures of ordinary stiffness, and observations of angles made successfully. In this way areas of from 400 to 700 square miles have been triangulated from a single base with no error greater than one-twentieth of a second in latitude or longitude of any point, this being determined by checking back on the Coast Survey primary triangulation. The cost of this work has ranged from 50 cents to 75 cents per square mile.

Next, a careful survey is made of all the roads of the district with odometer and compass; and, as the purpose of this survey is not merely to secure the location of the highways, but to furnish a network of reference-lines for the use of the topographer in locating his level stations and sketching topography, the aim is to secure a uniform distribution of these lines, and if highways are not sufficiently numerous for the purpose, by-roads, wood-lanes or even paths are thus surveyed. A series of lines, always readily found by the topographer, are thus secured. These lines are plotted at once by assistants in the office and from them field sketch-maps are prepared, showing the lines and all the points at which streams, railroads, etc.,

are intersected. If well done the odometer work furnishes a valuable instrumental reconnoissance for the topographers.

The topographer takes the field, accompanied by an aid, and furnished with a light Y level (Gurley's architect's), a Hutchinson prismatic compass, protractor and scale, and, if in very hilly country, an aneroid barometer and Abney clinometer are added to his outfit. He is furnished with the previously-prepared sketch-map, which has compass meridians drawn on it, and is mounted in such a form that any part of it is readily accessible, while the unused folds form the tablet on which to work. The level is provided with a specially designed range-finder attachment, by which distances less than half a mile may be determined, with an error of not more than one and one-half per cent., in less than five minutes. Thus equipped he proceeds to level over the country and sketch the shape of the surface, tracing up streams, swamp lines and all topography met with, and determining the elevation of all points necessary to show the shape of the surface, locating the more important with the range-finder, and plotting all the results on his sketch.

In the office, during the portion of the year unsuitable for field operations, the work is plotted. The triangulation is computed and the stations plotted in their true geographical positions on a projection of the earth's meridians and parallels for every minute, made on a scale of 3 inches to a mile, by the polyconic method used by the United States Coast and Geodetic Survey. These stations having been also connected with the odometer survey, that survey is next laid down, being adjusted to fit the triangulation. The sketches are then worked over and adjusted to the corrected odometer survey, all the horizontal element of the survey being laid on the map. The elevations taken from the level books are next plotted in their true positions, and, lastly, the contour lines are interpolated between these level stations by the aid of the sketches. The inking and lettering of the sheet being completed, the map is ready for the engraver. The various operations of this method may now be briefly considered singly.

THE ODOMETER SURVEY.

The odometer has been long in use in a variety of forms. Probably the most noteworthy instance was its use by Fernel, who, in 1525, rolled a wheel from Paris to Amiens to determine the length of a

degree of latitude. It has for years been used by the county map-man with poor field-work, worse plotting and no triangulation or other check to eliminate the errors. It has also had an extensive use in route surveys for running rough meander lines under circumstances where accuracy was impossible. Hence, it appears to have been lost sight of as an efficient aid to the topographer for work of a better class than the above, yet it possesses advantages peculiar to itself, and will, no doubt, in time prove indispensable whenever good surveys are desired at a moderate cost. Odometer work carefully done, with the ordinary precautions observed in other kinds of surveying, and well checked by triangulation, has proved a simple, inexpensive and very efficient method in the Topographical Survey. When so used, every change of direction is carefully taken with a small 3½-inch compass. It must be remembered that in this case the compass merely becomes a ready means of measuring angles, and ultimate direction does not depend on it. It may, in all ordinary country, be relied on within about 15 minutes, and this is quite near enough for the short courses of topography. The lines are closed in short circuits, which allows the detection of accidental errors in reading either compass or index.

One class of errors incident to ordinary odometer work are much overrated by ordinary observers, viz., those resulting from measurement along the surface instead of on a horizontal line. The levels allow a correction to be applied for this when necessary—as it rarely is—for it is to be remembered that the measurements are made along the highways, and in but one instance in the State does the grade reach 600 feet per mile, and as this is barely surmountable with an empty vehicle it will rarely occur anywhere. A grade of 600 feet gives an excess of length of 34 feet per mile; one of 400 feet, 15 feet per mile, and one of 200 feet only 3 feet per mile; but the ordinary errors of the odometer from slipping are more than enough to neutralize any of these, and it therefore not unfrequently occurs that the best results are reached in hilly country. The ordinary error of a large number of comparisons of odometer work with triangulation, measured on the odometer plot and including the error of plotting, a number of short courses has been ascertained to be, in level country, 1 in 125 with the ordinary barrow odometer in use until the present season. It is believed that this error can be considerably reduced by improved construction. Being invariably in one direction it is easily rectified by distributing the error uniformly throughout the runs.

