GEOLOGICAL SURVEY OF NEW JERSEY

ANNUAL REPORT

OF THE

STATE GEOLOGIST

For the Year 1901

TRENTON, N. J.:
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1902.

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I. Congressional District.

CLEMENT H. SINNICKSON, ... Salem.
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II. Congressional District.

EDWARD C. STOKES, ... Millville.
EMMOR ROBERTS, ... Moorestown.

III. Congressional District.

HENRY S. LITTLE, ... Matawan.
M. D. VALENTINE, ... Woodbridge.

IV. Congressional District.

WASHINGTON A. ROEBLING, ... Trenton.
*WILLIAM J. TAYLOR, ... Bound Brook.

V. Congressional District.

FREDERICK A. CANFIELD, ... Dover.
ERNEST R. ACKERMAN, ... Plainfield.

VI. Congressional District.

GEORGE W. WHEELER, ... Hackensack.
WILLIAM F. HALL, ... Pompton Lakes.

VII. Congressional District.

WENDELL P. GARRISON, ... Orange.
*HERBERT M. LLOYD, ... Montclair.

VIII. Congressional District.

FREDERIC W. STEVENS, ... Newark.
*HARRISON VAN DUYNE, ... Newark.

IX. Congressional District.

†LEBBEUS B. WARD, ...
VACANCY, ...

X. Congressional District.

S. BAYARD DOD, ...HOBOKEN.
*JOSEPH D. BEDLE, ...JERSEY CITY.

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* Elected to membership on the Board January 10, 1902.
† Died July 3, 1901.

To His Excellency Foster M. Voorhees, Governor of the State of New Jersey and ex-officio President of the Board of Managers of the Geological Survey:

SIR—I have the honor to submit the annual report of the Geological Survey for the year 1901.

Yours respectfully,

HENRY B. KÜMMEL,

Acting State Geologist.

TRENTON, N. J., November 30th, 1901.

ADMINISTRATIVE REPORT.

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ANNUAL REPORT OF THE STATE GEOLOGIST FOR 1901.

ERRATA.

Page 136, 8th line from bottom, read .7 instead of 7.
Page 144, 8th line from top, read .09 instead of 9.

Administrative Report.

HENRY B. KÜMMEL, ACTING STATE GEOLOGIST.

The resignation of Professor John C. Smock as State Geologist, which was presented to the Board of Managers October 30th, 1900, was accepted on May 22d following, and took effect July 1st. By resolution of the Board, the Assistant State Geologist was placed in charge of the work of the Survey pending the appointment of a State Geologist. The accompanying report therefore covers the work done under Mr. Smock's direction from the beginning of the year to July 1st, and under my direction from that date to the close of the year.

The work of the Survey has been along the same general lines as in previous years. Mr. C. C. Vermeule has continued to act as consulting topographer and has had charge of the topographic work. Prof. R. D. Salisbury has had charge of the Surface Geology; Mr. Stuart Weller of the paleontological work; Mr. Lewis Woolman of the artesian well records, and Prof. William S. Myers of the chemical work. Prof. Heinrich Ries has been engaged to prepare a report upon the clay and clay industries of the State. Correspondence, distribution of the publications and sale of maps, in addition to other administrative duties, have taken a portion of the time of the Assistant State Geologist. Revision of manuscript and reading of proof in connection with the Report for 1900 occupied much of his time during the early part of the year. Later the preparation of the exhibit for the Pan-American Exposition and its installation at Buffalo demanded his attention. From July 6th to October 26th he was engaged in field work on the Paleozoic formations of the northern part of the State and on the Cretaceous clays of Middlesex county. Mr.

Hatfield Smith, general assistant, and Miss Laura Lee, stenographer, have given efficient service.

TOPOGRAPHIC WORK.

The topographic work has been in charge of Mr. C. C. Vermeule, who continues to act as Consulting Topographer and Engineer of the Survey. He has been assisted by Mr. Peter D. Staats in the field and Mr. J. R. Prince and Mr. William A. Coriell in the office.

During the past year the field work of the topographic survey has included some reviewing and perfecting of the Morristown and Atlantic City sheets which were mainly surveyed in the previous year. The Trenton sheet, Shark River sheet and east half of the New Brunswick sheet have been surveyed and some work has been done upon the South River and Matawan sheets. The number of square miles surveyed during the year was 220, making a total of 1,263 square miles of land surface re-surveyed for the large scale maps up to date.

In the office the following map-sheets were drawn and made ready for the printer: Amboy (completed), Long Branch, Navesink, Morristown, New York Bay and Atlantic City (except for the addition of some data from the U. S. Coast Survey). Considerable progress has also been made upon the Trenton sheet. The sheets drawn during the year cover about 240 square miles of land surface.

During the year the following sheets were published: Mount Holly, Woodbury, Taunton, Amboy, Navesink and Long Branch, making a total of thirteen with those previously issued, and covering 906 square miles of land surface. The following summary indicates the progress of the work upon the new sheets to date:

Sheets published, 13.

Sheets surveyed and drawn but not published, 3.

Sheets surveyed but not drawn, 2 (complete), 3 (in part).

Miscellaneous work such as furnishing working maps for the field geologists, the preparation of illustrations for the Annual

Report, revision of printed maps and reading of proof sheets have occupied a part of the time of this division of the Survey.

In connection with the exhibit of the Geological Survey at the Pan-American Exposition at Buffalo a series of large-scale relief maps or models of parts of the State were made. The preparation of four of these under the direction of Mr. Vermeule occupied the attention of Messrs. Staats and Coriell until late in June, and necessitated the cessation of the topographic work proper. The cost of this work was of course defrayed from the sum allotted to the Survey by the Pan-American Commissioners and was not paid from the regular Survey appropriation. In spite, however, of this interruption, the regular topographic work has proceeded as rapidly as the funds of the Survey would permit.

SURFACE GEOLOGY.

The work on the Surface Geology has continued under the charge of Prof. R. D. Salisbury, who was assisted by Mr. G. N. Knapp and Mr. C. E. Peet. Mr. Salisbury has given the Survey in all sixty-six days of service. The larger portion of this was spent in work upon his final report on the Surface Formations of the northern part of the State. The report is well advanced towards completion, and the State Board of Printing has arranged for its publication during the coming year. In connection with that work it was found necssary to review the field work over a portion of the area described. Mr. Salisbury spent a few days in this work, and later Mr. Peet gave several weeks to it. The result of this review has been to increase greatly our knowledge of the stages in the retreat of the ice-sheet across northeastern New Jersey.

In the southern half of the State the interpretation and mapping of certain formations was questioned by geologists who had examined similar formations in adjoining States to the south. Mr. Salisbury, therefore, spent some time in the field in reexamining these problems, and toward the close of the year he was assisted in this work by Mr. Knapp.

The cartographic representation of the results of study on the Surface Formations has been the subject of much consideration.

Several plans have been proposed and rejected. A start was made several years ago by the publication of a map of the glacial formations of the upper Passaic valley, using sheet 6 of the older series of maps as a base. This map accompanied the Annual Report for 1894 and was distributed with that volume. The results, however were not altogether satisfactory, and no further sheets were issued. It has been contemplated that the new large-scale maps would be used as a base for the geologic maps. In accordance with this plan four sheets are in preparation for the printer, *i. e.*, Newark, Jersey City, Camden and Woodbury, and they will be published as rapidly as the necessary funds can be obtained. Each map will be accompanied by a brief descriptive pamphlet explanatory of the map and of the formations represented. Mr. Salisbury and Mr. Knapp have each given a part of their time both in the field and office to the preparation of these sheets.

Mr. Knapp has rendered service to the Survey for about one hundred and fifty days during the year. Two-thirds of this has been office work, compiling data from his field notes of previous years, and preparing permanent office copies of his field-maps. His field work has already been alluded to.

Mr. Peet has spent fifty-nine days in the service of the Survey, forty-three days in the field, the remainder in office work. Under Mr. Salisbury's direction he has reviewed some of the glacial phenomena in Bergen and Passaic counties. His office work has been limited to the compilation of this data.

PALEONTOLOGY.

The paleontological work has continued in charge of Dr. Stuart Weller, who has rendered service for a total of one hundred and twelve days. All but twenty-three days of this represent office work in the preparation of his report of progress published in the last Annual Report and in the study and description of the fossils already collected by him. The final results of this study are not yet ready for publication, but preliminary papers have been published in the Annual Reports of 1889 and 1900.

During July, August and September Dr. Weller was relieved of his work for the State Survey in order that he might take charge of the paleontological work in the party of the Assistant to the Director of the United States Geological Survey in Northern Montana. He returned to New Jersey, however, the first of October and spent most of that month in the field in the Green Pond mountain region, where sufficient fossils were collected to determine the geological age of these formations. Supplementary collections were also made from the Trenton limestone formation near Blairstown, and valuable data obtained which throw much light upon the succession of the faunas inhabiting the ancient seas in which these limestones were formed.

PALEOZOIC FORMATIONS.

The work on the stratigraphy of the Paleozoic formations in the northern part of the State has continued in my charge. During the earlier part of the year a large part of my time was spent in the preparation of the report upon the Cement Rocks of the State, which was published in the Annual Report for 1900. During July and August work was continued upon the earlier Paleozoic formations, particularly those occupying the narrow valleys within the Highlands. The same differentiations are possible here as prevail in the wider belt of these rocks in the Kittatinny valley. During October the formations in the Green Pond mountain region were studied in company with Dr. Weller, their areal distribution mapped and their structural relations determined. A report upon this area has been prepared and is published in this volume.

The field work upon the Paleozoic formations of the State has now been practically completed and their limits mapped. Considerable office work remains to be done in compiling the data thus collected, preparing permanent maps and writing a full report upon these formations. Some of this work has already been done, and it will be continued as rapidly as administrative and other duties may permit.

CLAY AND CLAY INDUSTRIES.

New Jersey is the chief clay-producing State in the Union, the clay mined and sold to clay-workers in 1900 being valued at $407,881, or 25.4 per cent. of the whole for the country; but these figures do not include the value of the large amount of clay mined in the State by those manufactures who own clay banks and thus supply their own clay in whole or in part. During the same year the output of clay products of the State had a value of $10,928,423, or 11.36 per cent. of the whole amount for the country, New Jersey ranking third of all the States. Owing to its importance the clay industry of the State has always received considerable attention from the Geological Survey. The clay deposits were carefully discussed by Dr. Cook in the "Geology of New Jersey," 1868; a special report* was issued in 1878, and for many years was a standard work, being in great demand not only in New Jersey, but among clay-workers in other States. In the Annual Report for 1880 the results of an elaborate series of fusibility tests of New Jersey and foreign clays were given, and in the Annual Reports for 1897 and 1898 statistics of the Clay and Brick Industries of the State were published.

In spite, however, of all that has been done by the Survey in the past, it has been felt for some time that a new report upon the clays was demanded. The development of this industry has been so great, and the discovery of new clay deposits so numerous, that the Report of 1878, although still of great value and in demand, did not fairly represent the present state of the industry. Early in July, therefore, an arrangement was made with Dr. Heinrich Ries to take up the study of the New Jersey Clays and the Clay Industry. Dr. Ries has already prepared reports upon the clays of several States, notably Michigan, New York, North Carolina and Maryland, and is a recognized authority in this subject both in this country and abroad. It is a matter of congratulation, therefore, that the Survey was able

* Report on the Clay Deposits of Woodbridge, South Amboy and Other Places in New Jersey, 1878.

to secure his services. Owing to his previous engagements, Dr. Ries was not able to begin work until September 1st, and could spend but two weeks in the field. During this time, however, he was able to visit practically all of the clay banks of Middlesex county, and obtained enough samples for laboratory work during the coming winter. Before the next field season he will also have visited many of the potteries, brick and tile manufactories of the State, and will be ready to resume the field work with the early summer.

In addition to the economic and technical phases of the subject which will be considered by Dr. Ries, the plan contemplates the discussion of the geological relationships of the clay deposits and the preparation of maps showing their distribution. This portion of the work will be under my charge. In accordance with this plan I spent a portion of the past season in the clay district in company with Dr. Ries. No statement can be made at this time of the results of the work already done, for the preparation of a complete report upon so important an industry as this is a slow matter, particularly since the Survey must not fall short of the high standard set by previous reports. The work will be prosecuted vigorously by both Dr. Ries and myself during the coming year.

ARTESIAN WELLS.

Mr. Lewis Woolman has continued the collection of the artesian-well records and presents these data for the year in his customary report. The collection of these records by Mr. Woolman has continued since 1889, and the results have been published year by year, so that the Survey is now in possession of data from between 1,200 and 1,300 wells from many parts of the State. These have all been indexed upon a card catalogue during the past year by Miss Lee, so that the record of any well can be readily found. Frequent inquiries are directed to the Survey office by persons who contemplate boring wells, respecting the depth of water-horizons, the amount of water obtainable and the nature of the material penetrated. Many other inquiries also are made to Mr. Woolman directly. In answering these inquiries the data already collected are invaluable.

These records, however, are not evenly distributed over the State, so that there are regions of which we have very little knowledge. This is in part due to the absence of deep wells in these regions, and in part to the failure of well-drillers and property-owners to furnish the data to the Survey. If all the bored wells were regularly reported, the Survey would soon be in possession of data for giving even more accurate information concerning our supplies of underground water than at present.

FORESTRY.

Owing to the lack of an appropriation for this purpose the Survey was not able to carry on any forestry work during the past year. The demand for the Report on Forests, published in connection with the Annual Report for 1899, continues, but is less active than in the months first succeeding its publication. About 3,300 copies have so far been distributed to libraries and individuals.

In the last Annual Report the State Geologist, Prof. J. C. Smock, said:

"The next work before the Survey in Forestry is to continue in greater detail the woodland surveys to determine more accurately the nature of the timber trees and their species and the distribution of these species, and to ascertain what has been the probable determining cause of this distribution, particularly as indicated by geologic difference of habitat, or by variations in the composition and texture of the soil. The surveys to ascertain the kind of wood growing on different soils, the capacity of production per acre, and the present stand of timber and its value as a crop, are wanted everywhere. Supplemental to this information about present conditions should be practical instructions how to promote the interests of land-holders by planting more valuable kinds, by increasing the density of the stand and by greater care in cutting as well as renewing the stand. Scientific principles should guide in forest management, and the Survey should be enabled to employ a competent forester whose duty it might be to collect facts of the kind referred to above, and to disseminate this information and create a public sentiment generally and everywhere favorable to forest protection and forest improvement."

These words are as true now as when written and are repeated here with emphasis. The Report on Forests was not in any sense a Final Report. Work should be continued and information disseminated until a proper appreciation of the present and potential value of our forest areas prevails among all land-owners, and the question "Can Forestry methods be made to pay?" is answered in the affirmative by examples on every side.

Forest-fires continue to burn over large areas of timber, particularly in the southern portion of the State. A popular impression prevails that these forests are of no value, and that the fires, therefore, cause no material damage. It is true that much of the timber of these burned areas is small and stunted and of small value at present, but it does not follow from this that these fires do no damage. In the Report on Forests (page 40) it was shown that the yearly increment of value to the forests of the pine-lands is 25 cents per acre when it is protected from fires, as against nothing when it is not protected. Efficient fire protection means, therefore, an aggregate annual increase of value of $150,000 for the 600,000 acres of pine forests now most subject to fires. The money loss, however, is not the only one. With the destruction of the forest cover, which must come in time if the fires continue unchecked, the pine districts will become a forbidding waste of shifting sands, blown hither and thither by the wind and piled into great dunes. The destruction of the forests cannot but re-act unfavorably also upon the mild winter climate, to which is due in large measure the popularity of the numerous winter resorts.

It has been demonstrated that individual owners cannot be depended upon to stop this loss, for thorough co-operation seems impossible. There is no inducement for one enterprising land-owner to improve his forests, when the neglect or carelessness of another may start a fire and destroy the whole. "In the southern part of the State the necessity of public protection is imperative if there is to be any production of lumber in that part of the

State."* The only efficient system of protection against forest-fires is one under State control. The importance of the great pine belt as the gathering ground of an abundant water-supply for cities of the coast as well as of the interior cannot be neglected. With proper State control these areas will be conserved, and under efficient management the forests themselves will become valuable sources of pine and cedar lumber as well as other materials, and may even in time be self-supporting. The time is certainly ripe for the State of New Jersey to take some decided step in this direction.

DRAINAGE.

The drainage of wet lands of the State has received much attention in the past from the Board of Managers of the Survey, and the subject has been discussed in many of the Annual Reports. The problems connected with the drainage of the Newark and Hackensack meadows were discussed in great detail by Mr. C. C. Vermeule in the Annual Reports for 1896 and 1897. That the work of the Survey in these directions has borne good fruit is shown by steps now being taken by large capitalists looking to the reclamation of a considerable tract of these meadows.

As a result of the work of the Survey in pointing out the feasibility of these improvements, and in making known the necessary physical facts and estimated cost of improvement, there has been a concentration of ownership of the meadow land into large holdings. The tendency is now strongly towards the reclamation of these meadows by private ownership and by municipalities in tracts of from 1,000 to 6,000 acres or more. In all the steps which have been taken the maps and reports of the Survey have been constantly consulted, and to the Survey belongs the credit for having initiated this important work.

No progress has been made in the drainage of the swamp lands of the Upper Passaic valley. This work has frequently been referred to in the Annual Reports and the reasons for the delay fully set forth. At the request of the Governor the matter

* Report on Forests, 1899, p. 11.

was considered at length by the Board of Managers early in the year, and effort was made to secure additional legislation looking toward a re-survey of the region and a thorough investigation of the engineering problems involved. The effort, however, was unsuccessful, and nothing was accomplished towards the resumption of work upon this important undertaking.

CHEMICAL WORK.

Dr. William S. Myers has continued his analyses of the waters of the State, and in a brief paper with a map presents the results of the work up to the present. The importance of a pure water-supply for the rapidly increasing population of the State is rightfully emphasized, as is also the fact that systems of purification are at the best poor substitutes for an originally pure and uncontaminated supply. Attention is also called to the fact that while the figures published on the map do not represent the average of a long series of observations, yet they are in all probability sufficiently close to it for all practical purposes, and any wide departure of the cholorine content of a water from the normal of that of the region in question should raise a serious question as to its purity.

During the early part of the year Dr. Myers gave considerable time to the analyses of limestones in connection with the Report on Cement Rock, published in the Annual Report for 1900. The total chemical work done under his direction during the year may be tabulated as follows:

Analyses	of	50 limestones,	with	a	total	of	264	determinations.
"	"	42 waters,	"	"	"	"	84	"
"	"	1 ore,	"	"	"	"	2	"
"	"	1 mineral,	"	"	"	"	4	"
"	"	1 clay,	"	"	"	"	9	"
Analyses	of	95 specimens,	"	"	"	"	363	"

It is a matter of regret that as a result of business changes Dr. Myers has been obliged to give up his Survey work.

In connection with the work on the clays, Dr. Ries has done a certain amount of chemical work, but an exact statement of it is not possible at this time.

THE MINING INDUSTRY.

The customary statistics of iron-ore and zinc-ore production during the year have been collected and the notes on the active mines prepared. These are given in Part IV.

PAN-AMERICAN EXPOSITION.

On March 19th the Legislature appropriated $25,000 for the Pan-American Commissioners. Of this sum $4,500 were promptly voted by the Commission to the State Geologist to defray the expenses of an exhibit by the Geological Survey in the Mines Building. Application was at once made for space, but owing to the late date at which the application was received only a small fraction of what was requested could be obtained. One hundred and seventy-eight square feet were finally allotted the Survey upon the express condition that the exhibit be shipped on April 15th—in less than a month.

Under the circumstances it was not possible to make an extensive display of the mineral resources of the State, nor to add materially to the collections already in hand. The most that could be done was to select from the collections in the Museum sufficient material to fill the space available and make the best display possible. Mr. F. A. Canfield kindly consented to assume the responsibility for the exhibit of New Jersey minerals, and supplemented the Survey's collection with choice specimens of his own. It is safe to say that this part of the exhibit was not surpassed nor even equalled by that of any other State. A synoptic collection of rocks illustrating the various geologic horizons of the State, specimens of clay, marl, sand, building stones, Portland cement rock, zinc, iron, copper-ores, slate and enameled brick filled to overflowing the remaining space available for the exhibition of the mineral resources of the State. A silver medal was awarded for this exhibit.

The excellence of the various topographic, geologic and forestry maps have always given New Jersey a pre-eminent place among the States. It was fitting, therefore, that this feature of the work of the Survey should receive adequate attention. Seven relief maps or models were constructed on a large scale to show the topography and the geology of typical areas. Four of these are in the northern part and two in the southern part of the State. They are: (1) The Palisades of the Hudson near Alpine; (2) The Terminal Moraine west of Hackettstown; (3) The Gravel Plains south of Newton; (4) The Hamburg Kame Area and Glacial Delta; (5) The Ogdensburg Drift Embankment; (6) The Area around Woodbury, Camden county, and (7) The Monmouth Shore from Sandy Hook to Asbury Park. In addition to the maps and models typical geographic views were shown by large glass transparencies placed in the windows, which together with large framed photographs added greatly to the attractiveness of the exhibit. The total cost of the models and transparencies was about 45 per cent. of the total appropriation, but this expenditure was justified in view of the subsequent educational value of these in the State Museum. A gold medal—the highest premium—was awarded the Survey for its display of maps, models and photographs in the Mines Building, and a silver medal for its display of forestry maps in the Forestry Building.

The New Jersey Slate Company of Newton made an attractive display of slate in connection with the Survey exhibit and was awarded a gold medal. A bronze medal was awarded to Sayre & Fisher for their display of enameled brick in the Survey space, so that the State's exhibit in these departments received two gold medals, two silver medals and a bronze medal.

Upon the close of the Exposition, November 2d, the exhibits were packed and shipped to Trenton, where they will be added to the collections in the Museum. Although the minerals and ores of the Museum were not greatly increased by special collections made for this Exposition, yet the new relief maps and transparencies will prove a most valuable addition to the Museum.

The preparation and supervision of the exhibit has demanded a large allowance of time, which was necessarily taken from the regular work of the Survey, but the renewed recognition of merit won by the Survey and the new material for the Museum have warranted this expenditure.

MUSEUM.

Early in the year the collections were moved to the room designed for them in the newly-completed addition to the State House. For a time it was necessary to use this room also as the Survey office, owing to repairs being made in the old quarters, so that for several months the Museum was closed to the public. As already noted, it was necessary to draw heavily upon the collections of the Museum for the Survey exhibit at Buffalo. For all these reasons the Museum has been for the greater portion of the year in a very incomplete state, but with the return of the collections from Buffalo much can be done towards making the collections truly representative of the natural resources of the State. Additional cases are urgently needed in which to display the great bulk of material now in boxes in the Survey storerooms, while the appearance of the Museum would be greatly improved and the available space would be greatly increased if the present antiquated and battered cases could be replaced by the type of case in use in modern museums.

The most available additions to the Museum during the year have been due directly or indirectly to the Pan-American Exposition. The money allotted the Survey was spent with an eye to obtaining, as far as was consistent with a successful exhibit, material of most permanent value to the Museum after the Exposition had closed. The numerous specimens of New Jersey woods, mentioned in the last Report, were cut and varnished so as best to display the natural grain. The large relief models displayed at Buffalo will add much to the value of the Museum from an educational point of view. The large glass transparencies will also contribute to a better knowledge of the surface features of the State. New specimens of building stones have been prepared and suites of specimens illustrating the concentration of zinc, iron and copper-ores obtained.

Through the kindness and co-operation of the Jersey City Water-Supply Company large collections of fossil fish were obtained from the excavations made at the site of their dam at Boonton. The bulk of the material was collected during the previous year, but this was supplemented by additional specimens obtained later, and the whole was removed to the Survey storerooms in July. It is intended to have these examined and classified by an expert paleontologist as soon as possible, and it is hoped that among the large number of specimens new species, heretofore undescribed, may be found. When this work has been completed a part of the collection will be placed in the Museum and the remainder distributed in accord with the terms agreed upon with the Water-Supply Company.

LIBRARY.

The Library of the Survey is made up chiefly of reports and pamphlets received in exchange for its publications. The usual number of additions have been made from this source during the year. In addition to these, the Survey is now a subscriber to several important geological and mining periodicals, and from time to time purchases important works which are needed for reference.

The Library now contains about 624 bound volumes, 339 unbound volumes of periodicals and reports and 237 pamphlets, besides about 100 duplicates. These are all catalogued so that they are easy of reference.

The Library also contains about 1,400 engraved map sheets issued by other Surveys, and about 350 manuscript maps, county atlases, etc. Nearly all of these have been catalogued so as to be readily accessible.

In spite, however, of this good showing, there are many gaps in the Library which ought to be filled. Not infrequently the investigations of workers on the Survey are seriously hindered by lack of the necessary books. It is hoped that by small but steady accessions by purchase and exchange the most serious of these gaps can be closed in the course of a few years.

PUBLICATIONS.

The publications of the year have been the Annual Report for 1900, an 8vo containing xl + 231 pages, illustrated with three inset plates and thirty-three figures in the text. This report was ready for distribution in July, and about 2,800 copies have been sent out. The exchange list of the Survey contains the names of 346 libraries and other surveys, all the newspapers of the State and more than 2,300 individuals. Constant effort is made to eliminate from the list the names of all persons who do not care for the reports, at the same time that care is taken to include everyone, particularly citizens of the State, who take an intelligent interest in this work. Requests for reports should be addressed to the State Geologist.

Of the new large-scale maps the following sheets were published: Mount Molly, Woodbury and Taunton in March; Amboy in June; Navesink and Long Branch in August. A copy of each of these maps when issued was sent to a few libraries and Geological Surveys in this country and abroad, sixty-three in all, to the Managers of the Survey and to the various bureaus of the State. Further distribution is by sale at the uniform price of twenty-five cents, which includes the cost of mailing. The price barely covers the cost of paper, printing and mailing or express charges.

PART I.

The Rocks of the Green Pond Mountain Region.

By HENRY B. KÜMMEL and STUART WELLER.

The Rocks of the Green Pond Mountain Region.

BY HENRY B. KÜMMEL AND STUART WELLER.

In connection with the work upon the Paleozoic formations of northern New Jersey, the rocks of Green Pond, Copperas, Kanouse, Bowling Green and Bearfort mountains and of the associated valleys have been studied during the past season. These formations form a narrow belt in Morris and Passaic counties, extending from near Flanders to the State line, a distance of thirty miles, and continuing for an equal or greater distance into New York State. In New Jersey this belt has a maximum width of a little more than four miles southwest of Newfoundland and about two miles at the State line. Near its southern termination its width is less than a mile.

From Flanders northward to the Rockaway river, west of Port Oram, these formations are represented at the surface by a series of isolated hills surrounded by thick deposits of stratified glacial drift, so that the relationships are exceedingly obscure. Northeastward, however, from the river the ridges are continuous, and although over wide areas, particularly in the valleys, the glacial drift is thick and exposures are few and far between, yet it is possible to work out the structure with a reasonable degree of accuracy.

Previous Work.—Below* are given references to the principal

* Henry D. Rogers. Report on the Geological Survey of the State of New Jersey, 1836, pp. 129-130.
Henry D. Rogers. Description of the Geology of the State of New Jersey, being a final report. Philadelphia, 1840, pp. 171-173.
William W. Mather. Geology of New York, Pt. I. Albany, 1843, pp. 362-363.
George H. Cook. The Geology of New Jersey, 1868, pp. 79-89, 133-134, 143-144, 148-149, 153, 163.
D. S. Martin. Proc. Lyceum Nat. Hist., New York, Vol. I, p. 259.
T. Sterry Hunt. Trans. Roy. Soc. Canada, Vol. I, Sec. IV, p. 254.
John C. Smock. Annual Report of the State Geologist, 1884, pp. 29-56.
T. Sterry Hunt. Mineral Physiology and Physiography, p. 591.
F. J. H. Merrill. Annual Report of the State Geologist, 1886, pp. 112-122.
D. S. Martin. Geological Map of New York City and Vicinity, 1888.
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papers dealing with these rocks. Later we shall give a brief resumé of the various conclusions of the different workers in the field. In this connection, however, we wish to speak particularly of the completeness and thoroughness of Mr. Darton's work, as set forth in his paper "On the Geologic Relations from Green Pond, New Jersey, to Skunnemunk Mountain, New York." Although we differ with him in a few details of stratigraphy and one or two minor points of correlation, yet we wish to bear testimony to the accuracy of his observations and the importance of his investigations. Since, however, his paper is not readily available to most residents of this State, a somewhat full description of this area may here be given even at the risk of repeating much that is already known to geologists. Where there have been so many previous investigators it is not always easy to give each the proper credit for his work. Although all the facts herein stated are the result of our own observations, unless otherwise mentioned, we must not be understood to claim originality for them except where our studies seem to have led to new conclusions. For the most part our work has been mainly corroborative of that of others.

GEOLOGICAL FORMATIONS.

The rocks of Green Pond mountain region comprise conglomerates, sandstones, shales and limestones. On the southeast they rest upon the eroded surface of the gneissic rocks of the Highlands, whereas on the northwest they are separated from them by a fault. Nine and possibly ten formations are recognizable, and from the top downward are as follows:

Skunnemunk conglomerate.	(Chemung-Catskill?)	Devonian.
Bellvale flags, Monroe shales,	(Hamilton),	
Newfoundland grit—	(Oriskany-Corniferous),	
Decker Ferry limestone –	(Niagaran),	Silurian.
Longwood shale, Green Pond conglomerate,	(Medina—Oneida),	
Hudson River shale?		Ordovician.
Kittatinny limestone, Hardyston quartzite,		Lower Cambrian.

Their areal distribution is shown on the map accompanying this report.

Hardyston Quartzite.*—The oldest formation of this region (excepting of course the crystalline rocks which surround this area) is a vitreous, gray-blue quartzite, which is somewhat conglomeratic in its upper portion, the quartz pebbles ranging up to one-half an inch in diameter, although usually somewhat smaller. This quartzite grades upward into a coarse, calcareous sandstone, which, when weathered, is reddish brown in color and very friable. The sandstone in turn grades upward into silicious limestones. The maximum thickness of the quartzite probably does not exceed thirty feet, and the exposures rarely show more than ten or fifteen feet. It makes a narrow, discontinuous line of outcrops east of Kanouse mountain for three miles north of Macopin lake. It is first seen at the edge of a swamp, half a mile or less north of the lake, and a few hundred yards south of Gould's quarry. Outcrops are more or less frequent also in the vicinity of Cisco's quarries, further north. In every case ledges of gneiss outcrop a few feet to the east, and there is no question but what the quartzite rests unconformably upon the crystallines. There can be no doubt also but that this quartzite is to be correlated with the Hardyston quartzite found in the same relationships in many places along the border of the Kittatinny valley and the limestone valleys in the highlands. This correlation is strengthened by the occurrence of the Olenellus fauna in its upper calcareous portion and in the lower beds of the overlying limestone, as was first announced by Mr. Walcott in 1893. Its lower Cambrian age is therefore well established.

Kittatinny Limestone.—Overlying the Hardyston quartzite and grading downward into it there occurs a massively bedded more or less silicious limestone, which is undoubtedly to be correlated with the Kittatinny limestone, the great calcareous formation of northern New Jersey. It is usually of a bluish-gray color, but occasionally has a pinkish tinge. It is best exposed east of Kanouse mountain, at Gould's and Cisco's quarries, three-fourths

* In the Annual Report for 1900 this name was spelled Hardiston, but the above spelling is that adopted by the U. S. Board on Geographic Names, and for the sake of uniformity is here adopted.

and two and one-half miles north of Macopin lake respectively, as well as at several intermediate points. It was also formerly quarried at Middle Forge, three-eighths of a mile southwest of the pond and about 150 yards west of the road, but the exposures are now greatly obscured by dirt and quarry refuse. A few rods to the west of this outcrop are ledges of the Green Pond conglomerate, which dip steeply westward, and apparently overlie the limestone, although the relations are not perfectly clear. The limestone is also exposed in a quarry on the west side of the Forge pond between two small peninsulas. Here the rock is an impure, silicious and somewhat shaley limestone, and, so far as known, entirely unfossiliferous. The beds are nearly horizontal in the main, but the exposures nearest the outcrops of conglomerate on the west, 200 feet distance, are greatly sheared and bent sharply upward to the west, as if affected by a fault with uplift on the west. The nearest ledges of conglomerate are likewise sheared or slickensided and dip sharply eastward, as if likewise dragged by the fault. Within the quarry itself minor faults are visible. Unless faulting is postulated the limestones apparently overlie the conglomerate, and this interpretation was accepted by Dr. Cook.* But in view of the facts observed elsewhere in the field the recognition of these limestones as Cambrian and their lower position as regards the conglomerate cannot now be questioned.

East of Kanouse mountain the total thickness is not much above 130 feet, but this is only the basal portion of the formation, which, in the Kittatinny valley, attains a thickness of 2,500 or 3,000 feet. The discovery of the Olenellus fauna, mentioned above, fixed its age as Lower Cambrian.

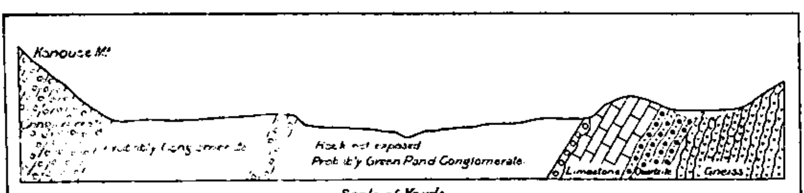


Figure 1.—Structure between Gould's Quarry and Kanouse Mountain.

* Geology of New Jersey, 1868, p. 81.

The relations at Gould's quarry are shown in figure 1. Ledges of gneiss, which strike N. 45° E. and dip 80° to the northwestward, lie to the east. Across a narrow depression, about twenty-five yards wide, are ledges of limestone with the underlying sandstone and quartzite. The dip of these beds is 60° to the northwest, and the limestone layers have a thickness of about sixty-five feet. The lowest beds exposed here are a hard, vitreous quartzite, which grades up into the limestone through a coarse, friable sandstone. At several places in the quarry a coarse conglomerate made up chiefly of white quartz pebbles with some cherts and some small limestone bowlders occur in patches on the Kittatinny limestone and fills fissures in it. The quartz and flint pebbles are three or four inches in diameter and the limestone masses are not infrequently two feet in diameter. The matrix is composed of smaller fragments of similar material, and is greenish in color.

As a result of the quarrying operations, the relationship between this conglomerate and the limestone is clearly shown. The most conspicuous mass of conglomerate fills a fissure in the limestone extending into it for several feet. One hundred and sixty yards west of the quarry, across a narrow swale, are the steep bluffs of purplish conglomerate on the east slope of Kanouse mountain. The nature of the intervening rock might be open to question but for the occurrence of a ledge of the purple conglomerate about midway in the low ground.

It is evident that the following relationships exist here. The Hardyston quartzite and the basal portion of the Kittatinny limestone are shown, together with an overlying conglomerate, which rests upon the limestone unconformably and contains waterworn masses of it in the basal portion. Except for the limestone pebbles and a slight difference in color, this conglomerate is closely similar to that which outcrops in the middle of the low ground and on the mountain, and there is no doubt in our minds but what they are the same, particularly as the higher conglomerate is by no means uniformly purple in color.

In the basal portion of the limestone a little above the Hardyston quartzite horizon there are occasional pockets of a conglomerate which resembles very closely the conglomerate of

Kanouse mountain. It is composed chiefly of quartz pebbles in a purplish matrix, and is usually surrounded by a thin zone of reddish shale concentric with the outline of the pocket. Various explanations have been suggested by different observers to account for these masses. In our opinion, they are not to be connected with the Hardiston quartzite, but are more probably masses of the overlying conglomerate which were washed into fissures and crevices in the deeply weathered and eroded surface of the older limestone. The fact that it is not possible with the present exposures to trace the conglomerate of these pockets continuously from the basal portion of the limestone to the top does not militate against this explanation of its origin. Somewhat similar occurrences have been reported from Franklin Furnace,* where, in the quarries, the Hardyston quartzite can be seen to penetrate the white limestone for many feet in a most irregular manner. We have been informed also that after extremely heavy rains material from the surface is washed into the lower levels of the zinc mine at Franklin Furnace through the openings in the limestone. The possibility, therefore, that, at the time of deposition of the overlying conglomerate, material from it may have found its way through fissures to the basal portion of the limestone at Gould's quarry cannot be doubted.

Somewhat similar relations are observed at Cisco's quarries. The Hardyston quartzite is seen a few rods south of the quarry, although not exposed opposite the workings. Here the limestone apparently has a thickness of at least 130 feet, and dips at a steep angle beneath the ledges of conglomerate in Kanouse mountain, which outcrop 275 feet to the westward. At this point the contact of the overlying conglomerate with the limestone is not seen.

Hudson River Shale.—This formation is not certainly known to occur in this region, but at two points exposures of a non-fossiliferous black shale have been found in such relationships that they may possibly belong to this formation. The first of these is along the road west of the Oak Ridge reservoir. Here small masses of a very much sheared black shale are found along

* Wolff 18th An. Rep. of the Director U. S. G. S., Pt. II, p. 454.

a fault line, which has brought the crystalline rocks on the west in contact with the younger sedimentary formations. A larger and better outcrop is found just south of the road to Holland, at the southern end of the narrow arm of Oak Ridge reservoir. The shale here forms a small knoll, separated from the crystallines on the west and from ledges of conglomerate on the east by drift-encumbered depressions. No fossils could be found in this shale, and no positive assertions can be made as to its age, but as it apparently underlies a heavy conglomerate, which is probably equivalent to the Oneida, it is tentatively regarded as Hudson River. It lies close to the above-mentioned fault, and, whatever its age, it is undoubtedly the same as the small mass of shale on the side of the reservoir.

Mr. Darton mentions a slate which occurs along the east side of Kanouse mountain, in the depression between the conglomerate of the mountain and the outcrops of Kittatinny limestone already mentioned. Careful search was made for this formation without success. From the data observed at Gould's quarry, it is very doubtful whether any formation intervenes between the limestone and the conglomerate, for the latter there apparently rests unconformably upon the former. At Cisco's quarry, farther north, it is possible that a narrow strip of slate intervenes between the two, but we found no outcrops of it.

The Green Pond Formation.—This consists of coarse, silicious conglomerate, interbedded with and grading upward into quartzite and sandsones. The pebbles of the conglomerate range from one-half to three inches in diameter, and are almost entirely white quartz, but some pink quartz, black, white, yellow and red chert, red and purple quartzite and a very few red shale and pink jasper pebbles occur. The white quartz pebbles have frequently a pink tinge on their outer portion. At Gould's quarry large masses of the underlying limestone are included in a conglomerate, which is believed to be the basal layers of this formation.

The matrix is comprised of quartz sand, is vitreous in texture and generally of a dull red color, but white, gray and greenish strata frequently occur, particularly in the basal portion, so that the formation is not so exclusively red as implied in most of the earlier reports. The beds are almost uniformly quartzitic in texture, and, on account of their hardness, form the long, narrow, steep-sided mountain ridges characterizing this region. Locally, however, the basal portion of the conglomerate is apparently quite friable and disintegrates readily, due probably to a greater or less amount of calcareous material derived from the limestone on which it rests in places. A good instance of this was found about two miles north of Macopin lake, where the basal beds are so disintegrated that they have been dug for gravel.

The quartzite which is interbedded in the upper portion of the conglomerate and rests upon it is in general a purple-red color, but presents various shades of pink, yellow, brown and gray. Some of these beds are massive and show no laminæ, but in others the thin stratification planes can be readily made out. The conglomerate beds are often very thick, with but slight trace of any bedding.

In the southwestern part of the area, in the isolated hills southwest of the Rockaway river, the rock is much softer than farther north, and is a friable sandstone rather than a quartzite. So completely disintegrated are some of these beds that they have been dug for sand and gravel for many years. This friable sandstone phase is well shown in the white rock cut on the D. L. & W. Railroad west of Port Oram and at the sand-pits in the vicinity of Flanders.

This formation makes up almost the entire mass of Copperas, Kanouse, Green Pond and Bowling Green mountains, the first three of which are long, narrow ridges. Ledges of it also occur southwest of Russia, where a sharp synclinal fold exists between their outcrop in Bowling Green mountain and the exposures along the crystalline highland border, section VIII, plate IV. This narrow strip can be traced northeastward to the western side of Oak Ridge reservoir, where it is last seen in a small outcrop at the water's edge.

Kanouse mountain diminishes in elevation northward toward West Milford, and the rocks disappear beneath the drift just southwest of the village. The same beds, however, appear again at the southwest end of Greenwood lake in frequent exposures in the woods west of the road and at the end of a gravelly point projecting into the lake. They also outcrop in the long, narrow island a mile farther north in the lake. Mr. Darton was inclined to class the conglomerate of this island with the Oriskany formation, but lithologically it is quite distinct from the fine-grained conglomerate of that formation, and resembles much more closely the beds of Kanouse mountain. The fact that these beds dip somewhat steeply to the southeast, whereas in Kanouse mountain the beds dip to the northwest, does not militate against our correlation, since at the north end of the mountain overturned dips to the southeast are quite common.

The relation of this formation to the underlying rocks is readily determined, although only in one place has the actual contact been seen. Throughout the entire extent of Copperas mountain it rests unconformably upon the eroded surface of the crystallines, which form the lower part of the southeastern face of the mountain. At the mines opposite Green pond the two formations are frequently exposed within twenty-five or thirty feet of each other, although not in actual contact. Here the lowest conglomerate bed is rather gray in color and resembles closely the conglomerate of the Kittatinny and Shawangunk mountains. Along this face of the mountain the contact can be located definitely at an elevation of about 1,100 feet, or 225 to 250 feet below the crest.

South of Macopin lake, also, the conglomerate rests upon the gneiss, but at the north end of the lake a narrow strip of the older sedimentary rocks is found between the conglomerate and crystallines. Their relations are best shown at Gould's quarry, a description of which has already been given. From this point northward to the State line the conglomerate rests, so far as we could determine, upon the limestone, or, according to Darton, upon a narrow strip of Hudson River slate.

The relationships of the conglomerate and quartzite to the older formations are not exposed in the isolated hills in the southwestern portion of the area.

At Middle Forge, in the quarry west of the road, the conglomerate of the Green Pond mountain apparently rests upon the Kittatinny limestone, but northward a quarter of a mile the conglomerate and gneiss are apparently in contact. West of the pond a fault evidently separates the high cliff of conglomerate from the Kittatinny limestone exposed in the quarry on the shore, both formations showing strong evidence of shearing and drag at outcrops nearest the hidden contact. Elsewhere along this mountain the conglomerate apparently rests upon the gneiss, and, although this contact is nowhere exposed, yet the two are shown in close proximity to each other at many places along the wild and narrow gorge of Green Pond brook, up which the gneiss can be traced continuously to about one-quarter of a mile southwest of the end of the pond, where it is lost in the swamp. However, it reappears again a mile and a half east of the upper end of Green pond, forming a narrow bench fifty yards in width and several hundred yards long, immediately below the prominent summit of Green Pond mountain. Toward the lake the ledge becomes buried beneath the drift and to the northeast it disappears beneath the great blocks of talus, the dip of its contact with the overlying conglomerate and quartzite being such as to carry it beneath the surface within a short distance.

The conglomerate is also seen to rest upon the gneiss in the offset of Green Pond mountain, southwest of Newfoundland, which is known locally as Brown's mountain. In Bowling Green mountain the conglomerate is wrapped around the northward end of a ridge of gneiss, and probably rests directly upon it; but the contact has not been seen, and nowhere have the rocks been found in such close proximity to each other as to eliminate beyond a doubt the possibility of a narrow strip of older sedimentary rocks between them.

The outcrops of this formation southwest of Oak Ridge reservoir apparently rest upon a black shale, which may belong to the Hudson River formation, but no positive assertions can be made. Farther to the southwest they apparently abut against the crystallines along the fault plane.

The relation of this formation to the overlying beds is simple. It passes upward somewhat abruptly into a soft red shale. Nowhere in New Jersey have the two been seen in actual contact, but they are frequently exposed in such close relationship as to render this conclusion a safe one.

Various estimates have been made of the thickness of this formation. These range from 400 to 650 feet. All of these estimates, however, are believed to come far short of the actual thickness. In some cases they manifestly take into account only that part of the formation exposed in the steep eastward facing cliffs which characterize these ridges, and take no account of the higher beds which outcrop with steep dips on the back slopes of the mountain, and which add greatly to the thickness. In some cases, too, the small estimates may be due to an assumption that the ridges are formed by closely compressed folds. Our own estimates, measured on numerous section lines* across the ridges, where at least the approximate portion of the enclosing formations were determined, and based on frequent observations of the angle of dip, indicate that the thickness of this formation is probably not less than 1,200 feet and locally it may be 1,500 feet. It is not asserted, however, that this entire thickness is exposed at any one locality, but we believe that these figures represent the thickness of the formation as developed along the greater portion of Green Pond and Copperas mountains. Toward the northern end of Kanouse mountain the thickness apparently diminishes somewhat; yet owing to the thick deposits of drift which conceal both the basal and upper portions, estimates of the thickness there may be somewhat in error.

In the previous discussions of this region published in the Reports of the Survey, the conglomerate which occurs along Bearfort mountain was assumed to be the same as of Green Pond and Copperas mountains. Mr. Darton was the first to

* These sections are as follows:
On Green Pond Mountain—
At Berkshire Valley. 1,200 feet. Both top and bottom concealed by drift.
Upper Longwood. 1,215 feet.
West of Green pond. 1,500 feet.
Newfoundland. 1,260 feet.
Copperas Mountain—
Green pond. 1,225 feet.
Two miles south of Newfoundland. 1,160 feet (minimum).
Kanouse Mountain—
Southern end. 1,110 feet (minimum); 1,400 feet (possible maximum).
Gould's Quarry. 1,000 feet from base of beds to outcrops west of crest; 200-400 feet more on western slope.
One and one-half miles south of West Milford. 1,000 feet.
Island in Greenwood lake. 470 feet (only a portion of the formation).

point out that this was an error, and the same conclusion was announced about the same time by Mr. Walcott. Our work corroborates completely the conclusions of these investigators in this respect. Although the conglomerates of Bearfort and Green Pond mountain resemble each other somewhat closely, yet critical examination of the two discloses at once marked lithological differences. These will be pointed out in connection with the description of the Bearfort conglomerate.

Since the Green Pond formation rests unconformably in places upon the Lower Cambrian limestone, and perhaps upon Hudson River slate, and is overlain conformably by a red shale, which, as will be shown later, passes upward into a siliceous limestone containing Niagaran fossils, the correlation of the Green Pond formation with the Oneida conglomerate exposed in Kittatinny mountain is probably correct. The lithological differences between the two are not so great as has been assumed by some observers. The lower beds of the Green Pond conglomerate are not infrequently of the same grey color and in almost every way identical with the conglomerate of Kittatinny mountain. Moreover, reddish conglomerates so common in the Green Pond rocks are not infrequent in the Kittatinny mountain beds. Although lithological resemblances and differences are not always safe guides for correlation, particularly in a formation which is so subject to variation as a conglomerate and sandstone, yet the structural position of the two is practically the same, and there can be no question as to the correctness of this correlation, which was first announced by Merrill. He, however, included the conglomerate of Bearfort mountain as a part of the Green Pond formation.

Longwood Shales.—The quartzite of the Green Pond formation passes somewhat abruptly into a soft red shale, in which cleavage is frequently so highly developed that the bedding planes cannot be determined. This formation makes a narrow belt at the foot of the northwestern slope of Copperas, Kanouse and Green Pond mountains and around the outer edge of Bowling Green mountain, but outcrops are found at comparatively few places. Good exposures were noted along the road a mile southwest of Newfoundland at the northern end of Green Pond mountain. These beds outcrop somewhat frequently along the west slope of Green Pond mountain, from Lower Longwood northward to the road leading from Russia over the mountain to Green pond. Traces of them have also been found along the southeastern side of Green pond and at a number of points along the western slope of Kanouse mountain, between Postville and West Milford. At the southwest end of Greenwood lake, also, a low ridge of red shale lies just west of the outcrop of the Green Pond conglomerate there exposed. Traces were also observed at Oak Ridge reservoir where the road crosses the southwest arm of the pond, and still better outcrops occur near the southeastern end of a high conglomerate ridge one mile south of Russia. Some of the best exposures are found along the border of Bowling Green mountain south of Milton. Here somewhat accurate estimates show a thickness of 200 feet, although the top of the formation is not exposed. These estimates correspond somewhat closely with the figures given by Merrill and Smock.

Since this formation rests directly upon the Green Pond quartzite and underlies a limestone carrying Niagaran fossils, its reference to the Medina formation by Merrill, Darton and Foerste is probably correct.

The name Longwood was first applied to these shales by Darton, from their occurrence in the Longwood valley, and is used here, not because it is the best name which might have been chosen, but because it has already been used in the literature of the subject. The conspicuous shales of the Longwood valley are not these red shales, but are black shales belonging to a higher horizon. The latter outcrop on both sides of the road for several miles, whereas the outcrops of red shale lie along the lower slope of Green Pond mountain for the most part in the woods, and can only be found after considerable search.

Decker Ferry Formation.—An impure silicious and shaley limestone has been found overlying the Longwood shale at a number of places, the most important of which are Upper Longwood, Woodstock and Newfoundland. At Newfoundland the limestone is conspicuously exposed along the road and in the adjoining fields to the south on the Cobb property, a mile and a half south of the depot, but these outcrops are so isolated with respect to other ledges that by themselves nothing can be asserted of their relationships. At Upper Longwood there are good exposures in an old quarry three hundred yards southeast of the forge ruins. The limestone beds dip 80° to the westward and are succeeded eastward within a few rods by outcrops of Longwood shale, dipping in towards the limestone. Just below the dam at Woodstock Forge, also, ledges of a green shale and silicious limestone are found apparently overlying the Longwood shale, which outcrops a few yards eastward and higher on the hill. Here the beds dip steeply to the southeast, owing probably to overturned dips. Between Woodstock and Longwood are other exposures of the same calcareous beds. A limestone was reported to occur also in excavations at Milton in similar relations, but was not seen upon the surface. Traces of the formation have been found by Darton and ourselves in the old "hematite" diggings at the southwest end of Greenwood lake, closely adjoining a low ridge of red shale. Although the contact of the limestone and the Longwood shale is nowhere exposed in New Jersey, their normal sequence is shown in the section near Cornwall Station, New York,* and there can be no reasonable doubt but that it forms a narrow belt adjoining and parallel to the outcrop of the Longwood shale. This is the more probable, since it has been observed in this position at somewhat widely separated localities. Its thickness can nowhere be accurately measured, but it probably does not exceed forty or fifty feet.

Fossils have been reported from this formation since 1858, but the identification of the species has not always been correct. The following fauna was found by Mr. Weller:

1. South of New Foundland:

Favosites sp. undet.
Monotrypa sp. undet.
Chonetes jerseyensis.
Orthis flabellites.
Rhynchonella neglecta?
Rhynchonella sp. undet.

* Darton. Am. Jour. Sci., 3d Ser., Vol. XXXI, pp. 209-216.

Atrypa reticularis.
Dalmanites sp. undet.

2. Upper Longwood Quarry:
Monotrypa sp. undet.
Chonetes jerseyensis.
Stropheodonta bipartita.
Orthis flabellites.
Rhynchonella neglecta?
Rhynchonella sp. undet.
Atrypa reticularis.

The presence of *Chonetes jerseyensis, Stropheodonta bipartita,* and *Orthis flabellites* connect these limestones with the Decker Ferry formation of Walpack Ridge, Sussex county* (Niagaran), and not with the Helderbergian limestones, to which they have been referred by previous writers.

At all the exposures the rock is the same as the *lower beds* of limestone shown in the railroad cut near Cornwall station, Orange county, N. Y. Here we found the following section from the base upward.†

1. Coarse red conglomerate,—Green Pond formation, (Oneida),......	23 ft.
2. Red shale and sandstone,—Longwood shales, (Medina),..........	120 "
3. Siliceous limestone, shaley towards the top,—Decker Ferry formation, (Niagaran), ...	33 "
4. Blue siliceous limestone,—on a weathered surface, rusty brown and distinctly laminated—unfossiliferous as far as noted, ...	18 "
5. Heavy bedded, dark blue limestone, very cherty and fossiliferous in its upper portion,—Coeymans (Pentamerus) limestone, (Helderbergian), ...	40 "

In the siliceous limestone (No. 3) the following fossils were noted: *Rhynchonella* sp. (?), *Atrypa reticularis, Chonetes jerseyensis* (?), an abundance of crinoid stems and *Cladopora seriata,* which in the upper portion makes up the mass of the rock. This last form is strongly characteristic of the coralline fauna of the Decker Ferry formation, and there is no hesitancy felt in ascribing the basal portion of the limestone shown in this section to the Niagaran and not the Helderbergian.

* Weller. Annual Report of the State Geologist, 1899, pp. 7-19.

† For full description of this locality see Darton Am. Jour. Sci., 3d Ser., Vol. XXXI, pp. 209-216.

At all the outcrops in the New Jersey area it is only the lower limestone of the above section which is exposed, and, as the list above shows, the fauna is Niagaran. Nowhere did we find any limestones carrying the Helderbergian fauna. At the old opening for "hematite" at Greenwood lake no fossils were found, but the fragments of rock about the old openings were identical lithologically with the lower limestone beds at Cornwall, and we believe they are the same. In view of these facts it seems necessary to conclude that it is erroneous to refer the limestones exposed at Longwood, Woodstock and Newfoundland to the Helderbergian. The occurrence, however, in this region of traces of the Helderbergian limestone above the Decker Ferry beds is not impossible, since they occur in the adjoining area in New York.

Nowhere has the Decker Ferry formation been seen in contact with the overlying beds. At Cornwall it is succeeded by sixty feet of limestone, the upper forty feet of which carry Helderbergian fossils. The nearest outcrops of the next succeeding formation in New Jersey are everywhere far enough removed from the Decker Ferry exposures to permit the presence of a few feet at least of these higher limestones, but if present we have not been able to find them.

Newfoundland Grit.—This formation is a heavy-bedded, fine-grained conglomerate below and a thinner bedded sandstone above, for which we propose the name *Newfoundland grit.* The basal portion is composed of white quartz pebbles from one-quarter to one-half an inch in diameter, usually set somewhat loosely in a siliceous matrix, so that the rock is of open texture and friable. Locally, however, the interstices are filled with a siliceous cement and the rock is decidedly quartzitic. These coarser beds grade upward into a hard, greenish, thin-bedded sandstone, which in turn passes into the black argillaceous shales (Monroe shales) carrying a Hamilton fauna. The lower, coarser beds are about 100 feet in thickness and the upper layers slightly more, the total thickness being about 215 feet, but owing to the absence of a complete section and any sharp line between these beds and the overlying formation, estimates of thickness are somewhat variable.

This conglomerate and sandstone undoubtedly forms a narrow belt parallel to the outcrop of the Decker Ferry beds and Longwood shales, but as compared to the numerous exposures of the Green Pond formation it is rarely seen. Ledges have been found (1) at Newfoundland, 300 yards east of Chamberlin's hotel and elsewhere in the vicinity; (2) at Petersburg, both north and southeast of Morris McCormick's house; (3) between Petersburg and Upper Longwood; (4) at Oak Ridge reservoir, where the road crosses its southwest arm; (5) southwest of West Milford, near W. K. Hastings' house, where the upper layers are exposed in a prominent knoll east of the road, and (6) along the west side of Greenwood lake, from Lakeside southward. Here it forms a rocky point in the lake half a mile south of Lakeside and a prominent ridge near the Rev. Dr. Peters' cottage. Still farther south it outcrops on both sides of the synclinal ridge, west of the old "hematite" openings.

Fauna.—The following fossils were found in this formation:

At Newfoundland (lower portion):

Zaphrentis sp.
Stropheodonta concava.
Schizopharia propinqua.
Amphigenia elongata?
Spirifer arenosus?
Spirifer arrectus?
Spirifer sp. undet.
Cyrtina hamiltonensis?
Pterinea sp. undet.

At Greenwood lake (upper portion):

Chonetes sp. undet.
Stropheodonta sp. undet.
Orthothetes sp. undet.
Anoplotheca acutiplicata.
Amphigenia elongata?
Spirifer macrothyris.
Cyrtina hamiltonensis.
Pterinea sp. undet.

Although fossils are not rare in this formation, particularly in the outcrops at Newfoundland, they are in most cases obscure and often greatly distorted, so that they are not readily recognizable. The above identifications show that the beds at Newfoundland contain a mixed Oriskany-Corniferous fauna, while the higher layers at Greenwood lake are more strictly Corniferous. This conclusion agrees with that of Merrill and Britton for the Newfoundland beds.