A two-wheeled odometer was constructed and used on the survey during the last summer. The form presented many advantages, such as greater stiffness, greater ease of operating and more reliable recording than the barrow form, but no opportunity for thoroughly testing the results has yet occurred. Although the barrow form is very objectionable in some respects it is probable that it will prove best for some kinds of topography.

The value of the odometer survey as a reconnoissance is so great that the small expense necessary to make it would probably be repaid even should other methods be thought necessary in working up the details of topography, but as used, it is a convenient and rapid means of obtaining the location of about $2\frac{1}{2}$ miles of lines per square mile of territory with sufficient accuracy for the scale used. One recorder can run at least 10 miles of lines daily.

Plotting the odometer work was at first a tedious labor and a drawback to the method, as an ordinary day's run embraces about 200 courses and distances. The substitution of a specially-devised protractor, which combined parallel rules, scale and angle protractor in one instrument, greatly lessened the labor; probably to the extent of one-third, at least.

LEVELING.

This constitutes a large part of the work of a survey made by this method. It is the most accurate known method for ascertaining elevations, the vertical element is therefore more than usually reliable.

In leveling for topography the observer's attention is so largely taken up with studying the ground and sketching, that it is impossible to secure the highest grade of accuracy in leveling, especially since, in order to make suitable progress with the topography, the work must be hurried. It therefore becomes expedient to cover the area with a system of carefully leveled primary lines, which serve as a basis for the topographical levels. These primary lines are run in closed circuits of about 100 miles, and carefully checked. The equipment in use is a 15-inch Y level, and, for the more important lines, a New York rod with target, although a self-reading Philadelphia rod has been also used with slightly inferior results. The rate of running is about 4 miles per day, and thus far with the New York rod and target, reading to .001 foot the error has not exceeded the square root of distance in miles $\times .02$ feet, and very long lines have been

leveled with an error of the square root of the distance in miles $\times .005$ feet. The greatest error with the self-reading rod, read to nearest .005 feet, was equal to the square root of the distance in miles $\times .03$ feet. These lines are permanently monumented on the plan described in the report of operations of the survey for 1885, and frequent temporary bench-marks on trees, buildings, etc., are left for the use of the topographers.

The equipment for topographical leveling is a light Y level, with 11-inch telescope and a self-reading rod, which is read to .01 foot. The lines are closed in short circuits of from five to ten miles, and any accidental errors are thus detected. It is possible to close the five-mile circuits when moving about five miles per day, and sketching topography with an error not exceeding 0.25 feet. Supposing the instrument to be in good order, which should be made certain by a most rigid examination by the observer, the precautions most strictly observed are to keep it in good adjustment; to always read the bubble after reading the rod, and if it has moved from the center to repeat the reading, to carefully equalize fore and back sights, and to provide solid supports for the leveling-rod. An ordinary iron spike, driven firmly, is mostly used for the last purpose.

SKETCHING TOPOGRAPHY.

This is an important feature of all topographical work. To do it well requires no mean skill. The faithful representation of forms so intricate and of so vast size as those which form the subject of the topographer's sketch, requires a minuteness and scope of observation unknown to any other kind of sketching. Topography is, in truth, both a science and an art. A trained and accurate eye and a hand schooled to follow its direction are essentials to success. At every glance he must gather some knowledge of his model; he can only see a limited part of it at once, and his mind must retain these separate parts and blend them in one harmonious sketch, with each occupying its relative size and position. More than this, his subject will deceive him unless he learns to guard against it. He sees a hill of intricate form, and may think he sees its true profile, but it is only the line of tangency of the visual cone whose vertex is his eye; the form changes at every change of the point of sight, and it is only by retaining them all and utilizing them in his sketch that he can represent the true form.