The exact relationship of this formation to the underlying limestone is not shown, an interval of a few yards at least being always found between their outcrops. Structurally the two are not apparently unconformable, but there is seemingly absent here a considerable thickness of beds, which a few miles northward occurs between the two. As already indicated, they pass gradually into the overlying beds.

Monroe Shales.—These rocks are black to dark grey, more or less slaty shales, which become more sandy in their upper portion. They are nearly everywhere strongly cleaved, so that the original bedding planes are not always readily discernible where the rock is of uniform texture.

They occupy the greater portion of the valleys between the ridges of the harder rocks and over considerable areas their outcrops are very frequent. They undoubtedly underlie most of the lower Longwood valley, but owing to the heavy drift accumulations south of Upper Longwood no exposures of any kind have been found. Between Upper Longwood and Petersburg outcrops are common, and again from Postville north to West Milford. Other good exposures occur along the west side of Greenwood lake, where they form two belts separated by a fault and the ridge of Newfoundland grit. They occur also west of Oak Ridge reservoir, and undoubtedly underlie much of the drift-encumbered lowland north and east of Milton. Their upper beds are seen near Oak Ridge and in the lowest of the ledges at Clinton falls.

Owing to the close folds which sometimes occur in the formation, and to the resemblance between bedding and cleavage (see Plate I), as well as to the indefiniteness of their upper limits, the thickness of these beds is not readily determined. A mile south of the State line on the west side of Greenwood lake we estimate their thickness at 700 feet, but their basal portion has been faulted

Monroe shales, showing bedding and cleavage, two miles north of Newfoundland. The beds dip gently to the left. The cleavage is steeply inclined to the right.

off. Darton gives 900 feet as their thickness along the valley southwest of West Milford, while Merrill estimates it as 1,000 feet at least for the Longwood valley.

These strata are locally somewhat fossilferous, and fossils have been reported from them by several observers, notably Merrill, Britton and Darton. We found the following forms, which corroborate the conclusions of these workers that this formation belongs to the Hamilton group. The name Monroe shales was given it by Mr. Darton from the good exposures in the vicinity of Monroe, New York.

Fauna. 1. Woodstock, Sylvester's Corners:

Fenestella? sp. undet.
Chonetes sp. undet.
Rhynchonella sp. undet.
Homolonotus? sp.

2. North of Clinton reservoir:

Crinoid stems.
Chonetes coronatus.
Rhynchonella sappho.

3. Southwest of West Milford:

Tropidoleptus carinatus.
Actinopteria? sp. undet.

4. South end of Greenwood lake:

Orthothetes chemungensis.
Anoplotheca sp. undet.
Tropidoleptus carinatus?
Platyostoma sp. undet.
Dalmanites sp. cf. *anchiops.*
Phacops rana.

Bellvale Flags.—The Monroe shales grade upward into a great mass of hard, heavy-bedded greywacke and dark grey flagstones, which have been called by Darton the Bellvale flags, from their occurrence and good exposures in Bellvale mountain, the New York continuation of Bearfort mountain. Although the greater portion of this formation is a monotonous succession of dark gray, hard, slabby sandstone, yet in their upper portions they contain some alternating red and green layers. They are succeeded by a heavy-bedded, reddish-purple conglomerate, and the transition beds consist of alternating red shales and sandstones, green sandstones and red or greenish conglomerates. Scattered quartz pebbles occur in the upper layers of the flagstone and increase in numbers in some horizons to form bands of conglomerate. The alternations of shale, conglomerate and sandstone continue for several hundred feet, and in default of continuous exposures it is difficult to draw the line separating the two formations. The attempt was made to draw it at the base of the lowest conglomerate beds, but probably with only partial success. Indeed, it is quite possible that the lowest conglomerate layers are not everywhere at the same horizon.

This formation makes the eastern slope of Bearfort mountain from the latitude of Cedar pond northward, and the eastern subordinate ridge thence southward to Clinton falls. Here the rocks are finely shown in the series of ledges over which the stream cascades, as well as in the higher beds just below the reservoir dam and near its western end. Scattered outcrops of the same beds are found at various points on the drift-covered hills southwest of Clinton falls towards the Oak Ridge reservoir, at the outlet channel of which there are fine exposures. A narrow strip of the same formation is found along the west side of Bearfort mountain, where the synclinal fold of the mountain brings the upper beds to the surface.

At Clinton falls the rocks are so strongly cleaved that it is no easy matter to distinguish between cleavage and bedding. At the Oak Ridge reservoir the rock is also much sheared and the fossils distorted, yet here the bedding planes are distinct.

At the outlet of Oak Ridge reservoir, which has been blasted through these beds, the following fossils were found in material on the dump-piles:

Crinoid stems.
Chonetes mucronatus?
Spirifer audaculus.
Grammysia alveata.
Palæoneilo emarginata.
Paracyclus elliptica.
Bellerophon sp. undet.
Strophostylus sp. undet.

This is a Hamilton fauna also, so that the lower beds at least of this formation belong to this period.

The indefiniteness of both the base and top of the Bellvale flags gives rise to considerable variations in the estimates of their thickness. Merrill gave 700 feet. Smock estimated their thickness in Skunnemunk mountain, New York, to be 1,300 feet, but believed they were much less in New Jersey. Darton gave 2,000 feet as a minimum for their thickness on the eastern flank of Bearfort mountain. Our own estimates gave 1,630 feet for a carefully measured section at the State line, from the black slate up to the lowest pebble-bearing beds; 2,000 feet at the gap south of West Milford, and at Hanks pond a less accurate estimate gave 1,840 feet.

Skunnemunk Conglomerate.—The typical beds of this formation are a coarse, purple-red, massive conglomerate, the pebbles of which are sometimes six or seven inches in diameter. Beds of red sandstone alternate more or less frequently with the conglomerate, and there are many gradations between the two. In the conglomerate the most conspicuous pebbles are white quartz, owing to the contrast they present to the dull red matrix. Dark red quartzite and sandstone pebbles are, however, almost as abundant as the quartz pebbles, and red shale pebbles frequently occur. In some of the lower layers green sandstone or greywacke pebbles are also abundant. The vari-colored cherts which were noted sparingly in the Green Pond conglomerate were not observed here. The matrix is in general the same material as the pebbles, only finer, and is firmly cemented together, sometimes so much so as to present a vitreous appearance. On the whole, however, this formation is not so vitreous and quartzitic as the Green Pond conglomerate. The rock is locally traversed by many white quartz veins, which add greatly to the contrast of colors and the variegated appearance.

These conglomerates form the great mass of Bearfort mountain from Clinton reservoir northward to the State line. In New York they outcrop along the crest of Bellvale mountain, and also form the central portion of Skunnemunk mountain, from which they obtain their name.

Although this formation is typically a very massive dark red conglomerate, forming innumerable ledges and cliffs in the region underlain by it, yet in its lower portion it contains many beds of red shale and sandstone as well as green flags and greenish conglomerates. These lower beds are well shown west of Hanks pond and along the carriage road leading to the summer residence of Mr. R. F. Cross, on the crest of Bearfort mountain. In fact the successive strata from the upper layers of the Monroe shale to the Skunnemunk conglomerate can be nowhere better studied than by combining the section below and above Clinton falls, the exposures west of the dam and those along this private road. Mr. Cross has tried the somewhat unique experiment of using these conglomerate beds for his house, with highly satisfactory results from an artistic point of view, although it is not likely that the rock will ever be greatly used for building purposes.* The lower alternating beds of red and green conglomerate, greywacke, red shale and red sandstones are also well shown on the western flank of the mountain, along the road leading to the club-house at Cedar pond.

Bearfort mountain is crossed by two gaps followed by roads, along both of which the rocks are well shown. The higher conglomerate beds occupy the central portion of a compressed syncline and the alternating shales, sandstones and conglomerates occur on either side. In the southern gap about five hundred feet of red shale and sandstone succeed the Ballvale flags on the east and then give place to red and green conglomerates with numerous red sandstone beds, above which come the great mass of conglomerates. A mass of red shale is exposed in the midst of these, very near the axis of the syncline. The lower beds are seen again on the west side of the syncline, south of Uttertown.

Since these conglomerates rest upon the Bellvale flags, which are of Middle Devonian age, they must be somewhat younger. Darton has suggested that they correspond to the Oneonta formation in Central New York, or that they are "equivalent to the coarse beds of Chemung age in the southern Catskills."

*A church at Morristown has also been built of this and the Green Pond conglomerates.

This formation resembles somewhat closely the Green Pond beds, so much so that they were assumed to be the same by all the earlier observers, and this mistaken correlation made necessary many of the complicated folds which were assumed to exist. Darton was the first to determine that the two were distinct and separate formations and the same conclusion was reached a little later by Walcott. Although there is a certain superficial resemblance between these beds, yet careful study of the two formations shows there are marked differences in composition and in the sequence of the beds. Although practically the same pebbles occur in both conglomerates, their proportions differ greatly. The Green Pond conglomerate has chiefly quartz pebbles, but the Skunnemunk has nearly as many red quartzite pebbles as white quartz, so that the general color of the rock is somewhat different. The Green Pond formation is on the whole more vitreous and quartzitic than the other, although the reverse statement might be true of individual beds in each. The Green Pond conglomerates are not infrequently white or gray; the Skunnemunk rarely or never so. The sandstone and quartzite beds occur in the upper portion of the Green Pond formation and in the basal portion of the other. The Green Pond beds are followed by a red shale, but in the Skunnemunk formation red shales occur at various horizons.

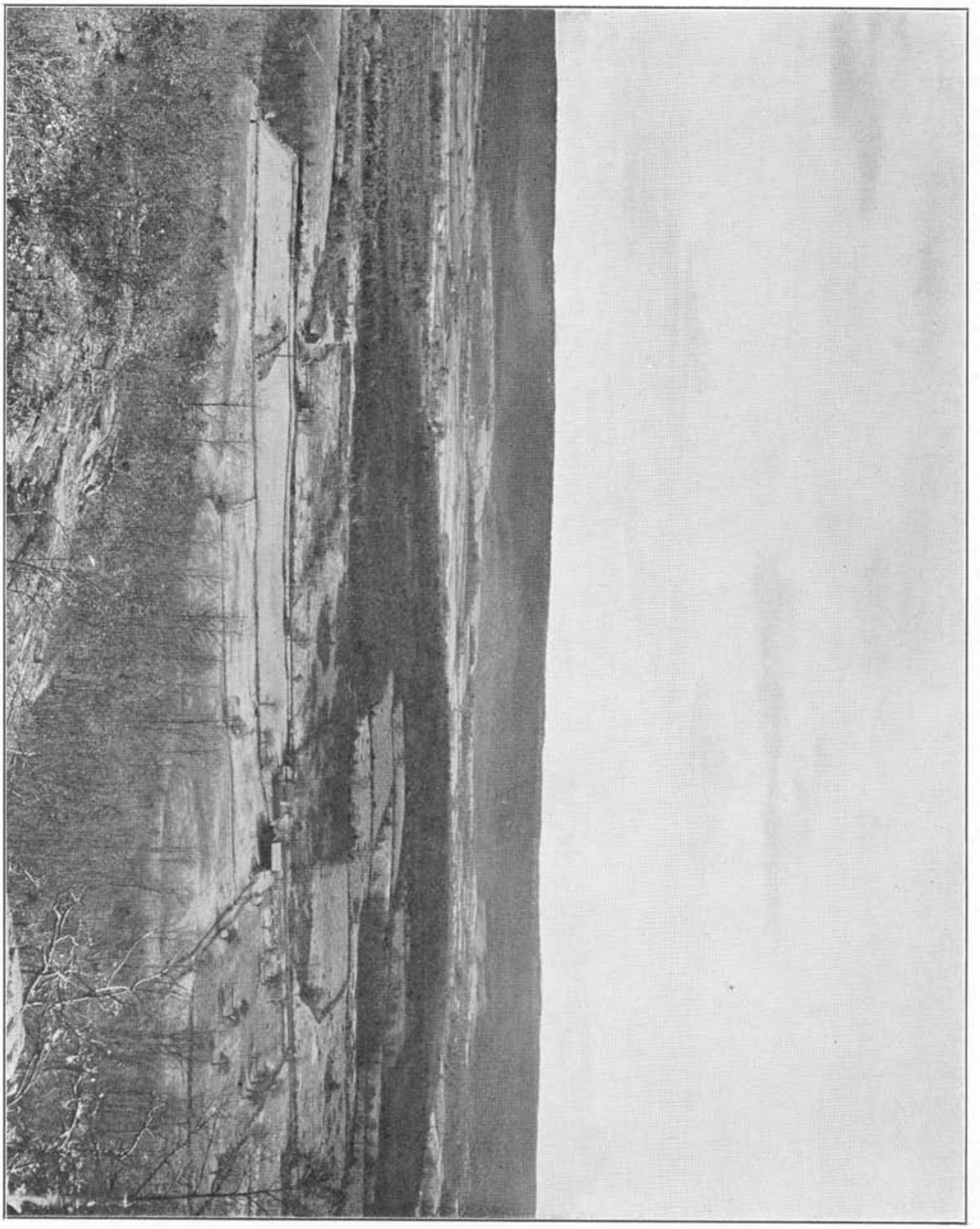
In the previous reports of the Survey the term "Green Pond conglomerate" included equally the beds of Bearfort mountain with those of Copperas, Kanouse and Green Pond mountain. Henceforth it must be restricted to the latter rocks and the conglomerates of Bearfort mountain must be given another name. The one used was proposed by Darton, from the occurrence of the formation in Skunnemunk mountain, New York, although Bearfort is equally applicable and more euphoneous.

STRUCTURE.

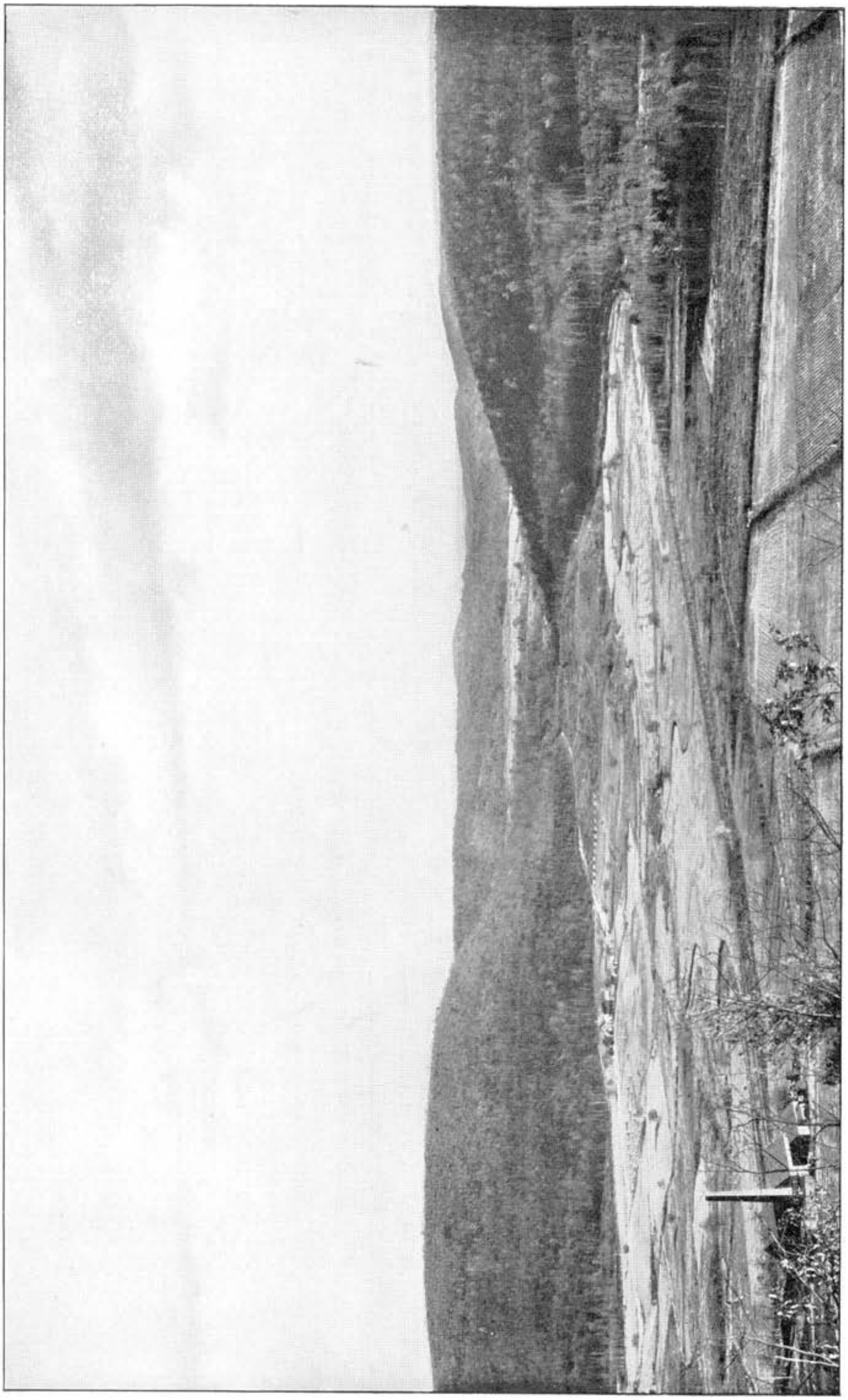
Owing to their hardness the Green Pond and the Skunnemunk conglomerates are pre-eminently ridgemakers, and form the long, straight, steep-sided mountains which characterize this area. The Bellvale flags are also ridgemakers, although to a slightly less extent than the conglomerates, the difference between the two being seen in the difference in elevation between the main ridge of Bearfort mountain formed by the conglomerate and the eastern ridge or bench underlain by the flags, as well as by the general lower level of the region southwest of Clinton reservoir. Locally the basal beds of the Green Pond conglomerate outcrop in low ground, as just west of Gould's quarry and at the old gravel beds a mile northward, where these disintegrated layers were formerly dug for gravel. So, too, some of the Skunnemunk beds underlie swampy depressions along Bearfort mountain, particularly near Cedar pond and near the State line.

The Longwood shales and the Decker Ferry limestones are pre-eminently soft rocks and their outcrops have everywhere been deeply eroded, so that they are now generally found along the lowest lines of the valleys, and exposures are rare. This is true to a greater degree for the limestones than for the shales, the latter being usually found at the base or on the lower slope of the Green Pond conglomerate and quartzite ridges. The Newfoundland grit and sandstone, although a hard rock, is of no great thickness, and outcrops only in the valleys, where it usually forms low knolls or ledges. Locally, however, it makes somewhat conspicuous ridges, the most important of which is on the west side of Greenwood lake opposite the long island. The Monroe shales occur in the valleys, where they form a succession of short, sharply-marked ridges, provided the glacial deposits are not exceedingly thick. These are well shown south of Petersburg and southwest of West Milford. The narrow outcrop of Kittatinny limestone forms a conspicuous depression north of Macopin lake, between Kanouse mountain and the crystallines, and the Hardyston quartzite is not thick enough to form a persistent ridge, although locally it makes conspicuous ledges.

This area presents many structural problems involving folds and faults, although on the whole the relations are not so complicated as seemed to be the case when the Green Pond and Skunnemunk (Bearfort) conglomerates were assumed to be the



Milton Valley and Green Pond Mountain, looking east from the bordering Crystalline Highlands near Russia. The



The Pequannock Gap at Newfoundland, between Kanouse and Copperas Mountains. A cross valley on the hard Green Pond conglomerates.

same. The important flexures and dislocations are shown by the series of sections on plate IV and will be described in connection with a general discussion of the different mountain ridges.

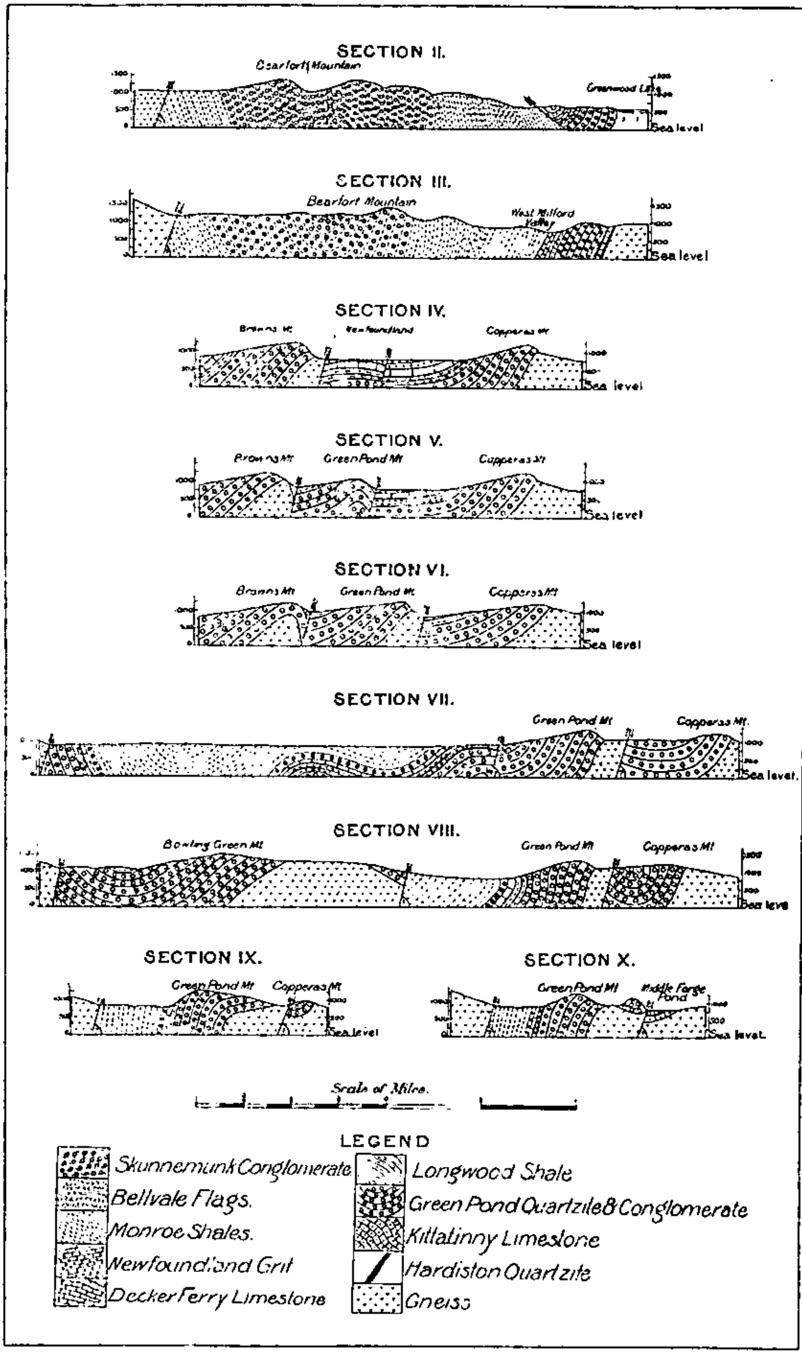
Copperas Mountain.—This ridge extends from Denmark to the Pequannock river, east of Newfoundland, its northern continuation being known as Kanouse mountain. The gap cut by the Pequannock is shown in plate III. The gneiss forms its eastern slope to within about 225 to 250 feet of the crest, above which conglomerate beds appear, dipping from 50° to 60° to the westward. At one of the old mine openings southwest of the Pardee mine the two are exposed within twenty-five feet of each other, but nowhere is the actual contact shown.

At the extreme south end of Copperas mountain, west of Denmark, the conglomerates form an unsymmetrical syncline faulted on its western side as indicated in section IX, plate IV. Here the relations are as follows: On the east ledges of gneiss, dipping 45° to the southeast, are overlaid higher on the hill by the conglomerates, which dip 65° to 80° to the northwest. These dips continue for some distance west of the crest, beyond which, at the base of the westward slope, a high ledge of conglomerate is found with dips of 10° to the southeast. A few rods further westward ledges of gneiss occur. The thickness of the eastward dipping beds is only a fraction of the westward dipping layers, and there can be no question but that most of the western half of the syncline has been faulted off. A few rods westward across the brook the nearly horizontal beds of conglomerate forming the eastern face of Green Pond mountain are visible above the gneiss. Northward the western limb of the Copperas mountain syncline steepens, the dips becoming 44° or 45° S. E., while in the eastern limb the dips range from 55° to 80°. In spite, however, of the increase in dip from 10° to 45°, only a portion of the formation is shown in the western limb, and the fault continues between it and the gneiss along the hollow of Green Pond brook (see map).

Approaching Green pond the axis of the syncline descends the side of the mountain obliquely and underlies the pond, while the mountain for the remainder of its length is composed of the steeply dipping strata of the eastern limb (sections IV, V, VI, VII). The promontory at the lower end of the lake may have as a rock-core the beds of the western limb, but the surface is drift-covered. The syncline pitches gently northeastward, so that whereas at the southern end of the mountain the conglomerates occur in the axis, further north the overlying quartzites are found. For a mile or more northeast of the head of the pond the drift is so thick as to obscure all exposures, but somewhere within this area, or beneath the pond itself, the Longwood shales are brought into the syncline above the quartzite. The continued pitch of the axis brings in the Decker Ferry limestone at Cobb's place, south of Newfoundland, and still further north the Newfoundland grit is exposed, east of Chamberlin's hotel. Owing to the heavy deposits of sand and gravel south of Newfoundland the rock structure in that vicinity is much in doubt. The Newfoundland grit may underlie the gravel plain from the depot southwest to the outcrops of limestone, as indicated on the map, but we have no positive evidence of it. North of Newfoundland the syncline cannot be recognized in the dips.

The fault which cuts off a part of the syncline at the south end of the mountain passes along the northwestern margin of the pond and separates the ledges of gneiss from the Decker Ferry limestone southwest of Cobb's (section VI). The throw of the fault is here about 1,500 feet, with uplift on the west. Northward it diminishes very rapidly, and the fracture probably dies out within a comparatively short distance, as no traces of it were found north of Newfoundland.

Kanouse Mountain.—This mountain, the northward continuation of Copperas mountain, is a simple monoclinal ridge. South of Macopin lake its eastern slope is formed by the gneiss capped by 200 to 300 feet of conglomerate, dipping 45° to 60° N. W. At Macopin lake the conglomerate beds descend to the lake level and the gneiss disappears. North of the lake the mountain is composed entirely of conglomerate and the overlying quartzite, and is separated from the gneiss by a narrow valley underlain by the Kittatinny limestone and perhaps in part by Hudson River shale (Darton). The bottom of the valley immediately west of the mountain is swampy and drift-encumbered, and outcrops are



Sections showing the structure of the Green Pond Mountain Region.
(Location of these sections is shown upon the map in pocket.)

Ledges of Green Pond Conglomerate resting upon Gneiss, Brown's Mountain, Newfoundland.