The perspective makes some distances appear greater than other equal distances; the state of the atmosphere makes a distance appear greater at one time and less at another; the surroundings, particularly the background, have the effect of increasing or decreasing the apparent steepness of slopes, or may even make a descending slope appear to ascend. Thus, nature herself seems to oppose him, and only long experience will arm him against these deceptions.

Equipped, as previously described, the topographer proceeds to level over the surface and trace its form. In moderately level country he usually traces the actual contours at once, ten feet apart, working up his level notes as he goes, and studying the relative heights of the ground as he proceeds. In hilly country he does not attempt to sketch actual contours, but only close approximate contours showing the direction which the true contours should take. The latter are afterward worked in from the elevations.

The level is kept swinging around the horizon, and is a great aid in sketching. When he finds that the level-plane just cuts some neighboring point, the elevation of which is desired, the topographer notes the fact, and when convenient, locates the point on his sketch. Nearly all the roads are leveled over, not because they are of special importance, but because they furnish convenient avenues by which to reach all parts of the district under survey. When it is necessary, in order to obtain the elevation of important points of the topography, side runs are made to such points. The principal points of the surface to be represented may be enumerated briefly as (1) summits or peaks, from which the ground descends on all sides, (2) passes, gaps or saddles, from which the ground ascends in two opposite directions and descends in the other two directions. (1) and (2) occur alternately along ridge lines. A special and very important case of (2) is the *divide* in a valley where its drainage turns in opposite directions. The above two classes of points are indispensable to an accurate knowledge of a surface. (4) Lowest points of depressions, such as craters or sinks. This class of points is common along the glacial moraine which crosses New Jersey from Belvidere to Amboy. (5) Points of change in the inclination of slopes, such as the brow of a plateau, the foot of an escarpment, the front or rear of a terrace on a hillside, the head or foot of the rapids in a stream. As no rule can be given to cover all cases, the judgment of the field topographer must be exercised in determining how many of these latter points are worth leveling to, and which

may be safely left to the eye and sketch; but on the number actually determined, both in position and elevation, will depend the faithfulness of representation.

In the mountainous portions of the State, where a great amount of leveling and undue expenditure of time would have been required to determine all these minor points in this way, a small aneroid was used for the less important ones. The method of using it was to take its reading at the instrument where the elevation was known, then to proceed to the point desired, and after sketching the surroundings, to read again, and on returning to the instrument read a third time. In this way, when the interval did not exceed about an hour, the difference of elevation was usually determined within 10 feet.

These points, as previously remarked, may be located by the range-finder, where a clear line of sight can be secured to any point of the road-lines already plotted on the sketch-map, or, as the distance of any of them from a road very rarely exceeds half a mile, an accurate pacer can step a random to them through the timber with sufficient accuracy for all purposes. The range-finder in use is constructed on the principle employed in the Pratt instrument, but utilizes the pointing power of the level telescope, and is much more accurate. A pair of sights are attached to the top of the telescope, at an angle with its collimation of 87° .8′. The telescope, at the point A, is set with its vertical wire on the object, C, to be located. The rod-man is sent off on the line indicated by the sights, with a right-angle mirror, to some point B, where the image of the sights coincides with the image of the object C. A B C is then a right-angled triangle, with A C equal to twenty times A B, the distance from instrument to rod. The rod-man having carefully ascertained the point B, holds his rod there, the telescope is revolved and the distance A B read with the stadia wires, with which the levels are provided, and multiplied by 20 for the required distance A C.

In hilly country, it is possible for a topographer to greatly economize his work with no falling off in results. To do this effectually, he must be able to predict, by inference from his surroundings, what topography will be found ahead of him. Close observation will soon enable him to do this with remarkable accuracy, and he will thus be able to approach every point in the most direct and easiest way. He will not be caught leveling through the timber up a slope 1,000 feet high, to obtain the elevation which he might obtain later from the

top of the plateau, with one-twentieth of the labor; or, if compelled to level to the summit of a peak, he will do so from a side which commands the neighboring elevations, each of which he will obtain as he raises the plane of his instrument to its height, thus saving, perhaps, days of labor.

The power of foreseeing the outcome of certain topographical conditions will also enable the surveyor to give increased fidelity and expression to his sketches.