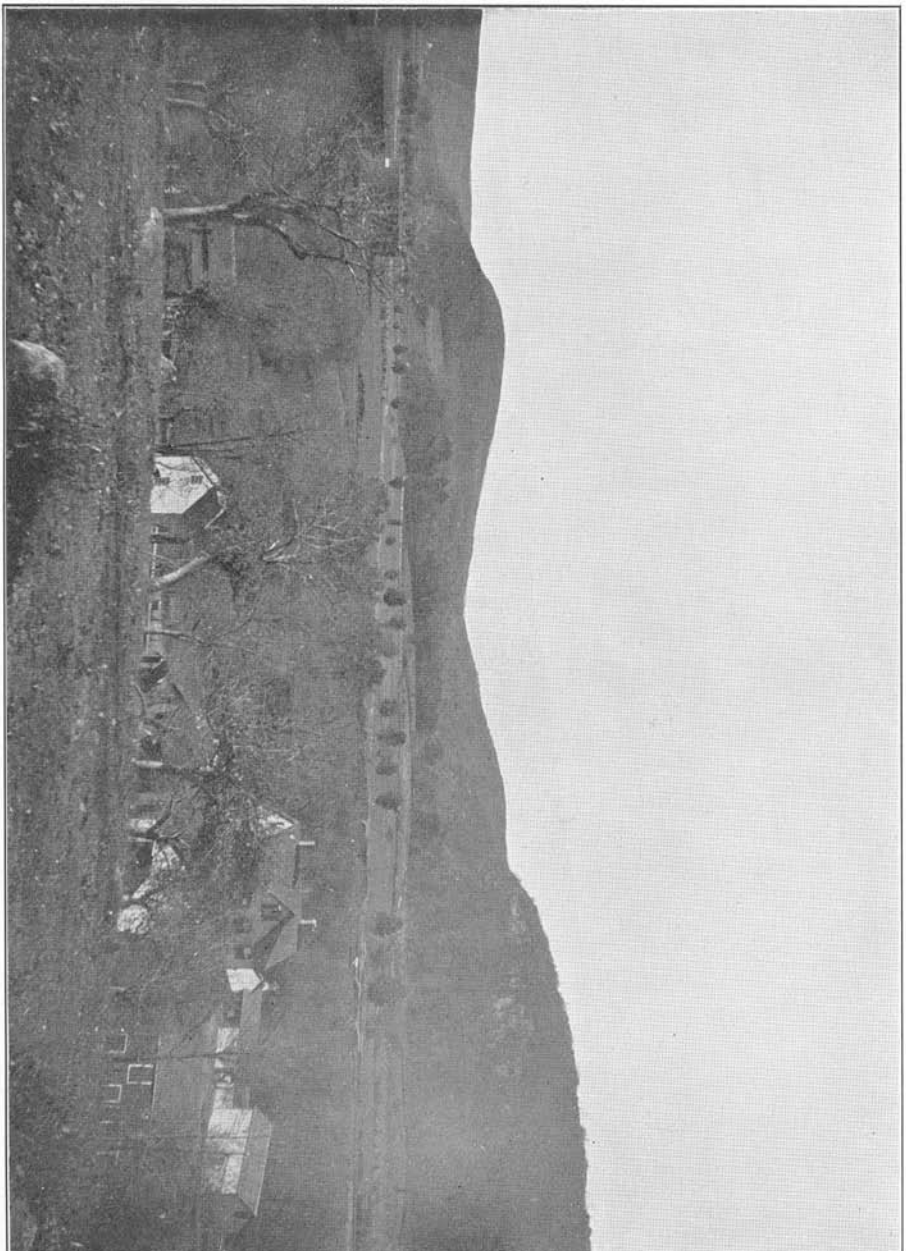
wanting. Towards West Milford the mountain diminishes in altitude, the dips become nearly vertical, or even overturned, and the formation is apparently a little thinner than farther south. It disappears beneath the drift at West Milford, but the ledges of coarse pink and gray conglomerate at the southwest end of Greenwood lake and in the long narrow island mark its northward continuation. Here the beds dip 60° to 75° to the southeast, but the occurrence of the Longwood shales adjoining these ledges on the west indicates that they have probably been overturned.

Green Pond Mountain.—This mountain begins north of the Rockaway river and two miles northwest of Port Oram as a narrow sandstone ridge 200 feet above its surroundings, and terminates a mile south of Newfoundland, a distance of twelve miles. It attains its maximum width, a mile, opposite Lower Longwood, and its greatest height, 1,388 feet (650 feet above the valley), at Upper Longwood.

It is composed of the Green Pond formation, with a core of gneiss on its eastern flank from Middle Forge northward, and presents many of the same features as Copperas and Kanouse mountains, but with some important variations. At its northern end an offset portion, known as Brown's mountain, overlaps it on the west for two miles and a half.

This offset portion rises abruptly at the railroad west of Newfoundland, as an arch or anticlinal fold in the quartzite. The axis of the fold ascends rapidly to the southwest, so that opposite a small reservoir, three-quarters of a mile south of the station, the gneissic core in the axis of the fold is brought to the surface. At the northern end of the ridge, where it rises from the plain, the anticlinal structure is clearly shown, the steepest dip, 70°, being to the southeast. Opposite the reservoir ledges of gneiss form the lower 100 to 150 feet of the steep bowlder-covered slope, above which rise overhanging cliffs, 200 feet or more in height, composed of the conglomerate, with dips of 15° to 30° N. W. (section IV). At several points the eastward face of this gneiss is greatly sheared and brecciated, indicating strongly crushing and faulting. Traced southwest for 400 yards or more the gneiss ledges rise higher on the slope and at length disappear along the crest beneath beds of conglomerate, which wrap over them and dip steeply to the southeast, thus forming the eastern limb of the anticline. A quarter of a mile southwest of the last outcrop of the gneiss, a traverse of the ridge shows the beds of conglomerate dipping 45° S. E. on that flank, nearly horizontal along the crest and changing to 35° N. W. on the northwestern slope (section VI). The axis here has a slight pitch to the southwest, as shown by the slight inclination of the beds along the crest, and the mountain gradually decreases in height in that direction. Where it is crossed by the road from Petersburg to Green pond the Longwood shales are seen to wrap around the disappearing fold. Near Morris McCormick's house, westward and eastward dipping outcrops of the Newfoundland grit afford the last trace of it, unless the eastward dips of the siliceous limestone at the Woodstock forge are in some way due to it.

Merrill and Darton have published sections showing a simple syncline between this offset portion and the main mass of Green Pond mountain. We believe that the facts will not sustain this conclusion, and our interpretation is shown in sections IV, V, VI and VII. Our reasons for postulating a fault along the valley between the two are briefly these: The sheared and brecciated face of the gneiss ledges near the small pond indicate faulting. Without a fault it is necessary to suppose that a great thickness of very hard conglomerates and quartzites underlie the low, swampy ground just east of the gneiss outcrops and at the foot of the high cliffs. But ledges of Longwood shales occur within this area so close to the gneiss that there is not room for the entire Green Pond formation between them. Moreover, an outcrop of the Newfoundland grit was reported by Merrill south of Newfoundland, in the area now flooded by the small reservoir. This bed is probably nearer the gneiss even than the Longwood shales. Section V, which is drawn to scale, shows the necessity of postulating a fault along the east face of Brown's mountain with upthrown on the west, by which the larger portion of the eastern limb of the anticline was faulted off. Since the axis of the fold pitches steeply to the northeast and more gently towards the southwest from the highest point of the ridge, the throw is greatest at that point—



Green Pond and Brown's Mountains from Newfoundland. A fault passes along the gap between the ridges. The plain is probably underlain by the Newfoundland Grit.

equivalent to a thickness of 1,500 feet of strata—and decreases rapidly in either direction.

At the northern end of Green Pond mountain, a mile south of Newfoundland, the structure is also that of a faulted anticline, the axis of which pitches steeply to the northward (section V). By this pitch the hard beds forming the ridge are carried below the level of the valley and the mountain terminates, showing good exposures of the Longwood shales along road where these beds wrap around its end. As the axis rises southward the mountain gains in height, and eastward dipping ledges of quartzite on the east limb of the fold occur just above the road for half a mile. North of Cobb's house the fold is breached along its crest by a deep, narrow ravine, at the head of which the arching over of the strata are well shown. The beds of the western limb here dip 70° to 80° N. W., those of the eastern 50° E., while the axis pitches 20° or more northward. The eastern limb is soon cut off by a fault and a few hundred yards southward the gneissic core is shown at the surface and forms a bench fifty yards in width and several hundred yards in length. Above it rise nearly vertical ledges of conglomerate, the beds dipping 35° N. W. In the low ground east of the gneiss the Decker Ferry limestone outcrops and the east half of the fold is wanting (section VI). Northward from this point the movements of the strata constituted an upward-arching fold (an anticline) with a fracture and faulting along the eastern flank. As the upward movement of the strata increased to the southwestward the movement along the fracture increased at the expense of the folding, so that, except at its northern end, the ridge is only the western half of an anticline, with a great fault along its eastern face.

Along the shores of Green pond the beds on the steep east-facing escarpment dip 45° to 50° N. W., becoming steeper towards the base of the western slope. Between Upper Longwood and Denmark they vary from 80° N. W. on the west side to 35° N. W. on the crest, and 10° to 15° N. W. on the east slope, where they rest upon the gneiss. In the Annual Report of 1884 (p. 45) the ridge is pictured along this section as an unsymmetrical syncline, but our observations do not support this conclusion, a conclusion apparently necessitated by the supposed identity of the Green Pond conglomerate and that of Bearfort mountain.

West of the Middle Forge pond the beds in the high cliff have gentle westerly dips, but lower ledges nearer the pond are much sheared and apparently dragged sharply downward to the east by the fault which is believed to separate them from the adjoining limestone outcrops, section X. Opposite the southern end of the pond is a bold point, terminating abruptly southward, in which the rocks form a close-folded syncline, separated by a gentle anticline from the main ridge on the west. The gneiss outcrops along the breached axis of the anticline and apparently underlies the syncline.

Further south, however, westerly dips only were found, 70° N. W. being noted at the ledges near the old limestone quarry southwest of the pond and 65° N. W. near the crest of the ridge. But south of Berkshire valley, along the Sparta turpike, the dips are 75° to 70° S. E. and are apparently overturned.

South of the Rockaway river this formation does not occur as a continuous ridge, but forms long, narrow isolated hills, in line with Green Pond mountain, but separated from each other and from all other rock outcrops by heavy accumulations of glacial drift, chiefly sand and gravel. The first of these is at the "white rock" cut on the D. L. & W. railroad, two miles west of Port Oram. Here about 185 to 200 feet of white and pinkish sandstones are exposed, all dipping uniformly 45° S. E. Many of the beds are thinly laminated and fissile. The vitreous quartzitic phase, so characteristic of the formation farther north, is entirely absent. Much of the rock is so friable as to crumble to pieces at a gentle blow with a hammer.

Half a mile southwest of this knoll is a long, narrow ridge extending to Kenvil and bordered on the east by the Morris and Essex canal. At various points along this ridge dark red quartzitic sandstone with some conglomeratic layers are exposed. At the openings at the southern end of the hill a synclinal structure is exposed, with dips ranging from 60° on the western flank to 30° on the eastern. Along the crest of the ridge the dip is 35° S. E.

A mile farther south, and east of the Ledgewood station on the Central railroad, white and purple sandstones and conglomerates form another elliptical hill. Here also the structure is apparently synclinal, the axis of the fold lying east of the crest.

Still farther southwest and near Flanders is an ill-defined, drift-covered hill, at several points of which sand pits have been opened. The material is in reality a disintegrated white sandstone with some pebbly beds, and in spite of its dissimilarity to the hard vitreous conglomerate and quartzite of Green Pond mountain, it undoubtedly belongs to the same formation. From occasional undecomposed masses, the dip is seen to be 45° to 60° S. E. Absence of exposures along the eastern flank of the hill renders it impossible to determine whether the synclinal structure prevails here also.

Owing to the isolation of these various outcrops it is not possible to trace the transition in structure from the westward dipping monoclinal ridge near Middle Forge to the synclinal ridge at Kenvil and Succasunna, but since the ridges are apparently the extension of Green Pond mountain, such a transition seems to occur.

One other isolated mass of this formation occurs just southwest of Mt. Arlington station on the D. L. & W. railroad and west of the dynamite works. It is best exposed above the magazines in ledges of gray conglomerate of white quartz pebbles, which dip 40° N. W. towards the gneiss, 200 yards distant. Higher beds of reddish quartzite are exposed at the corners near the old Drakesville depot. The conglomerate undoubtedly is faulted against the gneiss on the west, but its relationship to the ridges of similar rock on the east (noted above) are unknown. as is also the nature of the rocks underlying the low sand plain between them. The simplest explanation is that this ledge forms the western limb of an anticlinal fold, the crest of which formerly was high above the low ground, but has been eroded away. From the occurrence of Kittatinny limestone at Middle Forge and under the whole valley southwest of Flanders, it is believed that these isolated masses of the Green Pond formation here rest upon it rather than on the gneiss.

Longwood Valley.—This valley, which lies west of Green Pond mountain, between it and the crystallines, is underlain chiefly by the Monroe shales, with narrow strips of the Decker Ferry limestone and the Longwood shales along the eastern side. From Upper Longwood southwestward, the valley is deeply filled with glacial deposits, and rock exposures were not found. North of Upper Longwood the beds dip in general steeply northwest, as shown in section IX, plate IV. Along the western side of the valley the Monroe shales abut against the gneisses of the Highlands, from which they are separated by a fault. This fracture can be traced for thirty miles southwest along the northwestern side of German Valley, where it marks the eastern face of Schooley's mountain. This is one of the most persistent faults recognized in the State, but it apparently dies out between Petersburg and Oak Ridge reservoir.

Bowling Green Mountain.—As already noted, this mountain is composed of an anticline of the Green Pond formation wrapped around the northern end of a ridge of gneiss. In general the conglomerate beds are less red than in Green Pond mountain, and are often more gray and white, but the two formations are the same. The outcrop forms a rude crescent, with dips of 35° to 60° to the north, northeast, east and southeast. Outcrops of the Longwood shale occur at the base of the mountain south of Milton. The northeastward pitch of the gneiss core beneath these beds carries them far below the surface in the low ground between Milton and Oak Ridge, so that the Monroe shales and Bellvale flags outcrop in that region. The dying out of the great fault of the Longwood valley, which was caused by the uplift of the gneissic rocks to the surface is apparently coincident with the pitch of this anticline.

At the western end of Bowling Green mountain the conglomerates are folded up against the gneiss in a sharp syncline, the western limb of which dips 75° to 90° S. E. They are probably separated from the gneiss on the northwest by a slight fault, which, however, increases northeastward until at the north end of Clinton reservoir the gneiss and Bellvale flags abut against each other. The conglomerates and quartzites outcrop along the western side of this syncline as far north as Oak Ridge reservoir, where the last trace of them is seen in a small ledge of coarse gray conglomerate on the west side at the water's edge. The overlying Longwood shales, Decker Ferry limestone and Newfoundland grit undoubtedly underlie the reservoir, and the first and third are obscurely exposed along the road across its southwestern arm.

Bearfort Mountain.—This mountain which extends from Clinton reservoir into New York State is for the most part composed of three parallel ridges, and is perhaps the wildest and most rugged mountain in the State. Structurally it is a synclinal fold of the Bellvale flags and the overlying Skunnemunk conglomerate. The Belvale flags form the steep eastern slope and towards the southern end, the eastern ridge also. Moreover, they outcrop along the western side, while the conglomerate with included beds of sandstone and shale forms the main central mass. Toward the southern end the beds of the eastern limb dip from 30° to 70° N. W., and those of the western limb 80° to 85° S. E., the dips being nearly vertical along the axis. Along the gap north of Cedar pond dips of 80° to 90° N. W. occur on the east flank, diminishing to 65° to 85° towards the axis. West of the axis the dips range from 80° S. E. near the center, to 60° or 70° S. E. nearer the flanks. Along the northern gaps the dips are almost all to the southeast, the syncline here being close folded and overturned on its eastern limb. They average 60° S. E. on the west flank, 90° near the center and 85° S. E. (overturned) on the east limb. These relations are shown in sections II and III, plate IV.

The axis of this fold rises gently both northeastward and southwestward, finally carrying the conglomerates above the present surface, so that in the northern portion of Bellvale mountain, N. Y., and southwest of Clinton reservoir they have been eroded away and the Bellvale flags are found along the central portion of the fold. The continued rise of the axis, becoming more rapid towards Milton, at length brings to the surface the Green Pond conglomerate in the sharp syncline on the west side of Bowling Green mountain, as described above. Throughout its entire length from the west end of Bowling Green mountain to the State line the syncline is bordered on the west by a fault which brings the gneiss in contact in succession with all the formations from the Green Pond conglomerate to the Bellvale flags, although owing to the glacial deposits the actual contacts are nowhere seen.

West of Greenwood Lake.—West of the southern end of Greenwood lake the structural relations are slightly complicated and our observations do not bear out the conclusions of previous observers. At the southwest end of the lake eastward dipping ledges of coarse, grey conglomerate form the end of a gravelly point in the lake. Southwestward along the strike and west of the road ledges of reddish conglomerate and quartzite outcrop north of the corner. We have no hesitation in referring both of these exposures to the Green Pond formation, the southeastward dips being an overturned structure agreeing with the overturned dips of the east flank of Bearfort moutain to the west and of the north end of Kanouse mountain to the south. This conclusion is strengthened by an outcrop of Longwood shale in a low swell west of the purplish quartzites.

A few rods west of these exposures is the southern end of a narrow steep-sided ridge which extends northward two miles or more. In the shallow depression between this ridge and the low swell of Longwood shale are the old "hematite" openings, already mentioned several times, where fragments of the Decker Ferry limestone were found. On the eastern slope of the steep ridge are ledges of a hard white quartzite and grit, grading upward into a greenish sandstone—the Newfoundland grit. These beds dip 35° N. W., a gradual change from the overturned dips of the Green Pond formation near the lake to the normal dips being clearly traceable. Higher on the slope and along the crest the basal beds of the Monroe shales outcrop, while on the west slope, which is here very steep, the hard greenish sandstones and below them the white quartzite and fine-grained conglomerate of the Newfoundland grit is again exposed with an average dip of 65° S. E. In brief, then, the ridge at this end is a syncline of Newfoundland grit with the basal portion of the Monroe shales in the axis. Thirty-five feet west of the lowest outcrops of the white grit the black Monroe shales again appear in a series of low knolls which extend westward to the lower slope of Bearfort mountain. Owing to the strong cleavage the dip is not easily determined, but it was finally fixed at 65° S. E. Inasmuch as these pass upward into the Bellvale flags on the west, the beds are here overturned, and are separated from the synclinal ridge of grit by a fault. These relationships are shown in figure 2, repre-

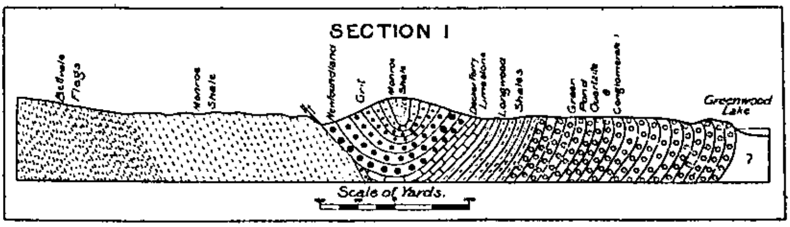


Figure 2.—Section at the southwest end of Greenwood Lake.

senting a section from Bearfort mountain to Greenwood lake at the hematite openings.

The strike of these beds is such that northward those on the east limb of the syncline soon pass into the lake, and opposite the long island only the western limb of the fold is seen. Traced northward the beds of grit and quartzite on the west side of the ridge ascend the slope and soon form its crest, while the Monroe shales in the axis of the fold are seen on its eastern slope and along the highway at the shore of the lake. At Dr. Peters' cottage still further north the grits form the lower eastern slope of the ridge and the Monroe shales west of the fault form the crest. The western limb of the fold finally passes into the lake, the last exposure of the Newfoundland grit being seen in the rocky point about a mile south of the State line. In this vicinity the evidence of the overthrust of the grit upon the Monroe shale west of it is somewhat clearly shown. We have described this region in considerable detail for the reason that Cook* represented an eastward dipping monocline from Bearfort mountain to Greenwood lake, and Darton† mentions an *anticlinal* ridge of Oriskany here which we were not able to find.

West Milford Valley.—South of Greenwood lake for several miles there are no rock exposures, the valley being deeply filled

* Geology of New Jersey, 1868, p. 149.
† Bulletin Geological Society of America, Vol. V, p. 386.

with glacial drift. Southwest of West Milford, however, the valley between Bearfort and Kanouse mountains is occupied chiefly by the Monroe shales, with probably narrow outcrops of the Newfoundland grit, the Decker Ferry limestone and the Longwood shales along its eastern side. Throughout most of the valley the dips are steeply 70° to 80° N. W., although near West Milford the shales are overturned and dip 80° to 85° S. E., so that the valley apparently has a monoclinal structure. South of Postville, however, at the corner of the road to Clinton reservoir, a gently folded anticline is shown in a prominent ledge of Monroe shales by the roadside. On either flank the beds dip about 30 , although the bedding is somewhat obscured by the cleavage. Half a mile northward no trace of this fold was discernible in the dips, although the ridge was continuous and outcrops across it were frequent. The dips are uniformly to the northwest, increasing from 57 on the eastern slope to 70° along the crest and 80° on the western slope. Examination of all the exposures between these two sections indicated that the east flank of the anticline steepened rapidly and within half a mile became overturned, so that the northern section would apparently show only a monoclinal structure. Since this fold is in line with the flexure at the northern end of Green Pond mountain the two may be the same, but between them is a considerable area in which no rock exposures are found.

Summary.—Along the eastern border of the Green Pond area the sedimentary rocks rest unconformably upon the crystallines, but are faulted against them on the western border, except where the conglomerate beds of Bowling Green mountain rest upon the gneiss. A fault also marks the eastern side of Green Pond mountain and another separates it from its offset, Brown's mountain on the west. Both of these fractures apparently die away rapidly northward into folds, as is the case also with the fracture on the west side of Longwood valley.

Kanouse and Copperas mountains are monoclinal ridges, except at the southern end of the latter where it is a synclinal fold faulted on its western flank. Green Pond mountain is a monoclinal ridge marked by a fault along its eastern margin, except at its northern end, where it is a pitching anticline faulted on its eastern limb. Brown's mountain is an anticlinal ridge with axis pitching steeply northward and gently southward and faulted along its eastern flank. Bowling Green mountain is a semi-quaquaversal anticline, pitching steeply northeast with a sharply-marked syncline at its western end. The northeastward pitch of this syncline brings in the Bellvale flags southwest of Clinton reservoir and has preserved the Skunnemunk conglomerates in the closely pressed fold of Bearfort mountain. Longwood valley is apparently monoclinal in structure and the West Milford valley is essentially the same, but with probably one or two small close folds.

CONDITIONS OF FORMATION.

The full discussion of the conditions under which these formation were deposited will be deferred until the publication of the report upon the Paleozoic formations which is now in preparation, but a few of the most obvious conclusions may be here stated in order to emphasize the fundamental facts.

All geologists are agreed that these and similar formations were deposited in bodies of water, in great part at least beneath the sea. The reasons for this conclusion are many, the presence of remains of marine animals in many of the beds being the most conclusive. It is well recognized that the beds of conglomerate are nothing more than beds of gravel, which since their accumulation have been consolidated into hard rocks. The sandstones were once beds of sand, the shales, beds of clay and the limestones beds of limy mud composed chiefly of the ground-up fragments of shells, coral reefs and other animal remains.

Similar deposits are being formed along the shores and in the deeper waters off the coasts of the continent at the present time. Beds of gravel and sand are accumulated along the present beaches and in the shallow water near shore, where the waves and currents are sufficiently strong to carry the coarser material. Farther from shore where the water is deeper or in protected places where the motion is gentle, only the finer material is deposited and beds of clay are formed, while around coral reefs and far from shore where the material from the land does not reach, remains of shells, coral mud, etc., are deposited. We must conclude, therefore, that when these formations were deposited, the area under discussion was ocean-bottom in which horizontal beds of gravel, sand and clay were successively formed, and since the formations attain a thickness of more than five thousand feet, it must have remained beneath the sea for an enormously long time. Since, moreover, the deposits range from coarse conglomerates to limestones, there must have been great changes in the force of the currents and the depth of water during this period to permit the formation of such different deposits to such thicknesses. Furthermore since heavy conglomerate beds occur both near the base of the series (the Green Pond conglomerate), and also at the top (Skunnemunk conglomerate), similar conditions must have occurred at different intervals in this period.

Judging, therefore, from their resemblance to modern deposits in our oceans we can make a few inferences as to the successive conditions under which the rocks were formed. At the base we find the Hardyston quartzite, a fine gravel formation, probably not more than thirty feet thick. It represents a period when the water was shallow and the shore line of the sea was not far away. For reasons which are not apparent without the study of a much wider area than this, we know that the land at this time lay chiefly to the southeast while the ocean stretched mainly to the northwest.* The somewhat abrupt passage of the Hardyston quartzite into the overlying Kittatinny limestone indicates that the shallow waters, turbid with sand and gravel from the nearby shore, were succeeded by clearer, probably deeper water, in which there was little land derived sediment but much limy material, so that limestones instead of sandstones were formed. This

* Darton and Walcott have held that the rocks of this region, at least those subsequent to the Cambrian limestone, were deposited in an inlet separated by a land area on the west from the great sea, which lay still further west. We have observed no facts in the New Jersey area which necessitate this assumption. On the contrary, we believe that the weight of evidence there favors the view that these formations were formerly continuous with the corresponding beds in the Kittatinny valley and northwestward. Recognizing, however, that the evidence in New Jersey is not decisive, and not having had an opportunity of examining critically the field in New York, we are unwilling to oppose the conclusions of these workers, although from what we have seen we are inclined to believe that the facts are capable of a different interpretation from that of Mr. Darton. In any event, there can be no doubt but that the seas in which these beds were formed had a much wider extension than the present area of the formations.

change was probably brought about by a somewhat rapid retreat of the shore line to the southeast, and the advance of the sea over what had formerly been land, changes apparently due to the gradual subsidence of the continent.

At Gould's quarry the Green Pond conglomerate rests upon the eroded surface of the Kittatinny limestone, which indicates that after the formation of the limestone, and perhaps of even higher beds, an elevation of the land brought this region above sea-level and permitted the erosion of these beds. The limestone was greatly eroded and seems to have been entirely removed from much of the region, since over wide areas the Green Pond conglomerate rests directly upon the underlying gneiss. The amount of limestone worn away during this period of erosion was probably considerable, since in Warren and Sussex counties it is between 2,000 and 3,000 feet thick and in this region apparently not more than 130 feet is preserved. Although it does not necessarily follow that its original thickness here was as great in Sussex county, nevertheless, the period of erosion must have been a long one. At its close, however, marine conditions were reestablished.

The heavy beds of coarse conglomerate in the Green Pond formation indicate a subsidence of the land with a return of the sea and the formation of a thick beach deposit, the shore-line being at no great distance. The passage upward from the conglomerates into the quartzites, thence to the Longwood shales, and finally to the Decker Ferry limestones, indicate a gradual but steady advance of the ocean upon the land to the southeast, and the deepening of the waters within this region, so that the land-derived sediments became progressively finer and less abundant until at last the clearness of the water permitted the growth of corals and numerous other forms of marine life, the remains of which have formed the thin limestone beds.

Above the limestone comes a pebbly quartzite and sandstone, the Newfoundland grit, which grades upward into the fine-grained black Monroe shales. Here we have evidence again of shallow waters, probably near a shore, with currents capable of moving coarse sand and pebbles up to half an inch in diameter, followed in turn by deeper waters and finer sediments. The actual relationship of this grit to the underlying limestone is nowhere exposed in this region, so that we cannot say with certainty how the transition from the previous limestone-depositing seas to the subsequent gravel-carrying waters was brought about. But the apparent absence here of formations which elsewhere occur between the two, indicate that the deposition of the limestone was terminated by an uplift which raised it above sea-level and permitted the erosion of some beds. A later downward movement again permitted the incursion of the sea to this area and the deposition again of a fine-grained conglomerate followed by a sandstone and shale as the sediments changed from gravel to clay.

We find, however, that at this advance of the sea the shore-line did not retreat far enough to the southeast to establish clear water conditions and permit the growth of coral reefs and the deposition of limestone following the Monroe shales, as was the case following the Longwood shales. On the contrary, the Bellvale flags and the Skunnemunk conglomerate indicate that the sediments became coarser and coarser again, as if the neighboring land areas were being uplifted, the shore advancing upon the ocean, and the streams bringing to it coarser material, so that towards the close of the period pebbles of six or seven inches in diameter were rolled about by the waves and currents and deposited with finer material to make up the great conglomerate beds of the Skunnemunk formation. Many of these pebbles are lithologically identical with the quartzite beds in this Green Pond formation, and seem to have been derived from it. From this it is inferred that the sea at this time did not extend so far to the southeast as at the earlier period, and that somewhere in that direction the Green Pond formation was at this time exposed to erosion. Whether or not higher beds than the Skunnemunk conglomerate were still later deposited in this region we do not know from any observations made here. If so, all traces of them have been worn away.

The conditions of formation being such as we have outlined above, it follows that each of the formations was once more widespread than at present. Each succeeding formation was laid down upon the preceding one, and buried it deeply out of sight. Farther to the southeast, that is nearer the old shore-line, some of the older formations may have projected beyond the covering of later ones, or one of the younger beds may have overlapped the edges of those immediately beneath it, but for the region here described that does not appear to have occurred. Here each formation seems in turn to have covered the one beneath it, the entire mass having a thickness of apparently more than 5,000 feet.

At length the region was permanently uplifted above the sea, and added to the continental area. It was probably during this uplift that the rocks were, in part at least, bent into their present folds and at the same time faulted. Very little is known of the causes in the earth's interior occasioning this uplift. That it was due chiefly to enormous horizontal pressure exerted along a northwest-southeast line is shown from the direction and parallelism of the axes of the folds. That it was due in some way to the cooling and shrinking of the earth's interior is the common hypothesis. That the movement was very slow is altogether probable; that it was not due to any sudden convulsion of nature or upheaval such as were so frequently referred to by the earliest writers of geology and still linger in the popular mind is certain. That it was in any way the result of an earthquake or volcanic eruption is out of the question, although in the course of our studies this explanation has been more than once suggested to us by persons who had noted the overhanging cliffs, the steep talus slopes of huge bowlders and the evidently fragmental character of the rocks. For the sake of these it may be said here that there is not the slightest trace of volcanic action in the formations, and what is commonly supposed to be such is rather the work of frost, running water and waves.