The prepared sketch maps, showing the routes of travel and approximate drainage lines, are a great aid to the exercise of this power. They also allow the topographer to approximately locate any notable feature of the surface as soon as it comes into view, although still some miles distant, and thus to study its form and relations to surrounding topography more satisfactorily and intelligently than would otherwise be possible. The advantage of sketching in this connected way, on a map of some extent, over-sketching detached parts in a sketch-book and afterwards joining them together, is very great.

All sketches are made on the scale of the final plot, 3 inches to a mile. The supposed advantage of sketching on a larger scale and afterward reducing has been found to be more than neutralized by the errors incident to reducing the sketches a considerable amount. So far as possible, one scale is used throughout for sketching, as the topographer soon learns to think in this scale, so to speak. A distance comes to represent not so many yards and feet, but so many inches or parts, corresponding to the scale of the sketch.

Sketching from too great distances is not safe, as the illusions of perspective rapidly increase with the distance, and the topographer is expected to travel over and inspect the surface at short range. The stations at which elevations are determined are indicated on the sketch by a small cross with a station number corresponding with a number opposite the elevation in the level-book.

By means of the above method of surveying, topographical maps have been secured at the following cost for field-work and plotting, not including expenses of organization and general superintendence, the topography being classified to correspond with the geological formations: Archæan and Paleozoic topography, $7.80 per square mile; Triassic, Cretaceous and Tertiary topography, $6.12 per square mile, and it is not expected that the average cost per square mile for the entire State will exceed $6.50.

CONCLUSION.

There remains now the pleasing work of showing that the surveys have accomplished the ends for which they were designed. 1. To encourage our people to remain in New Jersey and not emigrate. 2. To develop our agricultural resources. 3. To explore and utilize our mineral wealth. 4. To improve our advantages for manufactures. 5. To publish our remarkable means of communication, advantages in location, climate, and its salubrity.

POPULATION.

There were a few scattered settlers in New Jersey before 1664, when the English took possession of it. The increase of its population from that time on to 1790 is only to be gathered from incidental records and estimates. The following, however, is probably the nearest that can at present be given:

Year.	Population.	
1664	2,500	estimate; East Jersey under the Proprietors.
1682	6,000	estimate; East Jersey under the Proprietors.
1693	10,000	estimate; East Jersey under the Proprietors.
1700	10,000	estimate by Governor Hamilton.
1726	32,442	New Jersey Archives, Vol. 5, p. 164.
1737	47,369	Smith's History of New Jersey.
1745	61,403	Smith's History of New Jersey.
1755	109,000	estimate by Smith.
1776	150,000	estimate.

In 1790 the census was taken by the general government, and has been taken every ten years since. A census was taken by the State government in 1855, and this also has been taken every ten years since.

Years.	Population.	Percentage of increase each 10 yrs.
1790	184,139	.....
1800	211,149	14.6
1810	245,562	16.2
1820	277,426	12.9
1830	320,823	15.6
1840	373,306	16.4
1850	489,555	31.1
1855	569,499	....
1860	672,035	37.2
1865	773,700	.....
1870	906,096	34.8
1875	1,020,584	.....
1880	1,131,116	24.8
1885	1,278,102	.....

An inspection of this table, both in the column of population and in that of percentages, shows a rapid increase since 1840, and also that the rate of increase has been greatly enlarged since that time. But this will appear more plainly when the rate of increase in New Jersey is compared with the rates in the States immediately around it, and with the increase in the whole United States.

PERCENTAGE OF INCREASE OF POPULATION AT THE SEVERAL DECENNIAL PERIODS.

	1790 to 1800.	1800 to 1810.	1810 to 1820.	1820 to 1830.	1830 to 1840.	1840 to 1850.	1850 to 1860.	1860 to 1870	1870 to 1880.
Massachusetts	11.6	11.6	10.8	16.6	20.8	34.8	23.7	18.3	22.3
Connecticut...	5.4	4.3	5.0	8.1	4.1	19.6	24.0	16.8	15.8
New York	73.1	62.8	43.0	39.8	26.5	27.5	25.2	12.9	15.9
New Jersey.....	14.6	16.2	12.9	15.6	16.3	31.1	37.2	34.8	24.8
Pennsylvania..	38.6	34.4	29.3	28.7	27.8	34.0	25.7	21.1	21.6
Delaware.....	8.7	13.0	0.1	5.4	1.7	17.2	22.5	11.4	17.2
Maryland.....	6.8	11.4	7.0	9.7	5.1	24.0	17.8	13.6	19.7
United States..	35.0	36.4	33.1	33.5	32.7	35.9	35.6	22.6	30.1

The conclusion, necessarily reached by a comparison of these records, is that for the last thirty years New Jersey has increased in population at a more rapid rate than any of the adjacent States which are in somewhat similar circumstances, and that its rate of increase does not now differ materially from the rate of the whole United States. And we also conclude that the State is not losing by emigration.