Relation of Structure and Topography.—As the region rose above the sea the topography and the extent of the strata were greatly different from the present. The youngest formation must have at first concealed the underlying beds, and all the strata probably extended far beyond the limits of their present outcrops. In order to restore even approximately the conditions which then prevailed we should have to extend the Longwood shales, Decker Ferry limestones, Newfoundland grit and Monroe shales, which now outcrop in the valleys, up the slopes and over the crests of the adjoining ridges. The great thickness of Bellevale flags must then be restored to its former extent above them, and lastly over all would stretch the beds of the Skunnemunk conglomerate, the whole series no doubt reaching considerable distances both east and west of the present borders of the region.

It is evident that as the region apeared above sea-level, the arches of the folds or anticlines formed ridges and were first subject to erosion. The down-folds or synclines formed valleys and appeared later. Since the elevation and folding were probably very slow the tops and slopes of the anticlines were probably much eroded before the bottoms of the synclines appeared, so that the topography even at that time was not exactly the same, as it would be, if we were now to restore all the strata eroded from these folds. But, nevertheless, it is evident that unless the uplift was no faster than erosion could wear down the strata, the anticlines must have formed ridges, the synclines valleys, and high cliffs must have marked the fault lines for a long time after this region was first uplifted. The southern end of Copperas mountain was then a synclinal valley, as was also the entire length of Bearfort mountain, while the steep sides of high ridges rose over the West Milford valley.

If we compare with this the present topography we see how great have been the changes. The synclines do not now always form valleys and the anticlines ridges. In the two conspicuous cases just cited synclinal folds now form mountains, and valleys occur, not where the rocks are bent downward to form troughs, but where soft rocks outcrop at the surface. It is evident, therefore, that the denudation which this region has experienced has been enormous. Thousands of feet of strata have been removed from even the tops of these mountains in the enormously long periods which have elapsed since the region appeared above sea-level. It is not necessary to visit the Grand Canyon of the Colorado to find evidence of enormous denudation. The testimony of the mountains and valleys of northern New Jersey is just as decisive and convincing, although the facts are a little more difficult to read. But we have not space to enter into the details of this story, however wonderful it may be. It has already been told in a previous Report of the Survey.* Attention may be called,

* Vol. IV of the Final Reports. The Physical Geography of New Jersey, R. D. Salisbury.

however, to two factors which in a large degree have determined the greater topographic features of this region.

The first of these is the contrast in the hardness of the strata, and the second is their position with respect to the baselevel of erosion. In consequence of the contrasts in hardness some beds have better resisted erosion than others, and consequently retain to a greater degree their original heights. The fact that certain formations are pre-eminently ridge-makers and others are always found in the valleys has already been pointed out. The explanation is not, as is commonly supposed, that the strata in the mountains have been raised to a higher level than those in the neighboring valleys. In fact, as shown by the folds, some of these mountains were lower than their surroundings when the folding and uplift ceased. The true explanation is found in the greater hardness of the beds in the mountains, whereby they have better resisted erosion and so made the mountains. The adjoining beds, since they are softer, have been worn down faster and have at length become lowlands, even though at first they may have been higher.

The influence of the second factor—the position of the strata in respect to baselevel—is also strikingly shown. At the north end of Green Pond mountain, and of Brown's mountain, its offset portion, the pitch of the strata carry the conglomerate and quartzite, which, because of their hardness, make the mountains far below the present surface. The beds which here overlie them are so much softer that they have been deeply worn away and hence the mountains terminate. The conglomerates and quartzites continue northward but at levels far beneath the present surface, so that they have not yet been revealed by erosion. Along the mountain, however, the folding raised these beds so high above the sea-level that the erosive agencies were enabled not only to strip off the overlying beds to a thickness of several thousand feet, but also to wear away the softer layers on either side, leaving the hard ledges to form the mountains. In the same way, too, the northeastward pitch of the hard beds of Bowling Green mountain carries them far beneath the surface over the low areas east of Milton and north of Petersburg. The overlying Monroe shales, being so much softer, have been deeply eroded and now form the lowlands. On the other hand, the gradual southward rise of the axis of the syncline in Bearfort mountain at length carried the conglomerate so high above baselevel, that southwest of Clinton reservoir it was particularly subject to attack and was at length worn away, thus exposing the underlying softer flags. These were thereupon eroded somewhat rapidly, so as to terminate Bearfort mountain northeast of the reservoir, where the conglomerate ends. Other similar instances might be given, but enough has been said to indicate the dependence of the present topography upon the contrasts in hardness of the strata, and their altitude with respect to base-level.

HISTORICAL SUMMARY.

The list of papers describing this formation has already been given. We add here a brief summary of the conclusions of previous observers that the various interpretations may be compared.

In 1836 Henry D. Rogers,* then State Geologist, described the conglomerates of this region and suggested that they might be coeval with the Potomac marble conglomerate, meaning the conglomerates along the northern border of the Trias or Newark formation. From his description it is evident he did not separate the conglomerate of Bearfort from that of Green Pond mountain. In his final report, 1840, Rogers describes the extent of the formations at greater length, reiterates the identity of the two conglomerates, differentiates the red quartzites from the conglomerates, and estimates the thickness of the latter at more than 600 feet. He states that their dip is usually 30° west-northwest, and infers the presence of longitudinal faults to explain the repetition of the strata in monoclinal ridges. The isolated area near Flanders is supposed to be part of a much older formation which was the probable source of the arenaceous material of these beds. The extension of these beds southwestward along German Valley as far as Clinton in Hunterdon county, and their connection with the middle secondary (Newark) formation there, are regarded as probable.

* Loc. Cit.

In 1839 Dr. William Horton* described portions of the New York extension to these rocks, but did not consider the New Jersey area, nor attempt to correlate them.

Prof. W. W. Mather† in 1843 was the first to recognize the correct position of some at least of these formations. The red shales, grits and red and white conglomerates were regarded as "the equivalents of the west side of Shawangunk mountain, and of the central portions of New York (the Medina sandstones, Oneida conglomerates, Onondaga salt group and gray sandstone)." He also stated that it was the same formation as that described by Prof. Rogers as occurring near Green pond. While Mather was correct in so far as the Green Pond conglomerates and quartzites are concerned, he was in error as to the conglomerates and shales in Bearfort (or Long pond), Bellvale and Skunnemunk mountains.

In 1868 Dr. George H. Cook,§ State Geologist, described this region in considerable detail, tracing the boundaries of the various formations and adding much to our knowledge of their relationships. The fossiliferous limestone at Longwood, Woodstock and Newfoundland (the Decker Ferry formation), mistakenly identified as Trenton, was seen to overlie the red shales, quartzites and conglomerates of Green Pond mountain, and apparently determined their horizon as younger than Trenton. Since over wide areas these beds rested upon the gneiss they were consequently regarded as Upper Cambrian (Potsdam), and equivalent to the conglomeratic quartzite found elsewhere between the gneiss and the magnesian limestone. The Monroe shales, owing to their position above the fossiliferous limestone, were regarded as the Hudson River shale, which they resemble somewhat closely. The conglomerate of Bearfort mountain was regarded as the same as that of Green Pond mountain on account of their lithological resemblances. The occurrence of the magnesian (Kittatinny) limestone at Middle Forge, Gould's and Cisco's quarries and the relations there exposed were interpreted as demonstrating

* Third An. Rep. of W. W. Mather, Geologist of the 1st Geol. Dist. of the State of New York, 1839. Appendix by Dr. Wm. Horton, pp. 146-7, 153.

† Geology of New York, Pt. I, Albany, 1843, pp. 362-363.

§ Geology of New Jersey, 1868, pp. 79-89, 133-134, 143-144, 148-149, 153, 163.

the superposition of the limestone on the Green Pond conglomerate, the thin bed of Hardyston quartzite being correlated with the latter. The masses of reddish conglomerate in the lower portion of the limestone which we interpret as material which washed into fissures in the limestone (pp. 7-8), were believed to demonstrate the younger age of the limestone. West of the southern end of Greenwood lake the exposures of the Green Pond conglomerate and Longwood shales were correctly referred to the Oneida and Medina formation respectively. The outcrop of the Newfoundland grit (Oriskany-Corniferous) on the western limb of the synclinal ridge was also regarded as Oneida, while the Monroe shales (Hamilton) on the west were put with the Hudson River shale, and those along the crest of the syncline were regarded as the Cauda-Galli shale. Obscure markings resembling this fossil do occur on these beds, but the later discovery in them of Hamilton fossils and the correct identification of the underlying grit has placed these beds in their proper position. As shown by one of the published sections, the conglomerates along the crest of Bearfort mountain were believed to underlie the shale, the overturned dips being mistaken for the normal position. On the geological map accompanying the report the areas are colored in accordance with the above classification. Although subsequent work has shown that to a large extent these correlations were incorrect, yet this report and the geological map gave the first detailed description of the region and the distribution of the most important formations, and in so far has afforded a substantial foundation for subsequent workers.

The next important contribution to the history of this region was made by Prof. D. S. Martin,* who in 1871 announced the discovery of fossil plants in the Bellvale flags on Skunnemunk mountain and fixed their "age as Devonian, probably of the Hamilton group."

In 1884 Prof. J. C. Smock,† then Assistant State Geologist, made a re-examination of the rocks of this region, and his conclusions are published in the Annual Report for that year. He

* Proc. Lyceum Nat. Hist., New York, Vol. I, p. 259.

† Annual Report of the State Geologist, 1884, pp. 29-56.

reviewed in considerable detail the observations of previous workers, giving an elaborate summary of the work already done. His conclusions were based on a study not only of the New Jersey but of a portion of the New York area. The conglomerate of Bearfort and Skunnemunk mountains was still considered as identical with that of Green Pond, Copperas and Kanouse mountains. As the Devonian age of the flags and conglomerates in Skunnemunk mountain was considered as demonstrated by structural and faunal evidence, the Green Pond conglomerates and quartzites were also regarded as Devonian. The Monroe shales were still classed as Hudson River, and the previous identification of the fossiliferous limestone as Trenton was not questioned. The *higher* structural position of the conglomerates of Bearfort mountain as regards the Oneida conglomerate at the southwest end of Greenwood lake was recognized. The inferior position of the magnesian limestone as regards the Green Pond conglomerate, at Cisco's and Gould's quarries and at Middle Forge, was correctly given, but the erroneous correlation of the fossiliferous limestone and the Monroe shales made necessary the supposition that they underlay the conglomerate at Longwood and Woodstock. The structure of Green Pond mountain was therefore represented as an inclined syncline. The synclinal structure of Bearfort, Copperas and Kanouse mountains was asserted, a conclusion true for Bearfort and the southern end of Copperas, but erroneous for the others. Various estimates of the thickness of the formations are given, "1,000 feet, including the shales, slates, sandstones and conglomerates, or the whole series," being considered probable for the New Jersey area.

In the following year, 1885, Darton* "found that the fossiliferous limestones in the Green Pond region were Helderberg in age," and while our identifications, based on the collections made the past season, differ slightly from this, yet this determination marks a notable advance in the study of this region. The approximately Oneida age of the underlying conglomerate in Green Pond, Copperas and Kanouse mountains was thus determined.

The following year, 1886, Dr. N. C. Britton and Mr. F. J. H. Merrill re-examined the region, and the results of their work

* Bull. Geol. Soc. of Amer., Vol. V, p. 370.

appeared in the Annual Report of the State Geologist for that year. In several respects it was the most complete presentation of the subject up to that time. All the formations between the Green Pond conglomerate and the Bellvale flags were recognized and described, but the names we have used were not applied to them. The Skunnemunk conglomerate, however, in Bearfort mountain was still correlated with the Green Pond conglomerate. The most important discovery was the finding of Oriskany-Corniferous fossils in the white grit and sandstone east of Newfoundland and elsewhere, thus proving the presence of Lower Devonian beds. Estimates of the thickness of these formations were made and something of definiteness was added to our knowledge in this direction. Furthermore the unconformable contact of the Green Pond conglomerate and the limestone at Gould's quarry was asserted. The anticlinal structures at the end of Green Pond mountain and its offset spur were clearly set forth, but we are not able to agree with other conclusions regarding the structure as shown by several of their sections.

The work of Mr. Darton in this region commenced in 1885 and continued at intervals for a number of years. In 1894 he published* a most important paper covering both this region and the adjoining New York area and accompanied by a map and many sections. Each of the formations is carefully described, and the principal stratigraphical features indicated. To Mr. Darton belongs the credit of being the first to recognize the diversity of the Green Pond and the Skunnemunk conglomerates, a most important advance in the correct solution of the problem, for much of the confusion and many of the contradictory conclusions have been due to this error. He was also the first to demonstrate the post-Odovician age of the fossiliferous limestones at Longwood and Newfoundland, and so to corroborate Mather's inference that the Green Pond conglomerates were equivalent to the Oneida. He also first applied the terms Longwood, Monroe, Bellvale and Skunnemunk to their respective formations. His description of the stratigraphical features is full and in all the main features correct for New Jersey, and most of his conclusions are corrobo-

* Loc. Cit.

rated by our observations which were made without a knowledge of the details of his work. Later, with his interpretations in mind, re-examination was made of the points in which we were found to differ from him, and our conclusions on these points were reached after careful consideration of both sides of the question.

Previous to the publication of Mr. Darton's chief paper, but after his work had been done, Mr. Walcott* visited the region and independently arrived at the conclusion that the Skunnemunk and Green Pond formations were diverse and that the formations ranged from Lower Cambrian to Upper Devonian. He was the first to determine the presence of the Olenellus fauna in the limestones east of Kanouse mountain and so establish their age by positive evidence, although their identity with the magnesian limestone of the Kittatinny valley had been asserted by Cook in 1868, and their Olenellus age had been inferred by Foerste a few months previous to Walcott's visit.

This review would not be complete without mention of the able summary of the various views published by C. S. Prosser† in 1892, and his discussion of the age of the plant remains found in the Bellvale flags on Skunnemunk mountain. No field-work was done in the New Jersey area, but his determinations strengthened the previous conclusions that these beds are Middle Devonian.

From this review it appears that many workers have contributed to the solution of these problems. Little by little correct determinations have been made and errors eliminated. The inferences of earlier investigators based upon meager facts have in some cases been confirmed by later detailed work. Although the earliest correlations of the State Survey were to some extent erroneous, yet the wealth of facts concerning the geographical distribution and the structural relations then collected afforded a firm foundation on which later workers could build.

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* Amer. Jour. Sci., 3d Ser., Vol. XLVII, pp. 301-311.

† Loc. Cit.

PART II.

Artesian Wells

By LEWIS WOOLMAN.

Artesian Wells.

OUTLINE.

INTRODUCTION.

I. Wells in Southern New Jersey.

At Anglesea.
At West Mills, near Parkdale.
At Bridgeton.
At Millville:
    Shallow wells.
    Deep wells.
At Island Heights.
At Toms River.
At Spring Lake.
At Belmar.
At Keasby's Landing.
At Perth Amboy. Two locations.
At Runyon.
At Lorillard.
At Vincentown.
At Cresson or Milford.
At Camden.
At Fish House.
At Torresdale, Pa.
At Philadelphia, Pa., foot of Chestnut St.
At Mount Ephraim or Hedding.
At Audubon.
At Clarksboro.
At Sweedesboro and north of.
At Tomlin Station.
At Mullica Hill.
At Pitman. Two wells to different water horizons.
At Kirkwood, N. W. of.
At Stratford.
At Laurel Springs. Sixteen wells.
At Blackwood.
At Clementon and west of. Three locations.
At Fairview, south of.
At Monroe Station.
At Corses Landing.
At Penns Grove.
At Pedricktown, N. W. of.
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Between Woodstown and Sharptown.
At Alloway, east of. Two wells.
At Penton, south of.
At Salem and west of.
At Fort Dupont, Del.
At Middletown, Del.
At Atlantic City. Deep well, 2,306 feet.
At Atlantic City. Deep wells, 833 to 843 feet.
At Atlantic City. Shallow wells, 80 feet.

II. Wells Mostly in Northern New Jersey.*

Sec. 1.—Wells reported by W. R. Osborne.

At Metuchen. Two locations.
At New Brunswick. Two locations.
At Oak Tree. Two locations.
At Park avenue, near Plainfield.
At Plainfield.
At Sand Hills.
At Valentine Station.

* The data in this and the following sections were furnished by the various operators. While it is believed that the records are accurate, the Survey has had no opportunity to examine specimens from the borings, or to verify conclusions. H. B. K.

Sec. 2.—Wells reported by P. H. & J. Conlan.

At Arlington. Two locations.
At Belleville.
At Hoboken.
At Harrison.
At Lake Hopatcong.
At Newark.
At New York. Two locations.
At Governor's Island, New York Harbor.
At Passaic.
At Pompton.
At Paterson.
At Plainfield.
At Waverly.

Sec. 3.—Wells reported by Stotthoff Bros.

At Alpha.
At Bayonne.
At Belvidere.
At Elizabeth. Three locations.
At Elizabethport. Five locations.
At Flemington.
At Linden.
At Lodi.
At Martins Creek.
At New Orange.
At Oxford.
At Passaic.
At Pennington.
At Sandts Eddy.
At Tranquillity.
At Westfield.
At White Hill.

Sec. 4.—Wells reported by Harry E. Estes, Ridgewood, N. J.

At Allendale. Four locations.
At Bogota.
At Belleville.
At Demerest. Three locations.
At Englewood.
At Fairlawn.
At Hillsdale. Four locations.
At Hohokus. Five locations.
At Harrington Park.
At Hoboken. Four locations.
At Midland Park. Three locations.
At Maywood. Eight locations.
At Mahwah. Three locations.
At Montvale. Two locations.
At North Paterson. Five locations.
At Oradell. Three locations.
At Paramus. Six locations.
At Paterson. Two locations.
At Palisade Park.
At Park Ridge. Two locations.
At Ridgewood. Fifty-seven locations.
At Saddle River. Three wells.
At Tenafly.
At Woodcliff. Nine locations.
At Waldwick. Two locations.
At Westwood. Six locations.

ARTESIAN WELLS.

INTRODUCTION.

In presenting data this year respecting artesian or bored wells we would acknowledge the uniform courtesy with which well-drillers, contractors, civil engineers and others have cheerfully given information and furnished specimens of the borings.

These specimens have been of great value in the geological interpretation and correlation of strata, since without them it would frequently have been impossible to be certain what particular beds were represented, no matter how accurate and perfect were the descriptions received.

Of the wells now reported there are a few that have been especially timely in revealing the structural relations of the various beds in the southern portion of the State. Of these a deep boring at Island Heights has perfected our knowledge of the beds above the Eocene, and has permitted the correlation of these beds in the upper portion of the Atlantic City wells with the same beds in Ocean and Monmouth counties.

Deep wells recently sunk at Fort Mott, N. J., and at Middletown and Fort Dupont, Delaware, and noted in this report, have shown what has been heretofore in part indicated by records that have already appeared in past annual reports respecting wells at Jobstown, Mount Holly, Woodstown, Fort Delaware and Reedy Island, namely, that the Raritan beds have a great thickness, the maximum of which, so far as now known, amounts to nearly 600 feet,* but which does not yet comprise its entire thickness, since the base of this formation has not been reached even by the deepest of these borings.

* See Middletown record in tabulated statement, page 106.

These and numerous other borings into the Raritan beds show that there is a large amount of water at various depths therein, and, at the same time, they demonstrate the decidedly heterogeneous composition and irregular stratification of the same. For these reasons accurate predictions as to the depth to water-yielding sands within this formation at any given point cannot be made. Approximately accurate predictions can, however, be made as to the depths to the water-horizons that are associated with the Upper Cretaceous and Miocene formations, since in these formations the stratification is more regular, and individual beds are more widespread.

But of all the well records presented this year by far the most important, from the geological and stratigraphical point of view, is the deep well at Atlantic City, sunk by Uriah White to the depth of 2,306 feet from the platform of Young's Ocean Pier. The borings from this well enable us, with our previous knowledge, to connect in orderly succession the various beds underlying the more superficial sands and gravels, viz., the Miocene, Eocene and Cretaceous beds, excepting only the Raritan formation, which was not reached, and the lower portion of the clay marl formation, which was not entirely penetrated by this boring.

One of the most interesting geological features revealed by this Atlantic City boring is a thickness of rock of about 460 feet, between the depths of 1,440 and 1,900 feet, which rock we apprehend represents the limesand that overlies the Middle Marl bed. At outcrops this limesand bed rarely presents a greater thickness than about 20 feet, and is generally composed of alternate layers of limestone and loose limesand, but in this boring it was one solid mass of rock, though of varying degrees of hardness. Bryozoa generally occur in the outcrops, but none were found in this well boring. We are, however, at least tentatively inclined to believe that the Bryozoa characterize the upper layers only, and of these only those which were laid down near the old shore line in water of but moderate depth, since the record at Vincentown, on page 71, shows 30 feet of limesand, with Bryozoa plentiful in the upper seven feet, less plentiful in the middle portion and with none at all in the lower five feet, which lower stratum seems to be lithologically identical with the bed in its entirety at Atlantic City. The top of this lime-sand rock was also met with in a boring at Millville at the depth of 680 feet, where again the Bryozoa are wanting. See page 64.

For the more complete elucidation of the structural relations of the various beds underlying the State from the Delaware river to the Atlantic ocean it is desirable that the Survey might obtain specimens from some deep-well boring within a radius of a few miles from Winslow and Hammonton. Should the sinking of such a well in the future be determined upon, those especially interested would confer a favor by communicating information of such intention to the State Geologist, at Trenton, in advance, so that arrangements can be made to obtain data and specimens of the borings.

ARTESIAN WELL AT ANGLESEA, FIVE-MILE BEACH.

Elevation, 5 feet; diameter, 6 inches; depth, 331 feet.
Water flows over the surface. Drilled by Uriah White.

The total depth of this well is 331 feet, and it was finished with a strainer 47 feet long. The water-horizon occupies the interval between the depths of 284 and 331 feet, the top being a medium quality of yellowish brown sand, and the base a coarse gravel of similar shade. This water-horizon is the same as that developed in 1900 by a well put down near Holly Beach station,* which we then named the Holly Beach water-horizon. It seems to have been overlooked or passed by in the drilling of earlier and deeper wells at Wildwood on the same beach. Last year we stated that this horizon "probably underlies the entire beach," a prediction that this well, located some two miles north of the Holly Beach well, would seem to verify.

Similar gravels with a similar depth are known to occur at an intermediate point, viz., at Wildwood, between the depths of 302 and 320 feet. We are informed that this well will yield, by pumping, 450,000 gallons per day.

From specimens kindly furnished we make the following record:

* See Annual Report for 1900, page 119.

Suface beds of which no specimens came to hand, ...	0 feet to	90 feet.
Fine sandy clay with *sponge spicules* and a few *diatoms*,..	90 " "	130 "
Medium brownish gray sand, ...	130 " "	140 "
Fine gray sand, ...	140 " "	160 "
Fine brownish gray sand, ...	160 " "	190 "
Gray sand with lignite, ...	190 " "	200 "
Medium quality gray sand, ...	200 " "	270 "
Sandy brown clay, ...	270 " "	284 "
Yellowish brown sand, *water-bearing*, ...	284 " "	320 "
Yellowish brown gravel, *water-bearing*, ...	320 " "	331 "

For more minute details as to the strata above 90 feet the reader is referred to the record of a well put down in 1895† to the depth of 665 feet, and for information as to beds still lower than 665 feet he is likewise referred to that of a well put down in 1894§ to the depth of 1,244 feet.

Comparison of the records and specimens at Wildwood and at Anglesea show the following notable correspondence of beds:

	Wildwood.	*Anglesea.*
Clay with *sponge spicules* and *diatoms*,	98 feet to 132 feet.	90 feet to 130 feet.
Gray sand with lignite, ...	185 " " 200 "	190 " " 200 "
Drab-colored clay, ...	268 " " 307 "	270 " " 284 "
Yellowish brown sand and gravel with *water*, ...	307 " " 320 "	284 " " 331 "

ARTESIAN WELL AT WEST MILLS, SOUTHEAST OF PARKDALE.

Elevation, 40 feet; diameter, 3 inches; depth, 90 feet.
Water rises within 7 feet of the surface.

This well was reported last year* as near Parkdale, but with some slight mistatements of facts, the principal of which were as to the elevation and the exact location. We, therefore, now present an amended report, for which we are indebted to A. J. Rider, in whose cranberry bog it is situated. The location is two and one-half miles southeast of Parkdale and about one mile southwest of a well in Rockwood's cranberry bog on Metchesa-

† Annual Report, 1895, page 86.

§ Annual Report, 1894, page 159.

* Annual Report for 1900, page 107.

taukin creek, of which records have been published in previous annual reports.*

This well at West Mills had been previously put down to a depth of about 55 feet, and in the year 1900 W. C. Barr deepened it by boring beyond to the total depth of 90 feet from the surface.

The following is the record of strata as furnished by W. C. Barr:

	Thickness.	*Intervals.*
Surface material,	8 feet.	0 feet to 8 feet.
Blue clay,	7 "	8 " " 15 "
White running quicksand,	53 "	15 " " 68 "
Yellow pasty clay,	18 "	68 " " 86 "
Coarse sand and small gravel,	4 "	86 " " 90 "

Beneath the last-named stratum there was a *chocolate-colored clay*, on which the boring stopped. We were informed that at the "depth of about 60 feet chips of wood (lignite) of a brownish color and one or two inches long were brought out by the bucket."

TWO ARTESIAN WELLS AT BRIDGETON, FOR ARCTIC MILK AND ICE COMPANY.

Elevation, 10 feet; diameter of each, 4½ inches; depth of each, 80 feet.
One of these wells was prospected to the depth of 200 feet.
Water rises within 7 feet of the surface.

Drilled and reported by Haines Bros.

During the year 1900 Haines Bros. prospected a well at the above location to a depth of 200 feet, but, not finding water at that depth, they afterwards finished this and another well, each with a depth of about 80 feet, finding a water-bearing sand between the depths of 60 and 80 feet that rose within 7 feet of the surface, or about to tide-level. From information furnished by the contractors we make the following stratigraphical record:

* Annual Report for 1885, page 138, and Annual Report for 1892, page 297.

Various shades of yellowish sands and gravels,	0 feet to	60 feet.		
Black clay,	60 " "	61 "	Age (?)	
Coarse gravel,	61 " "	85 "		
Dark brown clay,	85 " "	170 "	Miocene.	
Light-colored muddy sand,	170 " "	200 "		

In the Annual Report for 1900, page 110, there is a similar record of a deep boring (175 feet) and of two shallow ones (each 65 feet) about one mile east, at East Bridgeton. As these wells now reported at Bridgeton are about one-half mile farther back on the dip of the beds than those at East Bridgeton, it is probable that the deep well (200 feet) at Bridgeton is stratigraphically somewhat deeper than the deep one at East Bridgeton (175 feet), as well as actually deeper from the surface. These two deep borings are of interest, since they show a great thickness, somewhat over 100 feet, of Miocene clay. This clay represents the same bed as the one which presents a thickness of 90 feet in the two well-borings near Alloway, noted on page 102.

At Alloway only the base of the bed was passed through, while here the boring penetrated its upper portion only. The thickness at Atlantic City of what we apprehend to be the same bed is 130 feet, and it there occupies the interval between the depths of 860 and 990 feet. It therefore seems probable that had this boring at Bridgeton been continued from 20 to 40 feet deeper, it would have passed entirely through this clay-bed, and beneath it would have probably opened a water-yielding sand above the Eocene, since such a water-yielding stratum has been found in this stratigraphical position at Berkeley Arms, Seaside Park and Island Heights. The writer also thinks it probable that the water of the well at Winslow, 335 feet deep, and of the well at the Atlantic City Gas Works, 1,135 feet deep, belongs to the same horizon. This stratum was also doubtless passed in well-borings unsuccessfully drilled at Toms River and Barnegat Park, an opinion the writer has formed from an examination of the borings of these two places. A very complete set of the Toms River borings is still preserved by John D. Haines at that place.

The more shallow wells at Bridgeton, 80 feet deep, and East Bridgeton, 65 feet deep, indicate the thickness of the overlying yellowish sands at these two points.