AGRICULTURAL DEVELOPMENT.

New Jersey was settled as an agricultural State, and all the land within its bounds, which was thought to be worth farming without first enriching it, was cleared at an early day. In 1833 Gordon estimated that 76 per cent. of all the land in the State was in farms. In

the census of 1880 the amount of lands in farms is only 60 per cent. of the area of the State. But as this does not include the lands occupied by cities, towns and villages, or house-plots of less than three acres, it is plain that no close comparison can be made. But generally it may be considered that the whole amount of cleared land has not varied much in the last fifty years. In some of the northern counties it has diminished, and in some southern counties it has increased largely. But the value of the lands in farms has increased to a remarkable extent, and its estimated value per acre is greater than in any of the adjacent States; and this relative value it has maintained now for several decades.

VALUATION OF FARMS PER ACRE, COMPUTED FROM THE UNITED STATES CENSUS REPORTS OF 1880.

Massachusetts	$43 52
Connecticut	49 34
New York	44 45
New Jersey	65 36
Pennsylvania	49 65
Delaware	33 74
Maryland	32 32

In the stock on the farms there has been a notable increase:

	1830. Number.	1850. Number.	1880. Number.
Horses and mules	53,865	67,044	97,147
Cattle	122,805	211,261	223,886
Sheep	.....	160,488	177,020
Swine	.....	250,370	219,069

Farm products:

	Bushels.	Bushels.
Indian corn	8,759,804	11,150,705
Wheat	1,601,190	1,901,739
Rye	1,255,578	949,064
Oats	3,378,063	3,710,063
Potatoes	3,207,236	3,563,793
Sweet potatoes	508,015	2,086,731
	Tons.	**Tons.**
Hay	435,950	518,990
		Values.
Market gardens		$1,841,863
Orchard products		860,000

MINING STATISTICS.

		Tons.
1833.	Iron ore mined yearly	20,000
	Zinc ore mined yearly	none.

		Tons.	Value.
1830.	Iron ore	20,000	$657,000

1880.	Iron ore	754,872	2,900,442
	Zinc ore	39,381	451,070
	Minor minerals	33,828	40,270
	Total value		$3,391,782

	Value.
Building stone	$514,420

MANUFACTURES.

The following statistics, taken from Gordon's History of New Jersey, are estimates made in 1833, and are probably the best that can be got at this time. They are very incomplete, as there was no public provision for collecting statistics of manufactures at that time:

	Yearly Product.
Iron manufactures	$1,000,000
Glass manufactures	440,000
Delf ware	50,000
Woolen manufactures	250,000
Cotton manufactures	1,733,721

It is probable that the value of all the manufactures of the State at that time did not exceed $5,000,000 or $6,000,000 a year.

Of the manufactures above enumerated, the products for the year 1880 were:

Iron manufactures	$10,341,896
Glass manufactures	2,810,170
Pottery manufactures	3,030,000
Woolen manufactures	5,008,907
Cotton manufactures	4,548,275

But the growth of manufactures in the State is better shown by the statistics of manufactures, as published in the United States census reports for 1850, 1860, 1870 and 1880:

	Capital.	Annual Product.
1850	$22,293,258	$39,851,256
1860	40,521,048	76,306,104
1870	79,606,719	169,237,732
1880	106,226,593	254,380,236

RAILROADS.

The miles of railroad in the State are 1,918, which is 1 mile for every 3 $\frac{95}{100}$ square miles in the State. This represents the greatest number of miles of railroad, in relation to the area of the State, of any in the Union.