SIX SHALLOW ARTESIAN WELLS AT MILLVILLE, N. J.

Elevation, about 3 feet. Diameter of each, 8 inches. Depths, No. 1, 107 feet; No. 2, 107½ feet; No. 3, 105 feet; No. 4, 104 feet; No. 5, 118 feet; No. 6, 104 feet.
Water overflows at the surface.

The People's Water Co. Data from Hon. George Pfeiffer and W. H. Boardman, C. E.

These wells are located upon the flat meadow land on the east bank of Maurice river immediately south of City Hall. Through the joint courtesy of all the above named parties we have been furnished with full and separate series of the borings from five of these wells and with some notes upon the same. The following generalized section has been prepared after careful comparison of the borings and notes.

1 foot.	Meadow muck,	0 foot to	1 foot.
5 feet.	Black mud, containing *marine diatoms* of *recent species* and *sponge spicules*,	1 " "	6 feet.
2 "	Fine white sand,	6 feet "	8 "
4 "	Coarse white pebbles, size of marbles and larger,	8 " "	12 "
8 "	Dull yellowish sand,	12 " "	20 "
2 "	Yellow clay,	20 " "	22 "
3 "	Yellow sandy clay,	22 " "	25 "
6 "	Sand and iron stone crusts, reddish yellow in color,	25 " "	31 "
5 "	Mixture of clay, sand and very fine gravel, varying in color, being light yellow, orange yellow and dull yellow in different wells,	31 " "	36 "
54 "	Mixture of sand and gravel, varying in quality from coarse to fine, and in color from red and bright orange to light yellow and brownish yellow.	36 " "	90 "
	Iron stone crust at 52 feet in one well and at 78 feet in another. Some yellow clay seams between 40 and 60 feet.		
4 "	Black clay,	90 " "	94 "
2 "	Fine gravelly dark gray conglomerate (stone) in well No. 4,	94 " "	96 "
1 "	Black clay in well No. 6,	96 " "	97 "
20 "	Coarse mixture of gray sand and gravel, *water-bearing*,	97 " "	117 "
	In well No. 1 occurs a dark stone conglomerate 2 inches thick at the depth of 95 feet and a dark clay seam at 110 to 112 feet.		

DEEP ARTESIAN WELLS AT MILLVILLE, N. J.

Elevation, 3 feet above high tide.
Well No. 1, depth, 90 feet. Water at 66 feet to 90 feet.
Well No. 2, depth, 204 feet. Water at 185 feet to 204 feet.
Well No. 3, depth, 685 feet. No satisfactory water found below 212 feet.

The Millville Water Company, being desirous of ascertaining the number and depth of the various water-yielding horizons occurring at Millville, prospected three wells to the above depths.

We have been courteously furnished with a nearly complete series of the borings, from an examination of which we present the subjoined record:

Yellow sand from near the surface to the depth of		56 feet.	
("Supply of water, 200 gallons in 9 minutes.")			
Yellow sand and coarse gravel at		62 "	
Orange-yellow sand, with "a *good supply of water*" at		66 "	
Mixture of dark sand and clay at		80 "	
Mixture of dark sand and clay at		90 "	
Dark tough hard clay from	96 feet to	101 "	Probably in part if not wholly, Miocene.
Dark sand,	101 " "	110 "	
Dark clayey sand,	110 " "	115 "	
(No diatoms in the clays from 80 to 115 feet.)			
Alternations of sand and fine gravel, sometimes mixed with clay,	115 " "	185 "	
Water at 185 feet.			
Clay and coarse gravel, some *diatoms* and also iron pyrite,	185 " "	204 "	Miocene.
Gravel with "*a good flow of water.*"	204 " "	212 "	
Dark brown clay, no diatoms, but first appearance of *fossil shells,*	212 " "	221 "	
Gravel with some shells,	221 " "	233 "	
Dark clay, no diatoms,	233 " "	241 "	
Clay, gravel and some *shells,*	241 " "	255 "	
Clay, sandy at the top,	255 " "	300 "	
Clay with comminuted *shells,*	300 " "	310 "	
Dark brown clay,	310 " "	360 "	
Greenish clay,	360 " "	370 "	
Brownish sandy clay,	370 " "	375 "	(?)

Greenish mixture of quartz and green sand,	375	" "	395	"	Upper Layer Upper Marl Bed.	Probably in part Eocene.
Dark olive-green sandy marl, with abundance of greensand grains,	395	" "	438	"		
Similar dark olive green sandy marl, but somewhat more clayey,	438	" "	526	"		
Greenish mixture of quartz and greensand with some fossil shells,	526	" "	552	"		
					(?)	(?)
Greenish sandy clay with some greensand and some fossil *shells*,	552	" "	630	"	Lower Layers Upper Marl Bed.	Cretaceous.
Similar greenish sandy clay, but with much more green sand,	630	" "	675	"		
Dark olive-green clayey marl,	675	" "	680	"		
Hard rock, slightly calcareous,	680	" "	685	"	Probably Limesand.	

These wells are located about one mile northwest of the wells noted in the preceding record.

The water from well No. 1, at the depth of 66 to 90 feet, rose slightly above tide-level, while that from well No. 2, at the depth of 185 to 204 feet, rose some 10 feet or more above tide.

In well No. 3, at various depths below 212 feet, water said to be of unsatisfactory quality was found that likewise rose to 10 feet or more above tide.

FIVE ARTESIAN WELL-BORINGS AT ISLAND HEIGHTS.

No. 1—elevation, 5 feet; depth, 1,145 feet.
No. 2—elevation, 5 feet; diameter, 6 inches; depth, 368 feet.
No. 3—elevation, 5 feet; diameter, 3 inches; depth, 46 feet.
No. 4—elevation, 5 feet; diameter, 3 inches; depth, 47 feet.
No. 5—elevation, 5 feet; diameter, 3 inches; depth, 48 feet.

Water at 26 to 48 feet that rises to the surface. Supplies wells Nos. 3, 4 and 5.

Water at 145 to 150 feet that rises within 18 inches of the surface. Not utilized.

Water at 280 to 290 feet that rises about 3 feet above the surface. Supplies well No. 2.

Water at 300 to 368 feet that rises about 3 feet above the surface. Supplies well No. 2.

Island Heights Water Co. Edgar A. Alcott, engineer.

The two deep wells drilled by Kisner & Bennett.

The three shallow wells drilled by Thomas Roberts.

Through the courtesy and co-operation of the three first named of the above parties we have been furnished with a series of specimens from the two deep wells, from an examination of which, coupled with some information also received from the same persons, we are enabled to present the subjoined detailed record. In the process of drilling well No. 1, it was cased with 10-inch pipe to the depth of 48 feet; then with an 8-inch casing inside of this to 336 feet; then similarly with a 6-inch casing to 500 feet, and then with a 4½ casing to 927 feet, the drill being continued beyond this without casing to the total depth of 1,145 feet. From a calculation of the dip of the water-bearing beds of the region it was confidently expected that a copious water-bearing stratum would be found at about the depth of 1,000 feet, but though the drilling was continued as above stated to 1,145 feet, or about 150 feet farther, no free water-bearing sand was found such as occurs to the northward at Mantoloking* between the depths of 872 and 922 feet and at Bay Head† at the depth of 885 feet. At both the last-named places lignite was found associated with the water-yielding sand, but though lignite occurs in this boring in its lower portion the drillers state that no noticeable sand occurs, the beds seeming to consist nearly entirely of fine black micaceous silty sand, with perhaps two or three very thin sand seams below 1,000 feet.

RECORD.

Surface beds, yellow sand,	0 feet to	12 feet.	Age (?)
Sand and white clay,	12 " "	14 "	
White sand,	14 " "	26 "	
Heavy yellow gravel with plenty of *water*,	26 " "	48 "	
Fine gray quicksand,	48 " "	145 "	Probably Miocene, in whole or in part.
Heavy blue sand and gravel, with a little *water* that rises within 18 inches of the surface, probably equivalent to the water-horizon at 126 to 132 feet at Mantoloking,	145 " "	150 "	
Brown *Miocene* (?) clay, the rotten stone of the drillers, the astringent clay of Prof. Cook,	150 " "	285 "	

*Annual Report 1896, page 152.
†Annual Report 1896, page 151.

"Pepper and salt" sand—*water-bearing*,	285 feet to 300 feet.	Possibly in part Miocene and in part Eocene.	
Streak of clay at	300 "		
Gray sand with water, equivalent of that at 465 to 490 feet at Seaside Park, ...	300 " " 368 "		
Marl, ... Some *mollusks* at 446 to 464 feet.	368 " " 504 "		
Light or ash colored fine marly clay, contains *Coccoliths* throughout, ... Rock at 542 to 564 feet.	504 " " 640 "	Lower layer Upper Marl.	Cretaceous.
Dark greenish marl, ...	640 " " 858 "	Middle and Lower Marl Beds.	
Black micaceous fine sandy clay, ...	858 " "1145 "	Clay Marl.	

Although water was not found at the base of this boring, yet water-yielding sands were noticed at intervals in passing down at depths noted above. Another well was therefore sunk to the depth of 368 feet, and the horizon between 300 and 368 feet developed. This yields a considerable quantity of satisfactory water. It is beneath the Miocene clays, "the rotten stone" of the driller, and is either at the top of or just above the Eocene (?) greensands which fairly commence as greensands at the depth of 368 feet. This horizon is doubtless the same as that supplying the wells four miles eastward at Berkeley Arms* and Seaside Park†. It was also doubtless passed in borings made some years since at Toms River§ and at Barnegat Park||, since a similar "pepper and salt" sand has been seen by the writer in the borings from these two wells at about the proper depth in each.

The writer also deems it quite probable that this horizon is the same as that opened by the first deep well sunk in the State, which was at Winslow and which has a depth of 335 feet.°

The horizon supplying the first deep well successfully put down at Atlantic City (at the gas works), and which has a depth of 1,135 feet, was also probably the same. This well is, however, the only one at that place that has so far successfully reached this horizon, although two other wells have been unsuccessfully bored

* Annual Report, 1885, page 133.
† Annual Report, 1898, page 101.
§ Annual Report, 1898, page 102.
|| Annual Report, 1896, page 154.
° Geology of New Jersey, 1868, page 291.

to still greater depths. All the many other wells at that locality that now furnish water not being deeper than 750 to 860 feet.

The supply of water from well No. 2 (depth 366 feet) is deemed likely to be sufficient for the usual needs of the town for some years to come. To provide, however, for any sudden call for an unusually large amount of water there have since been put down by Thomas Roberts three shallow wells, each three inches in diameter, to the depths of 45, 46 and 47 feet, so as to draw from the water-bearing stratum noted above as occurring between the depths of 26 to 48 feet. These three shallow wells were each finished with a strainer at the bottom twenty feet in length.

THREE SHALLOW BORED WELLS AT TOMS RIVER.

Elevation, 5 feet; diameter of each, 6 inches; depth of each, about 39 feet.

The city of Toms River is supplied with water by means of three bored wells put down a few years since to an average depth of about 39 feet. The material penetrated is described as consisting of alternations of fine and coarse sand and gravel, the prevailing color of which is yellow.

The quality of water obtained is said in the certificate of the chemist who analyzed it to be "of high purity and suitable for all purposes."

ARTESIAN WELL AT SPRING LAKE.

Depth, 710 feet.

Kisner & Bennett report having sunk a well the present year at Spring Lake for the North Spring Lake Water Company to the depth of 710 feet.

ARTESIAN WELL AT BELMAR.

Depth, 664 feet.

Kisner & Bennett report that they have drilled a well the past year at Belmar for the Water Works there to the depth of 664 feet.

ARTESIAN WELL AT KEASBY'S LANDING FOR JOSEPH GALAIDA.

Diameter, 4 inches; depth, 80 feet.
Drilled and reported by W. R. Osborne.

This well passed through clays that were blue on top and were variegated white and red below to a whitish water-bearing sand at the depth of 80 feet.

ARTESIAN WELL AT PERTH AMBOY.

Diameter, 6 inches; depth, 140 feet.

Peterson Bros. Brewery. Drilled and record furnished by W. R. Osborne.

"Drift,"	30 feet.	
Bluish clays, and white clays faintly spotted with red,	80 "	
Water sand,	30 "	= 140 feet.

Finished with a Cook screen. Water good.

ARTESIAN WELL AT PERTH AMBOY.

Diameter, 6 inches; depth, 130 feet.

Standard Underground Cable Co.

Drilled and reported by W. R. Osborne. Water overflows 20 gallons per minute. Yields by pumping 100 gallons per minute.

Salt meadow and sand,	20 feet.	
Clay of various shades,	85 "	
Water-bearing sand,	25 "	= 130 feet.

Stopped drilling on tough blood-red clay.

This well is finished with a Cook strainer 10 feet long.

W. R. Osborne writes that several years since he put down a well at the Wood Vulcanizing Works at this place to the depth of 225 feet, passing in the lower portion through 75 feet of the same tough red clay deposit as that upon which this boring stopped, without, however, getting through the same.

TWO ARTESIAN WELLS AT RUNYON.

Well No. 1—Elevation, 10 feet; diameter, 6 inches; depth, 235 feet.
Well No. 2—Elevation, 10 feet; diameter, 6 inches; depth, 218 feet.
Well No. 1 flows about 235 gallons a minute.
Well No. 2 flows about 150 gallons a minute.

In the Annual Report for 1900, page 147, there is a report of a 6-inch well put down to the depth of 212 feet by Kisner & Bennett for the Perth Amboy Water Works at Runyon, and which yielded by overflow the phenomenal amount of 500 gallons a minute. The same firm report the sinking at the same place the past year of two additional 6-inch wells to depths as stated above, and which yielded by overflow an unusually large amount of water as above noted, though not so great as that furnished by the well sunk last year.

All three of these wells are of course supplied from the same water-bearing stratum, one which we apprehend to be well within the Raritan division of the Cretaceous. As Kisner & Bennett state that the beds penetrated by all were identical, we copy the record from last year's report:

57	feet	white sand,	0	feet	to	57	feet.	
7	"	white clay,	57	"	"	64	"	Raritan Cretaceous.
8	"	red clay,	64	"	"	72	"	
4	"	white clay,	72	"	"	76	"	
7	"	white quicksand,	76	"	"	83	"	
19	"	gray clay,	83	"	"	102	"	
14	"	gray quicksand,	102	"	"	116	"	
60	"	very hard blue clay,	116	"	"	176	"	
12	"	black sandy clay,	176	"	"	188	"	
24	"	white sand and gravel with *abundance of water,*	188	"	"	212	"	

BORED WELL AT LORILLARD.

Diameter, 4 inches; depth, 282 feet.

Drilled and reported by W. R. Osborne.

This well was put down for the New York and New Jersey Fireproofing Co. on property now owned by the National Fireproofing Co.

Blackish clay used for fireproofing,	Surface to 40 feet.	Clay Marl.	Cretaceous.
Fine sand,	40 feet " 60 "	Raritan.	
Whitish clay,	60 " " 70 "		
Water sands,	70 " " 282 "		

Furnished with a Cook strainer 10 feet long. Well pumps 100 gallons per minute.

ARTESIAN WELL NEAR VINCENTOWN.

Elevation, 30 feet; diameter, 3 inches; depth, 109 feet.
Water rises within 15 feet of the surface.

Drilled by A. G. Dunphey for Wm. J. Irick.

Of this well the driller has furnished a complete series of specimens from an examination of which we compile the record as follows:

Yellow gravel,	Surface to 3 feet.		
Orange-colored sand and fine gravel,	3 feet " 9 "		
Yellowish sand with a few greensand grains,	9 " " 18 "	Limesand, 40 feet.	Cretaceous.
Yellowish lime sand with *Bryozoa* plentiful,	18 " " 25 "		
Ash-colored limesand with very few Bryozoa,	25 " " 44 "		
Grayish greensand with numerous *Foraminifera*, consisting of *Nodosaria, Cristellaria*, &c., Bryozoa wanting,	44 " " 49 "		
Dark greensand with *Terebratula harlani*, and *Gryphea vesicularis*,	49 " " 50 "	Middle Marl, 21 feet.	
Lighter colored greensand, no fossils,	50 " " 70 "		
Very dark-colored greensand,	70 " " 101 "	Lower Marl ? 31 feet.	
Grayish-colored greensand with molluscan fossils, viz.: *Paranomia scabra*, Morton. *Pecten craticulus*, Morton. *Gryphea vesicularis*, Lamarck. *Exogyra costata*, Say. *Belemnitella mucronata*, Schlot,	101 " " 104 "	Sands at the top of the Clay Marls.	
Grayish greensand with *Belemnites*,	104 " " 109 "		

The supply for this well is from the Marlton water-horizon at the top of the Clay Marls and immediately below the true greensand marls.

TWO ARTESIAN BORINGS NEAR CRESSON, FORMERLY MILFORD.

No. 1—Elevation, 175 feet; diameter, 6 inches; depth, 194 feet.
No. 2—Elevation, 175 feet; diameter, 6 inches; depth, 110 feet.
Water at 110 feet rises to within 42 feet of the surface.
Water at 160 feet rises to within 48 feet of the surface.

Surface gravel,	0	feet	to	6	feet.
Soft yellow sand,	34	"	"	40	"
Yellow gravel,	40	"	"	43	"
Sand,	43	"	"	70	"
Yellow sand,	70	"	"	95	"
White gravel with *water* that rises within 42 feet of the surface,	95	"	"	110	"
Black sandy clay,	110	"	"	118	"
Stiff black clay,	118	"	"	160	"
Shark's tooth at 150 feet.					
"Pepper and Salt" sand with *water* that rises within 48 feet of the surface,	160	"	"	161	"
Stiff clay,	161	"	"	180	"
Muddy clay,	180	"	"	193	"
Discontinued drilling on rock, probably limesand rock, at				194	"

The clays from 110 to 160 feet are probably Miocene. From 161 to 193 feet is possibly the lower member of the upper marl bed (Cretaceous), and the thin stratum at 160 feet, described as "pepper and salt" sand, may perhaps represent the Eocene or upper member of the upper marl bed.

Well No. 1 was abandoned at the depth of 194 feet, and well No. 2 was afterward sunk to the depth of only 110 feet, taking a supply of water from the base of the superficial sands and gravels overlying the Miocene (?) black clay.

ARTESIAN WELL IN CAMDEN. CAMDEN DYE WORKS AT EIGHTH AND SPRUCE STREETS.

Elevation, 10 feet; diameter, 6 inches; depth, 183 feet.

Drilled and reported by W. C. Barr.

	Black soft mud, like river mud, contains branches, vegetable fibre, &c., at	44 feet.
	Interval not described,	44 feet to 90 "
34 feet	red clay,	90 " " 124 "
16 "	blue or black clay,	124 " " 140 "
12 "	fine white sand,	140 " " 152 "
½ "	red sandstone crust,	152 " " 155 "
2½ "	yellow sand and pebbly,	
14 "	white sandy clay,	155 " " 169 "
14 "	fine sand and gravel, heavy pebbles at the base, water-bearing,	169 " " 183 "

This well from at least the depth of 90 feet downward is apparently in the Raritan formation.

TWO ARTESIAN WELLS AT FISH HOUSE.

Elevation No. 1—Diameter, 8 inches, depth, 105 feet.
Elevation No. 2—Diameter, 8 inches; depth, 119 feet.

Drilled and reported by Stotthoff Bros.

RECORDS.

Well No. 1.

Mud,	28 feet	= 28 feet.
Clay,	24 "	= 52 "
Whitish sand,	20 "	= 72 "
Clay,	20 "	= 92 "
Coarse yellow sand,	13 "	= 105 "

Well No. 2.

Mud,	42 feet	= 42 feet.
Sand and clay,	24 "	= 66 "
Clay,	17 "	= 83 "
Yellow sand and clay,	11 "	= 94 "
Clay,	12 "	= 106 "
Sand.	13 "	= 119 "

Well No. 1 was finished to draw its supply from the whitish sand between 52 and 72 feet; the yield was 15 gallons per minute.

Well No. 2 draws its supply from the sands at 106 to 119 feet; the yield was 40 gallons per minute.

Both wells are furnished with Cook strainers, and draw from the same horizon as the wells at Morris station that furnish the city of Camden with its water-supply.

TEST BORINGS AT TORRESDALE, PA.

Twenty-three test borings have been made at Torresdale, Pa., preparatory to the construction of an underground water conduit to be used in connection with a filtration system at that place to supply water to the city of Philadelphia.* Seventeen of these borings were deep ones and were made with the diamond drill into the underlying micaceous gneiss rock to depths from the surface ranging from 80 to 139 feet, the depth to rock ranging from 17 to 48 feet. The other borings were shallow ones put down in the marshes at the mouths of Pennypack creek and a small creek emptying into the Delaware nearly one mile southward. This smaller stream is marked but not named on recent maps. It is called Spewter creek in old deeds. The shallow borings were sunk by the jetty process and were prospected either to gravel or to rock, their depths varying from 15 to 35 feet. They show that the greatest depth of marsh in Spewter creek was 12 feet and in the Pennypack 26 feet.

The diamond drill or rock borings were made in two parallel series about 500 feet apart, and extend northeast and southwest about three miles near and parallel to the Delaware river. The series toward the west is along the line of Milnor street and the one toward the east upon a continuous and nearly straight course first along Delaware avenue and then along Eugene avenue from the point where Delaware avenue bends to the east and Eugene avenue forks therefrom to the northward.

* Full series of specimens of the materials from all of the borings have been placed in a room of the Survey Department at the City Hall. Through the appreciative courtesy of City Surveyor George S. Webster and his assistants we have been furnished with horizontal plans and vertical sectional drawings of the borings, and have also been permitted to make a free and full examination of the specimens.

In all but two of the borings of the series nearest the river there are three well-defined beds of unconsolidated deposits above the rock. The lowest of these is wanting in the other two because of a local rise of the rock.

Because of the general rise westward of the surface of the rock both the middle and the lower beds were wanting in four out of the five borings of the westward parallel series. In the fifth, however, the one farthest south (boring No. 2), these two beds occurred, the middle one presenting a thickness of six feet and the lower of about one foot.

The upper bed consists of sands and gravels with large pebbles and boulders. Owing to differences in elevation the thickness varies from 12 to 28 feet, the base, however, is very nearly level, being about 15 feet below tide. Midway in this gravel bed, about 12 feet from the surface, most of the borings showed a thin seam of clay about one foot thick. This clay, unlike the lower clay next to be described, was found on microscopic examination not to contain any fossil micro-organisms.

The next underlying bed, the middle one, is a fine tenacious clay varying in thickness from 17 feet on the south to about 5 feet on the north. Microscopical examinations of specimens of this clay revealed fossil *diatoms* and *sponge spicules* in the lower two feet of the same, from Wells Nos. 1, 7, and 14, that is, from the two wells on the extreme ends of the line and from one well near the middle. While the surface of this clay bed is nearly level the base is quite uneven.

The lowest of the three beds consists of a decidedly coarse gravel with some boulders, which increases in thickness from two feet on the south to about ten feet at the north end of the line, its thickness increasing as that of the overlying clay decreases.

This gravel rested upon a black hornblendic micaceous gneiss rock of the same general character as that which rises to the surface, and is quarried in the Philadelpha County House of Correction quarry immediately north of Holmesburg Junction. Along the line of the section nearest the river this rock floor was very even, only ranging from 27 to 38 feet below tide-level within a distance of about three miles, except locally for a space about one-quarter of a mile in length immediately adjacent to Pennypack creek on the south where its surface was only about 17 feet below tide.

FOURTEEN BORINGS IN PHILADELPHIA, PA., FOOT OF CHESTNUT STREET.

Elevation, about high-tide level; diameter of each, 12 inches; depth, 90 feet.

On Delaware river front. For Merchants' Warehouse Co. Drilled by Plunger Elevator Co.

These borings were made preparatory to putting in casings for the plungers connected with the elevator service of the building. The depth named is from the basement floor which we estimate is at about high tide-level. Through the courtesy of the Plunger Elevator Co. we have been supplied with a series of the borings which show the following section:

Grayish gravel with some clay,	Basement level to 10 feet.
Slightly reddish-yellow gravel pebbles, fine to coarse,	10 feet " 28 "
Still redder, but finer, gravel,	28 " " 41 "
Fine, slightly paler, red sandy gravel, some large pebbles,	41 " " 60 "
Medium fine yellowish gravel, not so red as any of the above strata,	60 " " 72 "
Decomposed soft micaceous gneiss,	72 " " 90 "

ARTESIAN WELL ONE MILE SOUTH OF MOUNT EPHRAIM, OPPOSITE HEDDING CHURCH.

Elevation, 80 feet; depth, 211 feet.
Water rises within 70 feet of the surface.

Data furnished and well drilled by Joseph W. Pratt.

20 feet	top soil and yellow clay,	0 feet to 20 feet.		Cretaceous.
140 "	dark very clayey sand, A thin sand seam in this stratum at 62 feet was slightly water-bearing.	20 " " 160 "	Clay Marl.	
37 "	black, solid clay,	160 " " 197 "		
14 "	gray sand with water,	197 " " 211 "	Raritan ?	

This well probably obtains it water-supply from the sands and gravels either near or beneath the base of the Clay Marls. The record closely agrees with that published on page 143 of last year's report (1900) for a well at the same place. Foraminifera, also Dentalium and some other mollusks were then noted as occurring at the depth of 187 to 195 feet.

ARTESIAN WELL AT AUDUBON.

Elevation, 60 feet; diameter, 3 inches; depth, 96 feet.
Water rises within 42 feet of the surface.

Sunk for John Randall. Drilled and reported by Frederick E. McCann.

This location is on the Reading Railroad Company's route to Atlantic City, about four and one-half miles southeast of Kaighn's Point, Camden.

At the depth of 95 feet water was found that rises within about 35 feet of the surface. As this location is west of the line of outcrop of the sands of the Cropwell water-horizon, it seems probable that the water is furnished from below the base of the laminated clays and sands of the Clay Marls. The writer was consulted before the commencement of this boring, and predicted that water would be found at the depth of about 100 feet, a close approximation to the results afterward obtained. This well penetrated the lower one-third of the Clay Marl formation.

ARTESIAN WELL AT CLARKSBORO.

Elevation, 65 feet; diameter, 3 inches; depth, 180 feet.
Water rises within 70 feet of the surface.

Drilled by Haines Bros. for Jos. T. Sickler.

This well is about one-half mile northwest from another well at the same place put down for Howard Buzby*. The con-

* Annual Report for 1899, page 64.

tractors state that the strata in both wells were identically the same, as should be expected, since the two wells are directly on the line of strike of the strata. We therefore insert the record of the former well, with a slight revision, copying the same from the Annual Report for 1899:

Loam,	0 feet to 3 feet.			
Clay,	3 " " 18 "	Clay Marls.		Cretaceous.
Black marl,	18 " " 38 "			
Black sand mixed with slime,	38 " " 58 "			
Running marl,	58 " " 173 "			
White sand with water,	173 " " 180 "	Raritan.		

ARTESIAN WELL AT SWEDESBORO.

Elevation 10 feet ±; diameter, 6 inches; depth, 130 feet.
Water overflows at the surface.

Woolwich Water Co. Drilled by Haines Bros.

The well is located directly in the town of Swedesboro, upon the narrow flood-plain of a tributary of Raccoon creek. The data were furnished by the contractor.

Made ground, meadow muck and running sand in succession,	0 feet to 10 feet.		
Black clay marl,	10 " " 70 "	Clay Marl.	Cretaceous.
Fine black sand,	70 " " 85 "	Age (?)	
Dry black clay,	85 " " 100 "		
Coarse sand with water,	100 " " 130 "	Raritan.	

The water rose to the top of the casing, one foot above the ground, so that it would have overflowed at the surface. The water-horizon is the same as that supplying the well at Mullica Hill (see page 80), 4½ miles eastward, the depth of the latter well being 265 feet. This is the Sewell water-horizon at the top of the Raritan formation.

ARTESIAN WELL NORTH OF SWEDESBORO, FOR HENRY JONES.

Elevation, 30 feet; diameter, 3 inches; depth, 70 feet.
Water rises within 9 feet of the surface.

Well drilled and record furnished by Harris Bros.

This well is located about two and one-half miles north of Swedesboro.

Surface soil, consisting of clay, loam, &c., without gravel,	0 feet to 20 feet.		Cretaceous.
Black clay marl,	20 " " 60 "	Clay Marl.	
Water-bearing sand,	60 " " 70 "	Raritan.	

The water-horizon is the same as that supplying the well noted in the preceding record viz.: the Sewell water-horizon.

ARTESIAN WELL ONE-HALF MILE NORTHWEST OF TOMLIN STATION.

Elevation, 40 feet; diameter, 3 inches; depth, 120 feet.
Water rose within 40 feet of the surface.

Drilled for Chas. Cook. Reported by Haines Bros.

This location is on the Salem (via Woodstown) branch of the West Jersey and Seashore Railroad. Haines Bros. state that the drilling from near the surface down to the depth of 105 feet was through black clay marl, beneath which the drill penetrated 15 feet of white water-bearing sand of which the grains were about the size of those of wheat. This horizon is probably the equivalent of the Sewell water-horizon at the top of the Raritan formation.

ARTESIAN WELL AT MULLICA HILL.

Elevation, 29 feet; diameter, 8 inches; depth, 265 feet.
Water at 100 feet overflows—Cropwell water-horizon.
Water at 230 to 265 feet rises to within about 20 feet of the surface—Sewell water-horizon.

Harrison Heights Improvement Co. Drilled by Haines Bros., Geo. Pfeiffer, contractor.

The well is located a few yards from the south bank of Raccoon creek, just above the road leading through the village from

Woodbury to Woodstown, and is immediately in the rear of Jacob Mounce's grist mill.

Through the courtesy of the drillers and the contractor, and also of a few others interested, we have received a pretty full series of the borings and considerable notes upon the same, which together enable us to present the following record:

Surface soil,	0 feet to 5 feet.	Recent, 5 feet.		
Yellowish gravel, as in the bluff adjacent,	5 " " 10 "	Sands, 5 feet.	Clay Marls.	Cretaceous.
Greenish clay with fragments of *shells*,	10 " " 45 "			
"Similar greenish clay," so described. No specimen received,	45 " " 75 "	Clays, 45 feet.		
Black micaceous sandy clay with *Gryphea vesicularis* Lam. and other *Cretaceous shells;* contains also thin yellowish calcerous rock seams,	75 " " 90 "			
Sand stratum from which a small supply of *water flowed over the surface*,	90 " " 110 "	Sands, 20 feet. Cropwell water-horizon.		
Black micaceous sandy clay, similar to that above the water-horizon just noted,	110 " " 125 "	Laminated clays, 40 feet.		
Yellowish-green clayey sand,	125 " " 130 "			
Black micaceous sandy clay,	130 " " 135 "			
Black sandy clay, tough and more micaceous,	135 " " 150 "			
Black micaceous sandy clay, still harder,	150 " " 165 "	Marly clays, 73 feet.		
Greenish micaceous clay with iron rusty speckles throughout,	165 " " 180 "			
Greenish micaceous sandy clay with green sand marl grains,	180 " " 215 "			
Greenish micaceous clay without greensand,	215 " " 223 "			
Crust of coarse white sand conglomerate cemented with iron pyrite at	223 "	Sand, Sewell Water-Horizon, 42 feet.	Raritan.	
Bluish-gray sand, water-bearing throughout; contains some lignite,	223 " " 265 "			

The lignite at the base of this well proves, on microscopic examination, to be coniferous, and probably represents one of the species of Cupressinoxylon, which have been described by Knowlton, from the Raritan beds.

This well was put down by the use of the drill and sand-bucket, and sufficient water was had all the way down to about 135 or 150 feet to facilitate the drilling. The lower clay beds, however, that is, those between the depths of 165 and 223 feet, were so impervious that water had to be introduced into the casing to ease the drill in its work. This impervious bed will probably prevent contamination of the water-supply.

The above record notes a thickness of the Cretaceous Clay Marls penetrated by the well of 218 feet, showing all the five divisions of that formation in their entirety, except the upper one, the Wenonah sand, of which but 5 feet is represented. If to this thickness we add 50 feet for the upper part of this sand, which thickness we estimate occurs between the top of well and the top of the bluff adjacent*, we prove a total thickness for the Clay Marls at this locality of about 275 feet, all five divisions of the same being represented in full.

There are three marked faunal horizons in the Clay Marls, all of them characterized by the occurrence, with other shells, of an ancient ponderous oyster *Exogyra costata,* Say. These three horizons occur, one at the top of the formation in the sand, and is seen as an 8-foot bed of shells at the top of the bluff adjacent to this well. Another occurs in the underlying clay division and was found in this boring somewhere between the depth of 75 and 100 feet. In both the above shell-beds the fossils consist of the shells themselves. The third faunal horizon is in clay near the base of the entire Clay Marl series. Associated with the *Exogyra* in this bed are two species of large *Ammonites*—the latter the present writer has never observed in the two uppr beds. Nearly all the fossils, however, in this bed, unlike those in the two higher ones, occur as casts, the shells themselves being seldom preserved. For this reason, possibly, fossils from this horizon were not found in this boring.

* Since writing the above the engineers' levels have been received, showing the difference to be 46½ feet, the elevation of the surface at the well being 29 feet, and at the top of the bluff 75½ feet.

At 90 to 110 feet a small supply of water was found in a sand stratum, the Cropwell water-horizon; this horizon, however, was not utilized by this well. A much more copious supply which is now used was afterward found between the depths of 230 feet and 265 feet. This horizon is the Sewell water-horizon of the writer, and occurs next below the Clay Marls and at the top of the Raritan formation.

In this latter formation and beneath this water-horizon, though not reached by this well, occur characteristic beds of white, yellow and red clays and alternations of heavy pebbly gravels, the latter forming a still lower series of water-horizons which we have designated as the Raritan group. It is from wells put down to the lowermost of this lower group that the water-supply of Camden and Gloucester is obtained.

FOSSILS.

From the clays at the depth of about 75 to 100 feet there were shown in the borings some shell fragment, among which we were able to identify *Gryphæa vesicularis*, Lamarck.

From the top of the Clay Marl sands at the top of the bluff, immediately adjacent and about 45 feet higher than the location of the well, the writer has recently obtained the following, the identifications being by C. W. Johnson:

MULLICA HILL, N. J.

Lamellibranchs.

Anomia tellinoides, Mort.
Axinea mortoni, Conr.
Cardium (*Leiocardium*) *dumosum*, Conr.
Cardium (*Pachycardium, Protocardium*) *perelongatum*, Whitf.
Crassatella vadosa, Mort.
Exogyra costata, Say.
Gryphæa vesicularis, Lam.
Gryphæa ostrea vomer, Mort.

Ostrea larva, Lam.
Lima species?
Neithea quinquecostata, Sowb.
Camptonectus (*Amusium*) *burlingtonensis*, Gabb.
Plicatula urticosa, Mort.
Idonearca vulgaris, Mort.
Trigonia Mortoni, Whitf.
Veniella conradi, Mort.

Gastropods.

Alaria rostrata, Gabb.
Anchura abrupta, Conr.
Anchura compressa, Whitf.
Gyrodes petrosus, Mort.
Lunatia halli, Gabb.
Natica abyssina, Mort.
Pleurotomaria crotaloides, Tuomey.
Pyropsis trochiformis, Tuomey.
Scala sillimani, Mort.
Strepsidura ripleyana, Conr.
Volutomorpha gabbi, Whitf.

Brachiopods.

Terebratella vanuxemi, Lyell & Forbes.

Cephalopods.

Belemnitella mucronata, Schlot.

Pisces.

Shark, tooth.

Reptilia. (?)

Gavial?, tooth.

Summary.

Lamellibranchs,	16
Gastropods,	11
Brachiopod,	1
Cephalopod,	1
Pisces,	1
Reptilia,	1
Total,	31 species.

ARTESIAN WELL AT PITMAN, NEAR THE RAILROAD STATION.

Elevation, 130 feet; diameter, 3 inches; depth, 180 feet.
Water rises within 50 feet of the surface.

Drilled for R. H. Corney by Haines Bros.

Haines Bros. report that the *Bryozoan* limesand was penetrated between the depths of 115 and 125 feet, and greensand marls between the depths of 125 and 160 feet, while a coarse *water-bearing sand* was found at the depth of 160 to 180 feet.

This is probably the Marlton water-horizon.

The beds from 115 to 160 feet are apparently the equivalents of the Limesand, Middle Marl and Lower Marl of the Cretaceous.

The same firm put a well down in the camp-meeting grounds at the same place in the year 1896, which was noted in the Annual Report for that year, page 128, to which for a more accurate and detailed record of the beds penetrated those especially interested are referred.

For a generalized exhibit of the various water-yielding horizons at this locality, with their depths and the geology of the beds, see the following record.

ARTESIAN WELL AT PITMAN.

Elevation, 140 feet. Diameter, 8 inches to 192 feet; 6 inches to 340 feet; 4½ inches to 478 feet; 3 inches to 498 feet. Total depth, 507 feet. Water rises within 140 feet from the surface.

This well was drilled by Thos. B. Harper to obtain a town water-supply, T. C. Alcott & Sons being the civil engineers. From both these parties we have received information which we incorporate below.

This well is on the easterly side of the railroad and near the station at Pitman, and on the lot adjoining the one on which a well was put down last year for Elmer H. Crane to the depth of 139 feet. It is also quite near the well noted in the preceding record, which has a depth of 180 feet, while upon the west side of the railroad within the camp-meeting grove there is a well with a depth of 190 feet which was recorded in the Annual Report for 1896. In the grove there are also a number of more shallow wells whose depths vary from 60 to 80 feet.

These various wells demonstrate the existence at this locality of the following water-yielding horizons:

Depth.	
60 to 80 feet.	At the base of the superficial sands.
110 to 129 "	In the Vincentown Bryozoan limesands. The Lindenwold water-horizon.
150 to 190 "	In the sands at the top of Clay Marls and beneath the true greensand Marls of the Middle and Lower Marl beds. The Marlton water-horizon.
478 to 507 "	In the top of the Raritan sands and beneath the Clay Marls. The Sewell water-horizon.

For a minutely detailed record of the first 190 feet those interested may consult the Annual Report for 1896, page 129. Below we present a record of this well, showing more broadly the succession of beds:

Surface, ...	0 feet to 10 feet.		
Orange-colored sands with thin clay seams, water-bearing at the base, ...	10 " " 70 "		
Dark clay, nearly black, ...	70 " " 80 "	Miocene ? 10 feet.	
Limesand, water-bearing and containing *Nodosaria, Echinus* spines and *Bryozoa,*	80 " " 100 "	Limesand, 20 feet.	Cretaceous.
Shells, probably *Terebratula,* &c., then greensand, marl, &c., ...	100 " " 140 "	Middle and Lower Marl beds, 40 feet.	
Marly clay, *Belemnites* and ponderous *shells,*	140 " " 150 "	Clay Marls, 338 feet.	
Yellowish sand, water-bearing,	150 " " 190 "		
Alternation of dark micaceous and marly clays, ...	190 " " 478 "		
Fine sand, followed by coarse sand, water-bearing, ...	478 " " 507 "	Raritan, 29 feet.	

ARTESIAN WELL THREE-QUARTERS OF A MILE NORTHWEST OF KIRKWOOD STATION.

Elevation, 90 feet; diameter 3 inches; depth, 129 feet.
Water rises within 46 feet of the surface.

Sunk for Walter Hunt. Drilled and reported by Frederick E. McCann. Water rises within 46 feet of the surface.

RECORD.

Thickness.		*Intervals of Depths.*
44 feet.	Yellow quicksand, ...	0 feet to 44 feet.
50 "	Dark greensand marl, ...	44 " " 94 "
15 "	Compact dark gray sand, hard to drill, with fossil *"snail shells,"*	94 " " 109 "
11 "	Still harder sand, ...	109 " " 120 "
9 "	"Pepper and salt" sand, *with water,*	120 " " 129 "

This well draws from the Marlton water-horizon that is found in the sands beneath the Lower Marl bed and at the top of the Clay Marls.

ARTESIAN WELL NEAR STRATFORD.

Elevation, 90 feet; diameter, 3 inches; depth, 107 feet.

Drilled and reported by Frederick E. McCann.

This well is about one mile south-southeast of the well last reported. The following is the record:

RECORD.

Thickness.		*Intervals of Depths.*
50 feet.	Yellow quicksand,	0 feet to 50 feet.
30 "	Black mud,	50 " " 80 "
12 "	Green marl,	80 " " 92 "
8 "	—— ——,	92 " " 100 "
3 "	Gray stone or rock,	100 " " 103 "
4 "	White sand with *water*,	103 " " 107 "

The supply of water comes from the Marlton water-horizon in the sand bed that occurs at the top of the Clay Marls and beneath the greensand of the Lower Marl bed.

ARTESIAN WELLS AT LAUREL SPRINGS.

Seven wells on the northeast side of the railroad.

Elevation, 90 feet; diameter of each, 3 inches; depths, 48 to 56 feet.

Six wells on the southwest side of the railroad.

Elevation, 80 feet; diameter of each, 3 inches; depths, 48 to 50 feet.

Two wells, one on either side of the railroad, near overhead bridge.

Elevation, 90 feet; diameter of each, 3 inches; depths, 73 and 83 feet.

One well southwest of the railroad, near mill pond.

Elevation, 60 feet; diameter, 3 inches; depth, 103 feet.
Water from this well rises within 19 feet of the surface.

All these wells drilled and data and specimens furnished by Frederick E. McCann.

This locality is a suburban settlement about ten and one-half miles from Kaighn's Point, on the Philadelphia and Reading route to Atlantic City.

The following section of F. Owen's well is representative of the material found in the first thirteen of the above wells.

	Thickness.	Intervals of Depths.
Yellow quicksand.	20 feet =	0 feet to 20 feet.
Black mud,	8 " =	20 " " 28 "
Hard, dry, gray sand,	20 " =	28 " " 48 "
Hard rock,	5 " =	48 " " 53 "
Gray sand, water-bearing, on the top of which boring was discontinued.		

For the three deeper wells, mentioned above, we present the record of the one which was put down for Joseph Eldridge, that being the deepest.

	Thickness.	Intervals of Depths.
Loamy yellow gravel, suitable for road-making,	18 feet =	0 feet to 18 feet.
Chrome or orange-yellow quicksand,	22 " =	18 " " 40 "
Green marl, blue marl, chocolate marl,	40 " =	40 " " 80 "
Dark-colored hard sand,	15 " =	80 " " 95 "
Shell bed,	7 " =	95 " " 102 "
Hard stone,	1 " =	102 " " 103 "
Then white sand, water-bearing, on the top of which the drilling was discontinued.		

The thirteen more shallow wells, whose depths vary from 48 to 56 feet, probably draw their water-supply from the Lindenwold water-horizon that occupies the loose sands which in this region are interbedded in the Limesand formation.

The three deeper wells (depths 73, 83 and 103 feet) obtain water from beneath the greensands of the Lower Marl bed in the sand bed at the top of the Clay Marls. This is the equivalent of the Marlton water-horizon.

TWO ARTESIAN WELLS AT BLACKWOOD.

One for F. Pine—Elevation, 50 feet; diameter, 3 inches; depth, 70 feet.
One for H. Runkel—Elevation, 60 feet; diameter, 3 inches; depth, 68 feet.

Wells drilled and data furnished by Frederick E. McCann.

These wells we are informed are about 2,000 feet apart. The description of strata is as follows:

Sand,	0 feet to 6 feet.
Red heavy stony gravel,	6 " " 16 "
Gray marl,	16 " " 23 "
Blue marl,	23 " " 28 "
Chocolate marl,	28 " " 60 "
"Pepper and salt" gray sand,	60 " " 70 "

No shells were observed by the driller in these borings, but what are locally known as "marl stone knockers" were found.

This well draws its supply from the Marlton water-horizon.

ARTESIAN WELL AT CLEMENTON.

Elevation, 70 feet; diameter, 3 inches; depth, 100 feet.

Sunk for William Wurts. Well drilled and data furnished by Frederick E. McCann.

This well is located well up the rise of the hill immediately west of and adjacent to Clementon Station.

RECORD.

Yellow quicksand,	0	feet	to	18	feet.
Black mud,	18	"	"	65	"
White glass sand,	65	"	"	68	"
Dark brown gummy clay,	68	"	"	78	"
White sand, no water,	78	"	"	81	"
Light steel-colored clay,	81	"	"	89	"
Shells of mollusks,	89	"	"	93	"
Gray sandstone,	93	"	"	99	"
White sand with black specks—water-bearing,	99	"	"	100	"

This well is probably supplied from loose water-bearing sands that are known in this region to be interbedded with the Bryozoan limesand rock strata. If so the supply is from the Lindenwold water-horizon.

TWO WELLS TWO AND ONE-QUARTER MILES WEST OF CLEMENTON, BETWEEN CLEMENTON AND BLACKWOOD.

No. 1—Elevation, 80 feet; diameter, 3 inches; depth, 81 feet.
No. 2—Elevation, 55 feet; diameter, 3 inches; depth, 62 feet.

Sunk for George Rief. Wells drilled and data furnished by Frederick E. McCann.

The following is the record of strata as received:

	Well No. 1. Thickness.	*Well No. 1.* Depth.	*Well No. 2.* Thickness.	*Well No. 2.* Depth.
Yellowish quicksand, ...	60	60	46	46
Fine smooth light clay, "the color of paris green,"	2	62	2	48
Bryozoan limesand, ...	10	72	10	58
Light steel-gray stone, ...	9	81	9	62

This stone rests on gray sand which supplies the water and on top of which the borings were discontinued.

These wells are supplied from the Lindenwold water-horizon which occupies the Bryozoan limesand above the pure greensand of the Middle Marl bed.

ARTESIAN WELL ONE AND THREE-QUARTER MILES WEST OF CLEMENTON.

Elevation, 80 feet; diameter, 3 inches; depth, 60 feet.
Water rises within 23 feet of the surface.

Sunk for Edward Brown. Drilled and reported by Frederick E. McCann.

This well is on the south side of the road from Blackwood to Clementon, somewhat nearer the latter place, and is about one-third of a mile east of the deeper well (81 feet) of the preceding record, the latter being on the north side of the road. The following is the record as furnished by the driller:

Commenced on the bottom of a dug well at the depth of ....20 feet.
Yellow quicksand, ... 20 feet to 25 "
Black mud, ... 25 " " 60 "
Water beneath in "pepper and salt" gray sand.

We are informed that no rock was encountered and no fossils were observed in drilling this well.

ARTESIAN WELL ONE AND ONE-HALF MILES SOUTH OF FAIRVIEW.

Elevation, 80 feet; diameter, 3 inches; depth, 72 feet.
Water rises within 21 feet of the surface.

Sunk for Mrs. Wolf. Drilled and reported by Frederick E. McCann.

This locality is southwest of Blackwood; the record received is as follows:

35 feet.	Yellow quicksand,	0 feet to 35 feet.
20 "	Steel-gray quicksand, contains water,	35 " " 55 "
7 "	Marl,	55 " " 62 "
10 "	Black and white sand,	62 " " 72 "

ARTESIAN WELL NEAR MONROE STATION AND TWO AND ONE-HALF MILES NORTH OF ELMER.

Elevation, 140 feet; depth, 60 feet.
Water rises within 14 feet of the surface.

Drilled by Haines Bros., who report as follows:

Good gravel, suitable for road-making,	0 feet to 15 feet.
Fine white quicksand,	15 " " 25 "
Yellow sand,	25 " " 35 "
Lighter colored fine sand, but not so light as at 15 to 25 feet,	35 " " 50 "
Coarse sand with water,	50 " " 60 "

Stopped on dark brown clay, probably Miocene.

This well is located on one of several remnants of a former plain, which in this region had an elevation of about 140 feet.

ARTESIAN WELL NEAR CORSE'S LANDING.

Elevation, 20 feet; diameter, 3 inches; depth, 98 feet.
Water rises within 8 feet of the surface.

Data furnished and well drilled by Haines Bros.

This well is located about one mile north of Salem creek, on the road leading from Corse's Landing to Auburn and about two miles slightly north of west from Sharptown.

Soil, clay, &c.,	0 feet to 12 feet.	
Fine sand, shade of light brown sugar,	12 " " 32 "	
Light brown, running, sticky mud,	32 " " 40 "	Clay Marls. Cretaceous.
Black clay marl,	40 " " 60 "	
Fine black sand, changing to coarser and and lighter colored at the base,	60 " " 98 "	

The contractors report that "good water" was obtained.

ARTESIAN WELL AT PENNSGROVE.

Elevation, 5 feet. Diameter, 6 inches. Depth to gneiss rock, 275 feet; depth in gneiss rock, 59 feet; total depth 334 feet.

George Pfeiffer, contractor; W. H. Boardman, civil engineer. Drilled by Joseph W. Pratt and Haines Bros.

This well was sunk for a public water-supply. Water in sufficient quantity was not, however, found, although a moderate supply that yielded by pumping 35 gallons per minute occurred at about 100 feet. The drilling has been abandoned. Excepting the first 48 or 50 feet, or perhaps only 30 feet, this well clearly penetrated the plastic clays and interbedded sands of the Raritan formation to the depth of 270 feet, where the characteristic micaceous gneiss rock of southeastern Pennsylvania was encountered. This rock occurs here at less depth than it does a short distance southward, since, while preparing this report, we have received information of a well being put down at Carney's Point on the river but a few miles southward which had reached a depth of 330 feet without finding any rock.

From both well drillers we have received specimens of the borings, and from W. H. Boardman a carefully kept record which we insert below, and which on comparison we find agrees with the specimens.

Orange-yellow sand,	0 feet to	15 feet.		
Yellow loamy clay	15 " "	22 "		
Coarse gravel with large pebbles and boulders,	22 " "	30 "		
Clay, black when wet, dries out gray,	30 " "	48 "		
Boulder of coarse, white, compact sandstone at		48 "	Probably Raritan.	
Black clay continued,	48 " "	86 "		
Heavy gravel with large pebbles at		86 "		
Black clay again,	86 " "	94 "		
Coarse gravel with pebbles, cobbles and boulders, with a little *water*,	94 " "	102 "	Raritan.	Cretaceous.
Coarse clean sand,	102 " "	106 "		
Red Plastic Clay,	106 " "	132 "		
Thin layers of sand and clay,	132 " "	156 "		
Fine white sand (no water),	156 " "	161 "		
Lead-colored clay,	161 " "	172 "		
Fine white sand,	172 " "	193 "		

Red Plastic Clay,	193 feet to 202 feet.	Raritan.	Cretaceous.
Clean, coarse, gray sand,	202 " " 207 "		
Red Plastic Clay,	207 " " 209 "		
Fine red sand and clay,	209 " " 234 "		
Very fine gray sand,	234 " " 238 "		
Coarse red sand,	238 " " 250 "		
Fine yellow sand,	250 " " 260 "		
Red clay and sand,	260 " " 270 "		
Soft micaceous rock,	270 " " 275 "		
Hard micaceous rock,	275 " " 350 "		

The red color of the clays below 106 feet may be appropriately described as blood-red.

THREE BORED WELLS ONE AND A-HALF MILES NORTHWEST OF PEDRICKTOWN.

Elevation, 5 feet; diameter of each, 3 inches; depth of each as finished, 24 feet.
Prospected beyond to the depth of 40 feet.
Water rises within 6 feet of the surface.

Well drilled and data furnished by Haines Bros.

These wells are located on the inner margin of the meadow flats near the mouth of Old Man's creek. The following is the record as furnished by the contractors:

Fine sand, shade of light brown sugar,	0 feet to 24 feet.
Coarse gravel, *water-bearing*,	24 " " 30 "
Lead-colored clay,	30 " " 33 "
Lead-colored sand,	33 " " 40 "
Iron crusts at	40 "

THREE ARTESIAN WELLS AT WOODSTOWN AT ICE AND COLD STORAGE CO.

No. 1—Elevation, 50 feet; diameter, 6 inches; depth, 160 feet.
No. 2—Elevation, 50 feet; diameter, 4½ inches; depth, 160 feet.
Marlton Water-Horizon—Water rises within 16 feet of the surface.
No. 3—Elevation, 50 feet; diameter, 6 inches; depth, 360 feet.
Sewell Water-Horizon—Water rises within about 50 feet of the surface.

These wells were drilled by Haines Bros., who have courteously furnished specimens of the borings from Well No. 3 taken every ten feet, and also considerable information respecting the strata as observed by them in all three of the wells. From a careful examination and study of the borings, supplemented by the information thus received, we present the subjoined record. These wells were put down by the drill and sand-bucket process which furnishes specimens of the materials brought out more nearly in their natural condition than do the various hydraulic or washout methods often employed, for which reason the description of the beds as given below may be relied upon as being unusually accurate.

RECORD.

Gravel and yellow clay, ..	0 feet to 25 feet.	Recent.		
Black clay, ...	25 " " 30 "	Miocene?		
Limesand with *Foraminifera*, ...	30 " " 40 "	Limesand.		Cretaceous.
Shell layer containing *Gryphea*, *Terebratula*, and other fossils (see notes on fossils below),	40 " " 50 "	Limesand. Middle and Lower Marl beds.		
Pure greensand marl, very dark in color, ...	50 " " 80 "	Middle and Lower Marl beds.		
Lighter green greensand marl mixed with light gray clay; contains *Belemnites* at about 90 feet, ...	80 " " 90 "	Greensand with Belemnitella.	Clay Marls.	
Slightly clayey, dull yellowish gray sand, about one-third greensand and two-thirds whitish quartz sand, with *Belemnites* and *Molluscan fossils*, same as at Mullica Hill, ...	90 " " 135 "	Sand. Marlton Water-Horizon.		
Black and white clear sand, resembles pepper and salt mixture, *Belemnitella*, *Terebratella* and other fossils, &c., as noted below, ..	135 " " 160 "			

The last two divisions, from 100 to 160 feet, are *largely water bearing throughout* and supply wells Nos. 1 and 2.

Clayey greensand with *molluscan fossils* (see notes below), ...	160	" "	170	"	Clay.	Clay Marls.	Cretaceous.
Dark sandy clay, large admixture of white quartz sand with a smaller proportion of geensand; contains mollusks, *Foraminifera* and *other fossils,* same as at Marshalltown,..	170	" "	190	"			
Greenish gray sand, consisting of white quartz and greensand grains, the former predominating. This stratum was slightly water-bearing, but was not utilized. These specimens contained *mollusks* and *Foraminifera,* &c., as noted below, ...	190	" "	210	"	Sand. Cropwell Water Horizon.		
Dark, very slightly greenish, micaceous clay with very little greensand. *Gryphea* and *Belemnitella* at 230 to 240 feet. Pyrite nodules at 210 to 220 feet and at 240 to 250 feet, ...	210	" "	250	"	Dark Clay with Fossils.		
Still darker, almost black, micaceous clay with yellowish pebbles between 270 and 290 feet. No fossils observed, ...	250	" "	290	"			
Decidedly greenish clay, contains at 290 to 300 feet some *molluscan fossils* similar to fossils at Lenola, but different from those observed in the overlying beds. (See notes on fossils below.) Nodules at 290 to 310 feet,	290	" "	330	"	Green Clay,		
Medium coarse gray or bluish - white sand, *abundantly water bearing,* supplies well No. 3, ...	330	" "	360	"	Sand. Sewell Water-Horizon.	Raritan.	

The Clay Marls, within which the writer includes all the beds from the Exogyra-Belemnitella layer next below the true greensands of the Lower Marl bed to the top of the sands and clays of the Raritan formation, show a thickness in this boring of 250 feet, which appears to be about the minimum thickness of these beds in the State. Studies of specimens from well-borings elsewhere and of good exposures of the uppermost sand-bed of the series immediately adjacent to some of the wells show that these clay marls thicken along the line of strike to the northeast as follows:

Thickness	at	Auburn,*	242	feet.
"	"	Woodstown,	250	"
"	"	Mullica Hill,	263	"
"	"	Sewell,	305	"
"	"	Pitman,	338	"
"	"	Mount Laurel,	305	" +
"	"	Mount Holly,	325	" ±

These wells at Woodstown and the wells at Auburn and Mullica Hill were all of them sunk with drill and sand-bucket by the same well-driller, who furnished specimens of the borings from each. These specimens are, therefore, especially valuable for comparison. Such comparison shows for the Clay Marls not only a five-fold division† as indicated in the record above, viz., in order downward, sand, clay, sand, black or dark clay and green clay, but also that certain features of each bed, such as slight differences in lithological composition or minor changes of shade in the colors, are repeated in the same order in each well. The change of the two lowest beds from a black micaceous clay above to a peculiarly greenish clay below has also been frequently noticed by the writer in well-borings at other localities where only the lower beds of series were penetrated, the upper ones being wanting.

* The well at Auburn, although not northeast of Woodstown, but about 3 miles N. N.-W., is here included, because it is in the same region as Woodstown and somewhat further up on the slope of the beds and should be considered jointly with the data at Woodstown as showing the minimum thickness of the clay marls toward the southwestern part of the State.