Table showing comparison of railroad facilities to a square mile of territory, and square miles of territory to 1 mile of railroad:

	One square mile of territory to—	One mile of railroad to—
New Jersey	0.253 miles R. R.	3 95 sq. miles of Tert'y.
Massachusetts	0.245 " "	4.08 " "
New England States	0.096 " "	10.43 " "
New York, Pennsylvania, Delaware, Maryland, Ohio, Indiana, Michigan, New Jersey, District of Columbia	0.114 " "	8.78 " "

CANALS.

There are 158 miles of canals in the State.

In concluding this account of the condition of New Jersey, at the present time, it may be stated, in short, that while she is the

35th State in size, she is the
19th in population,
25th in value of agricultural products,
6th in products of manufacture,
7th in products of mines,
8th in valuation of real and personal property,
1st in means of communication by railroads, roads and canals.

Many circumstances have contributed to favor this singularly rapid increase in population and wealth. It is situated between the two great cities of the continent, and has the advantages of the markets in both. Its soil is specially well adapted to garden and fruit culture, and to high farming. Its numerous and rich mines are so near

to the great markets that they offer special attractions for working. Its facilities for transport render it peculiarly favorable for the location of manufacturing establishments. Its climate is mild and healthy at all seasons, and its long line of seashore offers a standing and attractive invitation to throngs of people to come and find relief from the summer heat of the crowded cities and towns.

The policy of the State in describing and publishing its natural resources and advantages in this survey, is justified by the prosperity which has attended it from the beginning. And while it is not to be supposed that this is the chief cause of its prosperity, it may safely be said that it has done its share, and that the liberal course pursued in sustaining the survey, distributing its reports freely among the people, has had a material influence in supplying information and quickening enterprise.

V.

MISCELLANEOUS PAPERS.

PUBLICATIONS OF THE SURVEY.

THE ANNUAL REPORTS OF THE STATE GEOLOGIST are printed by order of the Legislature, and as part of the legislative documents. They are distributed largely by the members of the two houses. Extra copies are supplied to the Managers of the Geological Survey and the State Geologist, who distribute them to libraries, public institutions, and, as far as possible, to any who may be interested in the subjects of which the report treats. Most of the reports of former years have been distributed, and the editions are exhausted.

THE REPORT ON FIRE AND POTTERS' CLAYS OF NEW JERSEY has been widely distributed. Of the copies which were left, most of them were lost in the burning of the State House, last winter, and but few copies are remaining.

THE PRELIMINARY CATALOGUE OF THE PLANTS of the State has been generally distributed among botanists, so as to get in return reports of the localities of plants, and to thus have the assistance of botanists in making a *complete* list of all our plants. The revision is going on; several new plants have been discovered during the last year, and many new localities of well-known plants have also been found. A few copies of this preliminary catalogue are still on hand, and the coöperation of botanists in getting new species is earnestly solicited. It will be one or possibly two years before the revised edition will be completed so as to be published.

A TOPOGRAPHICAL MAP OF A PART OF NORTHERN NEW JERSEY, on a scale of one mile to an inch, is printed, and has been distributed to some extent. 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, etc.

THE ATLAS OF NEW JERSEY is now in course of preparation, and several sheets are done. These sheets are each 27 by 37 inches, including margin, and are intended to fold once across, making the leaves of the atlas 18½ by 27 inches. The completed work will be made up of seventeen of these maps, on a scale of 1 mile to the inch, and one map of the whole State, on a scale of 5 miles to the inch. The location and number of each map is given on the reference map, on page 11 of this report, and is printed on the paper cover of the atlas. Numbers 2, 3, 4, 6, 7 and 16 are done, and numbers 1, 9, 13 and 17 will be ready in March, 1886. The other numbers will be issued, probably, in 1887 and '88.

The following is a list of the titles of the sheets, with their numbers:

NEW JERSEY STATE MAP. Scale, 5 miles to an inch.

No. 1. Kittatinny Valley and Mountain, from Hope to the State line.

No. 2. Southwestern Highlands, with the southwest part of Kittatinny valley.

No. 3. Central Highlands, including all of Morris county west of Boonton, and Sussex south and east of Newton.

No. 4. Northeastern Highlands, including the country lying between Deckertown, Dover, Paterson and Suffern.

No. 5. Vicinity of Flemington, the country from Somerville and Princeton, westward to the Delaware.

No. 6. The Valley of the Passaic, with the country eastward to Newark and southward to the Raritan river.

No. 7. The Counties of Bergen, Hudson and Essex, with parts of Passaic and Union.

No. 8. Vicinity of Trenton, from New Brunswick to Bordentown.

No. 9. Monmouth Shore, with the interior from Metuchen to Lakewood.

No. 10. Vicinity of Salem, from Swedesboro and Bridgeton, westward to the Delaware.

No. 11. Vicinity of Camden, to Burlington, Winslow and Swedesboro.

No. 12. Vicinity of Mount Holly, from Bordentown and Burlington, southward to Winslow.

No. 13. Vicinity of Barnegat Bay, with the greater part of Ocean county.

No. 14. Vicinity of Bridgeton, including the country from Alloways town and Vineland, southward to the Delaware Bay Shore.

No. 15. Southern Interior, the country lying between Atco, Millville and Egg Harbor City.

No. 16. Egg Harbor and Vicinity, including the Atlantic Shore from Barnegat to Great Egg Harbor.

No. 17. Cape May, with the country westward to Maurice River.

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 was printed with the annual report of 1882, and was corrected up to that date, had some corrections in railroads, some minor improvements in the geological coloring, and much was added in new places along the sea-shore, and the life-saving stations were all located. A few copies are still on hand.

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 distributions of its collections, reports, &c. 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.

EXPENSES.

The annual appropriation of $8,000 a year has been sufficient to meet the expenses, and all bills are paid in full to date.

The expense of topographical surveys paid by the United States Geological Survey was:

From July 16th, 1884, to December 31st, 1884.....	$5,208 85
From January 1st, 1885, to December 31st, 1885.....	10,385 53
Appropriated for the survey from December 31st, 1885, to June 30th, 1886.....	5,597 24
Total from United States Geological Survey.....	$21,191 62

The expense of the Geodetic Survey, which is paid by the United States Coast and Geodetic Survey, is, for the fiscal year July 1st, 1885, to June 30th, 1886, $2,000.00, and the total expense for that survey since 1875, which has been paid by the United States Coast and Geodetic Survey, is $21,379.76.

PERSONS EMPLOYED.

My own time and attention has been given to keeping the survey, in all its departments, in operation. The triangulation, the topography, the works of drainage, the questions of water-supply, the agricultural improvement of our lands, the progress of our mining, quarrying and other industries of like character, demand attention, and the systematic resurvey of the geology of the State, with the aid of our completed topographic maps has been begun.

PROF. JOHN C. SMOCK, who has been the faithful and efficient Assistant Geologist since the resumption of the survey in 1864, continued in the service of the survey for a few weeks at the beginning of the year, when he left to accept an appointment at the Museum of Natural History, of New York State, in Albany, and to take charge of the Economic Geology of that State.

DR. NAT. L. BRITTON, of Columbia College School of Mines, has been engaged in surveying and constructing a series of sections across the Archæan rocks of the Highlands, and in collecting the characteristic rocks. This service was begun the first of June, and with some interruptions is continued to the present time. He still has the revision of the New Jersey Flora in hand.

MR. FRED. J. H. MERRILL, PH.B., was engaged with Dr. Britton in constructing the cross sections of the Highlands, and in the latter part of the season has been occupied in examining the geological features of the Atlantic coast of the State from Sandy Hook to

Cape May, in collecting the statistics of iron production in New Jersey and in some general work.

PROF. R. P. WHITFIELD is still engaged in figuring and describing the Cretaceous invertebrate fossils of New Jersey, and for the last season has been occupied with the Gasteropoda.

DR. J. S. NEWBERRY has continued his paleontological work of describing and figuring the fossil flora of the Triassic and Cretaceous periods, and the fishes of the Triassic.

MR. C. CLARKSON VERMEULE, Topographer in Charge, has been prosecuting the Topographical Survey steadily throughout the year. He has been aided by the following assistants:

MR. FREDERICK W. BENNETT, Assistant Topographer, has been engaged in running primary levels, and leveling and sketching for topography. He has also had charge of the transit parties at Sandy Hook and along the Delaware river.

MR. PHILIP H. BEVIER, Assistant Topographer, has been principally occupied with setting bench-marks and running primary levels along the coast.

MR. WILLIAM H. LUSTER, JR., Assistant Topographer, was employed in surveying roads until July. Since then he has been leveling and sketching for topography.

MR. CYRUS F. SPROUL, Assistant Topographer, was employed in the office until October 8th, and has since been leveling and sketching for topography.

MR. PETER D. STAATS, Assistant Topographer, has been engaged in surveying roads during the early part of the season, and later in leveling and sketching for topography.

MR. GEORGE HILL, Assistant Topographer, was engaged in leveling and sketching topography until the date of his resignation, November 1st.

All of the above assistants, except Mr. Bevier, were on duty in the office, mapping, until May 1st.

MR. ASHER ATKINSON, Odometer Recorder, has been surveying roads since July 1st.

MR. WILLIAM F. MARVIN, Odometer Recorder, has been employed as draughtsman, rodman, and later in the season in surveying roads.

MESSRS. JOHN E. HILL, FRANK VAN BRAKLE, GEORGE E. JENKINS and WILLIAM H. BARNES, have been occupied with mapping, furnishing necessary data to the field topographers, and other office duties during portions of the year.

MESSRS. JOHN G. TAIT, JOSEPH B. REYNOLDS, GEORGE G. EARL, LEAMING M. RICE, JR., HARRY S. SPROUL, HARRY J. SHERMAN, and THOMAS T. WATSON, have been employed as field aids during the season.

STATISTICS OF IRON AND ZINC ORES.

IRON ORE.

The output of the iron mines of the State for the year 1885, as shown by the shipments of iron-ore from stations in the State and the amounts used at furnaces which do not come in the tonnage of the railroad lines, aggregated 330,000 tons—a deficit of 63,710 tons as compared with the production of 1884. For the convenience of reference the statistics of iron-ore mined in the State for the years 1870–1885, inclusive, are here inserted in a tabular form. Estimates and U. S. census figures at intervals back to 1790 are also given at the head of the column :

1790.....	10,000 tons.....	Morse's estimate.
1830	20,000 tons	Gordon's Gazetteer.
1855.....	100,000 tons.....	Dr. Kitchell's estimate.
1860.....	164,900 tons	U. S. census.
1864...	226,000 tons.....	Annual Report State Geologist.
1867.....	275,067 tons.....	" " "
1870.....	362,636 tons.....	U. S. census.
1871.....	450,000 tons.....	Annual Report State Geologist.
1872.....	600,000 tons.....	" " "
1873.....	665,000 tons.....	" " "
1874.....	525,000 tons.....	" " "
1875.....	390,000 tons.....	" " "
1876.....	285,000 tons*	
1877.....	315,000 tons*	

* From statistics collected later.

1878	409,674 tons	Annual Report	State	Geologist.
1879	488,028 tons	"	"	"
1880	745,000 tons	"	"	"
1881	737,052 tons	"	"	"
1882	932,762 tons	"	"	"
1883	521,416 tons	"	"	"
1884	393,710 tons	"	"	"
1885	330,000 tons	"	"	"

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

ZINC ORE.

The product of the zinc mines for the year 1885, as shown by the shipments over the transporting lines, was 38,526 tons.

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

	Estimated tons.			
1868	25,000	Annual Report	State	Geologist.
1869				
1870				
1871	22,000	"	"	"
1872				
1873	17,500	"	"	"
1874	13,500	"	"	"
1875				
1876				
1877				
1878	14,467	"	"	"
1879	21,937	"	"	"
1880	28,311	"	"	"
1881	49.178	"	"	"
1882	40,138	"	"	"
1883	56,085	"	"	"
1884	40,094	"	"	"
1885	38,526	"	"	"

ERRATA.

COMPARISON OF TIDES—ADDENDA.

Page 35, table. Later and fuller information from the office of the United States Coast and Geodetic Survey gives as the result for elevation of tides at Cape May Landing, instead of the figures followed by interrogation marks in the table, the following: 2.05, –0.15, –2.35, showing a difference of fifteen-hundredths of a foot between mean-tide at Sandy Hook and at Cape May. These figures are obtained from a series of tidal observations covering only six high and eight low waters in August and September, and a longer series would probably still further reduce the difference.

Page 13, table. Figures after Ocean View should read 17,677, 17,628, —.049.

CONTENTS.

INDEX.

C.

H.

I.

J.

K.

L.

D.

E.

F.

G.

M.

N.

O.

P.

Z.