† This five-fold division was first recognized by G. N. Knapp, from a study of surface outcrops, and communicated by him to other workers on the Survey, though he has not himself published the same. In the Annual Report for 1898, page 30, Prof. R. D. Salisbury however states that Mr. Knapp had found that five distinct beds of the Clay Marl series can be traced across the State, and that to these beds he (Mr. Knapp) had assigned names.

We now note in tabular form and more in detail than in the preceding record the fossils found in the specimens of the borings at various depths.

LIST OF FOSSILS. *Intervals of Depths in Feet.*	MIDDLE MARL.	LOWER MARL.	CLAY MARLS.					
			Sand.		*Clay Fossils as at Marshalltown.*	*Sand.*	*Dark Clay.*	*Green Clay Fossils as at Lenola.*
Molluscan Fossils:								
Terebratula harlani, Morton,	40 to 50	......	....	....	....	....	....	....
Gryphea vesicularis, Lamarck,	40 to 50	......	120 to 130	140 to 150	170 to 180	200 to 210	230 to 240	....
Belemnitella Americana, Morton,	......	80 to 90	110 to 130	140 to 150	160 to 170	....	230 to 240	....
Ostrea larva, Lamarck,	......	......	110 to 120	....	....	190 to 200	....	....
Anomia, probably tellinoides, Morton,	......	......	120 to 130	140 to 150	....	190 to 200	....	....
Terebratella (finely ribbed), probably vanuxemi, Lyell & Forbes,	......	......	....	140 to 150	....	....	....	....
Dentalium ——— sp?	......	......	....	140 to 150	....	190 to 200	....	....
Exogyra costata, Say,	......	......	....	140 to 150	160 to 170	....	....	....
Gryphæostrea vomer, Morton,	......	......	....	140 to 150	....	....	....	....
Arca ?	......	......	....	150 to 160	....	....	....	....
Ostrea plumosa, Morton,	......	......	....	....	160 to 180	....	....	....
Pecten ——— sp?	......	......	....	....	160 to 180	190 to 200	....	....
Turritella encrinoides, Morton,	......	......	....	....	....	....	....	290 to 300
Alaria?	......	......	....	....	....	....	....	290 to 300
Gyrodes ——— sp?	......	......	....	....	....	....	....	290 to 300
Non-Mulluscan Fossils:								
Shark's tooth, not identified,	40 to 50	......	....	....	....	....	....	....
Nodosaria, several species, and other Foraminifera,	40 to 50	......	....	150 to 160	170 to 180	190 to 200	....	....
Echinus spines, several species,	40 to 50	......	....	140 to 160	170 to 180	190 to 210	....	....
Ostracoda, one species only,	......	......	....	140 to 150	170 to 180	190 to 200	....	....
Minute flat white calcareous striated spines, not identified,	......	......	....	140 to 150	170 to 180	....	....	....

The foregoing tabulated exhibit of fossils (if we may rely upon there having been no admixture in lower depths of fossils from short distances above) shows several fossil-horizons, the broader features of each of which we would note as follows:

At 30 to 40 feet.—The limesand or upper division of the Middle Marl bed, as defined by Prof. Geo. H. Cook, presents a thickness of about 10 feet. In this region, however, and but a few miles farther out on the dip, it attains a thickness of about 100 feet, as has been revealed by well-borings at Quinton* and near Penton†. Bryozoa and large Nodosarian forms of Foraminifera characterize this bed in outcrops. The Foraminifera noted in specimens marked 40 to 50 feet were probably contributed from the limesand which occurs next above the depth of 40 feet. The Bryozoa, however, were not found in these borings.

At 40 to 50 feet.—The top of the lower division of the Middle Marl bed was well indicated by numerous individuals of Gryphæa vesicularis, Lamarck, in specimens of the borings marked 40 to 50 feet. But one specimen, a fragment only, was seen of Terebratula harlani, Morton, notwithstanding that where this shell-bed outcrops in the State this brachiopod frequently occurs as a layer one to three feet thick immediately on top of the Gryphæa stratum, which likewise often has a thickness of about three feet.

At 50 to 80 feet.—The nearly pure glauconitic greensand marl making this interval showed a slight change in the shade of green at about 60 feet, which depth it is tentatively suggested may indicate the division between the middle and the lower Marl beds.

At 80 to 90 feet.—The appearance at this depth for the first time in this boring of the cephalopod, Belemnitella Americana, Morton, probably indicates the approximate base of the lower marl bed, which is generally in this State marked by a compact Exogyra shell-bed, often several feet thick, in which there are distributed numerous belemnites. Singularly, however, these molluscan fossils were not found associated with the belemnites at this horizon.

*Annual report for 1894, page 193.

†This report, page 103.

At 120 to 130 feet there occur a few species of mollusks; Foraminifera and other minute fossils being absent.

At 140 to 150 feet there are the same Molluscan fossils, with the addition of at least as many more species to the number, and with the further admixture of Foraminifera, Ostracoda, Echinus spines, &c. In this division we were able to identify a small fragment of shell as a brachiopod by means of the minute foramen or orifices which characterize that class of shells, and which were plainly revealed by the microscope. We have tentatively referred it to Terebratula vanuxemi, Lyell and Forbes, although the plications are, we think, somewhat finer than they are figured by Whitfield in his Paleontology, Plate I, figs. 1 to 4.

The three fossil-horizons last noted occur in the sand-bed at the top of the Clay Marls.

At 160 to 180 feet.—Here only a few of the molluscan species previously noted were found, but there occurred numerous specimens of Ostrea plumosa, Morton, not noticed either higher or lower, and there was also introduced a Pecten which we have been unable to identify. Nodosaria and other Foraminifera, Ostracoda and Echinus spines are also associated with the clay of this interval. This horizon is probably the same as that of outcrops of fossiliferous marl that have long been dug for fertilizing purposes near Marshalltown, about five mies to the westward.

The unidentified flat white calcareous spines at 140 to 150 feet and at 170 to 180 feet resembled, except for their flatness, the Echinus spines found at the same depth.

At 190 to 210 feet.—In the sand of this interval there were found most of the species of mollusks that occurred both at 140 to 160 feet and at 160 to 180 feet, and with these there were Ostracoda, Echinus spines, also Nodosaria and other foraminifera.

At 230 to 240 feet.—In the dark clays between these depths we found few fossils and but two species, a Belemnitella and a Gryphæa. There were no Foraminifera or other minute fossils such as characterized the three overlying beds.

At 290 to 300 feet.—Between these depths there were a few mollusks of species entirely different from all those observed in the beds above. These occurred in the form of indurated interior casts, in this respect differing from the mode of occurrence of all the mollusks in the higher beds, where the shell itself was preserved. This horizon is doubtless the equivalent of the well-known fossil-horizon at Reeves clay bank at Lenola, near Moorestown.

Correlation at Wilmington, Del.—The writer considers that an outlying fossil deposit discovered by Arthur Bibbins* in 1899, at the depth of about fifteen feet, in a dug well, on the top of a 200-foot hill north of Wilmington, Delaware, also represents the same bed. This locality the writer visited shortly afterward, and obtained a considerable number of the fossils. They also occurred as casts in the same character of indurated material and in about the same condition as those from this well. They were, however, more numerous both specifically and individually. The specific forms of the few shells at this horizon at Woodstown appear, so far as we can judge, to be identical with forms at Wilmington.

This locality is 12 miles due northwest from Woodstown and directly coincident with the true dip of the beds. If to 185 feet above tide, the altitude of the fossil bed at Wilmington, we add 150 feet, the depth below tide of the bed at Woodstown, we have a difference of level of 335 feet, indicating a dip of 28 feet per mile. Similar calculations made for the dip of the clay beds between their occurrence in this well at the depth of 160 to 180 feet and their outcrops gives the same dip per mile. This dip, however, is not so great as data in the writer's hand indicates for the beds to the northwest, which data, however, generally pertains to localities at a greater distance from the original shore line.

In drilling these wells three water-yielding horizons were observed, only two of which were utilized. These three horizons are as follows:

* Our knowledge of this locality and its fossil horizon was obtained from Arthur Bibbins, who, so far as we are aware, has not published his discovery. The writer however, in thus incidentally referring to the same, desires to give Mr. Bibbins full credit therefor.

The names given are those that have previously been used by the writer for the same water-yielding horizons at other localities:

At 90 to 160 feet.—*Marlton Water-Horizon.** Supplies wells Nos. 1 and 2. Yields a large quantity of water.

At 190 to 210 feet.—*Cropwell Water-Horizon.* Affords here only a scant supply, and was not utilized, although to the northeast the yield is sufficient to furnish such considerable towns as Columbus and Marlton.

At 330 to 360 feet.—*The Sewell Water-Horizon.* Supplies well No. 3. This horizon, in the southern part of the coastal plain portion of New Jersey, almost universally furnishes an abundant supply. It occurs at the *top* of the Raritan plastic clay formation, and is stratigraphically higher than the water-horizons which supply Camden and Gloucester, and which are in the *lower* parts of the same Raritan beds.

ARTESIAN WELL ONE MILE WEST OF WOODSTOWN AND ONE MILE SOUTHEAST OF SHARPTOWN.

Elevation, 50 feet; diameter, 3 inches; depth, 135 feet.
Water rises within 40 feet of the surface.

Drilled by Haines Bros., for Charles E. Allen.

This well is on the road from Sharptown to Woodstown and about one mile west of the latter place. The contractors furnish the following record:

Surface deposits, clay, gravel, &c.,	0	feet	to	30	feet.
Light colored sand,	30	"	"	35	"
Black mud,	35	"	"	50	"
Lime-sand mixed with marl,	50	"	"	65	"
Greensand marl,	65	"	"	100	"
Sand and marl mixed,	100	"	"	115	"
Gray sand with water,	115	"	"	135	"

* The Marlton horizon furnishes numerous wells in and around Marlton. The public supply, however, of that town, is obtained from a well sunk to the Cropwell horizon about 100 feet below the former at that locality.

TWO ARTESIAN WELLS TWO AND ONE-QUARTER MILES EAST OF ALLOWAY.

No. 1—Elevation, 40 feet; diameter, 1½ inches ;depth, 240 feet. Cased to 190 feet only. Water rises to within 17 feet of the surface.

Drilled by Abraham Darlington.

No. 2—Elevation, 30 feet; diameter, 3 inches; depth, 205 feet. Finished at the depth of 190 feet.

Drilled by Haines Bros.

Water-supply of both wells from the Vincentown limesands.

These two wells are near each other, upon adjacent properties, on opposite sides of the road leading from Alloway to Daretown, and, as above noted, are about two and one-quarter miles east of Alloway.

Well No. 1 is upon the farm of Parvin Lloyd, and Well No. 2 upon a farm owned by Samuel C. Reeve and occupied by Henry Hile. Both wells are at about the same elevation, which we estimate at about 40 feet above mean tide. Besides being directly upon opposite sides of the same road, they are also upon opposite sides of Cool run, one of the northerly branches of Alloway creek, and are back only a short distance on either side from the top of the ravine cut by that stream.

The drillers of these wells have each courteously furnished information about their respective wells which enables us to present the following combined record for both:

	18 feet yellow clay,.......	Surface	to 18	feet.	Miocene in part at least.	
	90 " "Blue mud,"	18	" " 108	"		
83 feet.	"Marl and sand,"	108	" " 180	"	Mostly Limesands.	Cretaceous.
	Gray rock, 18 inches, ...	180	" " 181½	"		
	Sand, water-bearing, ...	181½	" " 190	"		
	Gray rock again, 9 in.,....	190	" " 191	"		
49 feet.	Well No. 2 was prospected through "Marl and sand" from	191	" " 205	"	Middle Marl.	
	Well No. 1 was further continued through the same material from	205	" " 240	"		

It is most probable that there is next below the depth of 108 feet a thin stratum of Eocene Marl, as was the case in wells at Quinton, but of this the drillers have failed to take notice.

An interesting fact learned from the above record is that the Miocene clay has in this region a thickness of about 90 feet. The upper portion of this bed outcrops at the forks of the mill-pond immediately east of the Alloway. The same bed is also exposed in the lower level of David F. Haines' clay-pits at his brick and tile works, one and one-quarter miles south of Yorktown and two miles northeast of the location of these wells.

Another matter of interest is the confirmation of the considerable thickening of the limesand bed as it dips southeastward away from its line of outcrops, a fact first noted in the record of wells at Quinton in the Annual Reports for 1893, page 415, and 1894, page 193, and again revealed as noted in this volume, page 114, in the record of the deep artesian well at Atlantic City. The thicknesses now known for this bed are as follows:

At Quinton,	108 feet.
At Alloway,	83 "
At Atlantic City,	460 "

The water from well No. 2 is strongly impregnated with mineral matter. The writer thinks it probable that this well was continued too deep to secure a supply from within the limesand only, and that the water obtained comes largely from the true marls beneath. If continued at all beneath the limesand, this boring should have been drilled a short distance further and cased through the marl, when the next lower water-bearing sands, the Marlton water-horizon, immediately below the marl, would have been reached, which horizon supplies the wells at Quinton.

ARTESIAN WELL ONE MILE SOUTH OF PENTON.

Elevation, 10 feet; depth, 189 feet.

Abraham Darlington reports having put down this well for Thomas J. Yorke, at Penton Abbey, about one mile south of Penton Station, on the Elmer and Salem R.R. He states its depth is

189 feet; that he went through 80 feet of "blue clay" (Miocene), and that below that there are "twenty-two layers of stone, varying from a few inches to a few feet in thickness," each layer being separated by varying thickness of sand.

From its location we judge that this well, after passing the more superficial sands, penetrated in succession Miocene Clay, Eocene Marl (thin stratum), and the Cretaceous Limesands and Middle and Lower Marls, and obtained a supply of water beneath these in the subjacent sand-bed at the top of the Clay marls. This horizon supplies the wells at Quinton and is the equivalent of the Marlton water-horizon.

The twenty-two stony layers and their interbedded sands are corroborative of the thickness of 108 feet, already reported at Quinton*, and of 83 feet reported near Alloway†, for similar alternations of limestone rock and loose sand, and doubtless represent the limesand that constitutes what has been considered in outcrops as the upper layer of the Middle Marl bed.

THREE ARTESIAN WELLS AT SALEM.

Elevation, 3 feet; depth of each, 100 feet.

Drilled by Haines Bros. for John Q. Davis.

These wells are located upon the westerly side of the road from three other wells at the same place also put down for John Q. Davis, and which were noted in the Annual Report for 1897, page 249. Haines Bros. state that the wells of the present year were each of them sunk to the depth of 100 feet and cased to the depth of 80 feet, and that shells were noticed at the depth of 50 feet and again at 70 feet.

These borings penetrate the true marl beds from about the base of the Limesands to the base of the Lower Marl. The shells at 70 feet probably indicate the Exogyra and Belemnitella horizon that occurs next below the Lower Marl, and which we regard as belonging to the top of the Clay Marl series.

* Annual Reports for 1893, page 416, and 1894, page 194.

† See this Report, page 102.

The details of the strata would doubtless correspond with the record published in the above-noted Annual Report, to which the reader is referred.

The supply comes from the Marlton water-horizon, and is the same as that furnishing wells on numerous farms near Marlton, but is not the same as the water-horizon used to supply that town, which latter is the Cropwell.

ARTESIAN WELL ONE MILE WEST OF SALEM.

Elevation, 10 feet; diameter, 3 inches; depth, 40 feet.
Water rises within 7 feet of the surface.

Drilled for Howard Harris. Reported by Haines Bros.

Haines Bros. state that the drill went through fine yellowish sands from close to the surface to near the base, where the color changes to white. As this well is on the low-lying land near the mouth of Salem creek, where it debouches into the Delaware, and as no impervious clay strata are reported, we apprehend the supply obtained may be largely filtered river water.

ARTESIAN WELL AT FORT DUPONT, DELAWARE.

Elevation, 5 feet or less; diameter, 8 inches; depth, 734 feet.
Water overflows at the surface.

Correlation with wells at other localities.—This well was noted on pages 132 to 134 of last year's report (1900), as then unfinished, although it had reached the depth of 700 feet. At that time we presented a minutely detailed record. P. H. & J. Conlan have recently informed us that the well has since been finished at the depth of 734 feet as a flowing well, and that there was "found a good supply of water."

From the record of last year it seems evident that this supply is obtained from a whitish sand-bed 54 feet thick, extending from the depth of 680 feet to that of 734, and that this stratum is overlaid by an impervious clay-bed 152 feet thick, which occupies the interval between the depth of 428 and 680 feet. We now correlate the stratigraphy and geology of a number of deep wells, including this one, all of which have developed a water-supply more or less deeply in the Raritan beds.

Reference to Annual Reports, with pages.	*1892—303. 1900—144.*	*1892—305. 1897—280.*	*1900—131.*	*1898—115.*
Localities,	Mt. Holly,	Jobstown,	Fort Mott,	Ft. Delaware
Elevation of surface,	10 feet,	60 feet,	10 feet,	10 feet, ±
	Thickness,	Thickness,	Thickness,	Thickness.
Superficial beds,	12 feet,	14 feet,	25 feet,	110 feet+
Middle and Lower Marl,	Wanting,	Wanting,	Wanting,	
Clay Marls,	308 feet,	292 feet,	97 feet,	36 " ±
Raritan sands and plastic clays (bottom in no case reached),	355 "	409 "	198 "	244 "
Total depths,	675 feet,	715 feet,	320 feet,	390 feet,

Reference to Annual Reports, with pages.	*1900—132. 1901— —.*	*1901.*	*1892—302.*	*1896—140. 1897—248.*
Localities,	Ft. Dupont,	Middletown	Woodstown	Reedy Island.
Elevation of surface,	10 feet,	40 feet,	15 feet,	10 feet.
	Thickness,	Thickness,	Thickness,	Thickness.
Superficial beds,	25 feet (?),	27 feet,	8 feet,	91 feet.
Middle and Lower Marl,	Wanting,	48 "	46 "	
Clay Marls,	123 feet,	243 "	242 "	213 feet.
Raritan sands and plastic clays (bottom in no case reached),	586 "	503 feet (?)	480 "	270 "
Total depths,	734 feet,	821 feet,	776 feet,	574 feet.

In explanation of the varying thicknesses of the Clay Marls and the Plastic Clays at different localities, as noted in the preceding exhibit, it should be stated that the wells at Fort Mott, Fort Delaware and Fort Dupont went through only the lower portion of the Clay Marls, and hence do not show their entire thickness. This thickness, however, seems to increase from the southeast to the northwest, as is noted in the report of a deep boring at Woodstown, page 93. All of the wells, however, went to greatly varying depths in the Plastic Clay formation from its top, but none passed entirely through it. The well at Fort Dupont penetrated it to the greatest depth, and shows that the thickness exceeds 586 feet.

The borings from the wells on Reedy Island and at Fort Delaware, on Pea Patch Island, both in the center of the Delaware river, exhibit beds in their upper portion about 100 feet thick, which are probably river deposits, deposited in a trough which the river had previously eroded, this erosion having cut through the Middle and Lower Marls at Reedy Island and through the Lower Marl and partly into the Clay Marls at Pea Patch Island.

BORED WELLS AT MIDDLETOWN, DELAWARE.

Elevation, about 40 feet.
Three wells. Diameter of each, 6 inches; depth, 88 feet.
Water rises within 13 feet of the surface.

One well, diameter, 8 inches; depth, 552 feet.
One well, depth, 686 feet.
One well, depth, 821 feet.
Water from the last three wells rises to from 35 to 55 feet from the surface.

Water at	88 to 100 feet.
" "	170 " 204 "
" "	475 " 495 "
" "	517 " 534 "
" "	552 "
" "	660 " 686 "
" "	792 " 821 "

In the Annual Report for 1896 there are noted four of the above wells, and in that for 1898 one other, while the sixth, which has a depth of 821 feet, was sunk the past year. All of these wells were put down for the Light and Water Commission. The well of the present year was drilled by J. H. K. Shannahan, who has furnished a record of the strata penetrated below the depth of the deepest of the former wells; that is to say, below the depth of 686 feet.

In order to present in its entirety the stratigraphical record at this place we insert below the records as previously published to the depth of 698 feet and add thereto the record now furnished below that depth:

Surface sands and gravels,		27 feet.			
Iron-colored sands and crusts,	27 to	72	"	Lower Marl.	Cretaceous.
Indurated greensand,	72 "	75	"		
Red and yellow sand,	75 "	90	"	Clay Marls.	
Water-bearing sand§ *horizon of 88-foot Wells*,	90 "	110	"		
Greenish sand at		110	"		
Sand and clay,	110 "	133	"		
Fine sand with a little water,	133 "	140	"		
Black and green sand,	140 "	142	"		
White and yellow sand,	142 "	146	"		
Clay,	146 "	170	"		
Alternations of sands, clays and gravels, *water-bearing*,*	170 "	204	"		
Clay with three sand seams,	204 "	224	"		
Interval, no record, except "whitish crust at 275 feet"	224 "	318	"		
Very hard white clay,	318 "	347	"	Age ?	
Clay with abundance of Lignite,	362 "	365	"		
"Cemented (shells ?),"	390 "	400	"		
Red clay at		425	"	Raritan Plastic Clays and Sands.	
Hard crust, 3 inches thick, at		442	"		
White sand, *water-bearing*,	475 "	495	"		
White and red clay,	495 "	517	"		
White sand, *water-bearing*,†	517 "	534	"		
White clay,	534 "	538	"		
Sand with water,	538 "	552	"		
Rock (?) at		552	"		
Clay,	552 "	558	"		
Sand,	558 "	560	"		
Red clay,	560 "	563	"		
White clay,	563 "	580	"		
Red clay,	580 "	587	"		
Another boulder and very hard red clay,	587 "	589	"		
Light lead-colored clay,	589 "	655	"		
Sand with *water*,	655 "	686	"		
Red, white and yellow clays,	686 "	780	"		
Boulders in blue clay,	780 "	792	"		
Whitish *water-bearing* sand, contains some mica,‡	792 "	821	"		

Respecting the water-bearing sand developed this year at the depth of 792 to 821 feet, Norman M. Shannahan, who had

§ Water from this horizon rises within 13 feet of the surface.

* This horizon was not used. Water therefrom rises within 20 feet of the surface.

† Water from this horizon rises within 34 feet of the surface.

‡ Water from between 792 to 821 feet rises to within about 55 feet of the surface, as also elsewhere noted in the text.

immediate charge of the work, writes, "We pumped 150 gallons per minute, lowering the water to 110 feet; when not pumping the water stands at 55 to 60 feet from the surface. The water is softer than in any of the other wells."

Geologically this well is interesting since it shows a great thickness of the Raritan formation, with its red, yellow and white plastic clays and associated sands and heavy gravels. We have not received specimens of the borings from any of these wells, but, judging from the record, all below the depth of about 400 feet must certainly belong to this formation, and but for the "cemented shells" (?), noted at 390 to 400 feet, we should incline to regard all below 318 feet as belonging to that formation. We are not certain whether or not the "shells" so reported represent mollusks or whether they were shaly layers of rock, which are sometimes called "shells" by well-drillers.

The four shallow wells (depth 88 feet) of former reports, and noted at the heading of this well report, doubtless draw from the Marlton Water-Horizon at the base of the Lower Marl bed and the top of the Clay Marls. This horizon also supplies wells in New Jersey on the opposite side of the river at Quinton and Woodstown.

All the other and lower water-horizons tabulated at the head of this record draw from the Raritan group of water-horizons. Wells at Fort Mott, N. J., and Fort Dupont, Delaware, and at Fort Delaware, on an island in the river between the other two forts, also draw from the horizons within the Raritan formation. From the foot-notes accompanying the record it may be noticed that the water from these lower horizons does not rise so near the surface as that of the Marlton, or 88 to 100-foot, horizon. Similar conditions occur at Woodstown, on the New Jersey side of the Delaware, where water from the depth of 339 feet rose only to within 14 feet of the level reached by the water from the Marlton water-horizon, while from the depth of 776 feet the water rose only to within 18 feet of the same level. The facts at Woodstown are recorded in the Annual Report for 1892, page 302, and are also shown on a vertical section, Plate IX, page 202, of the Annual Report for 1894.

DEEP ARTESIAN BORING AT ATLANTIC CITY, ABOUT 1,000 FEET OUT ON YOUNG'S OCEAN PIER AT THE FOOT OF TENNESSEE AVENUE.

Elevation of pier, 20 feet. Depth below pier floor, 2,306 feet.

Water-horizons as follows:

At 780 to 860 feet, abundant supply. Water rises 10 feet + above tide level.

At about 950 feet, scant supply.
At about 1,200 feet (?) scant supply. } Water rose to the level of the pier.

At about 2,150 feet, scant supply. Water rose a few feet above the pier floor.

The water from all the above horizons rises and falls an average of one foot between tides.

Well abandoned at 2,306 feet.

This well was drilled by Uriah White during the years 1900 and 1901 to the unusual depth of 2,306 feet, as above stated. It is the deepest boring that has been made in New Jersey and, excepting a well at Key West, Florida (depth, 2,350 feet), is also the deepest boring that has been put down upon the Atlantic coastal plain.

Water that rose to various heights above tide level was found at different depths, as noted above. The horizon at 780 to 860 feet constitutes what we have heretofore termed the "800-foot Atlantic City water-horizon," the supply being abundant and the quality excellent. This horizon now supplies nearly 50 wells along or near the coast between Barnegat and Wildwood, 30 of which are at Atlantic City. The water naturally rises about ten feet above tide.

Respecting the water-horizon noted at *about* 1,200 feet, we may say that we have been unable to ascertain its depth more accurately. Owing to the circumstances attending the driving of the casing, our specimens may possibly have come from a somewhat higher level, though we think not from above 1,125 or 1,150 feet. The horizon is, however, probably the same as that which was developed in 1888 by a well at the gasworks, of which the writer has recently received reliable information from one of the men who assisted in drilling it that the water was found at the depth of 1,135 feet.* Specimens of sand obtained by the writer in 1888 from the bottom of the gashouse well and from this well in 1901 from *about* 1,200 feet or higher (?) are identical in character and are besides lithologically so different from all other sands obtained from these wells that the identity is the more clearly established. An exactly similar sand marked from the depth of 1,117 feet was furnished the writer from a boring made on the meadows in 1890 to the depth of 1,398 feet. The meadow well being farthest back on the dip of the beds, should show any given stratum at a somewhat higher level than the pier well, while the gashouse well, being intermediate in position, should find the same at an intermediate depth. It will be seen that the facts above stated seem to agree with our theory derived from the dip. Neither the meadow nor the pier wells were successful in developing a water supply from this horizon notwithstanding the fact that the gashouse well yielded at first and still yields a larger amount of water than any of the wells that have been put down to the great 800-foot water-horizon.

Through the courtesy of the contractor, Uriah White, and of his foreman in charge of the drilling, and with the consent of John L. Young, the proprietor of the pier, we have been furnished with a very full series of specimens of the borings taken mostly every ten feet.

Below we present the stratigraphical record, with such geological determinations upon the right as we feel can be safely made at the present time. Some doubtful and undetermined features connected with the geology can probably be satisfactorily solved when the numerous fossils which have been obtained shall have been fully studied.

* In correction of an error in the Annual Report for 1892, pages 276 and 277, it should be noted that the writer, having been misled by what he is now fully convinced was faulty information, reasoned that the water from the gas-works well could not have been obtained from a greater depth than 960 feet. This is erroneous. Statements in previous Annual Reports for 1888, page73, and 1889, page 90, which indicated that the supply came from the depth of 1,100 or 1,150 feet, are now substantiated as correct.

Floor of pier to mean tide level, ...	20 feet =	20 feet.	Between pier floor and water level, 20 feet.	
Beach sand with one species of *Foraminifera* a *Nonionina*, ...	35 " =	55 "	Recent.	Post-Miocene 252 feet.
Sandy clay with recent species of *Marine diatoms*, ...	15 " =	70 "		
Sand with recent species of *Marine mollusks*,...	6 " =	76 "		
Dark stiff clay, no diatoms nor other micro-organisms, ...	14 " =	90 "		
Heavy gravel with some thin seams of yellow clay, ...	36 " =	126 "	Age yet to be determined.	
Alternations of light yellow and bright orange colored and grayish sands and gravels without fossils, ...	146 " =	272 "		
Brownish and grayish sands with thin clay seams, contains some *lignite* but no mollusks and no micro-organisms,	118 " =	390 "		Tentatively Miocene 943 feet.+
Mainly bluish and brownish clays richly *diatomaceous throughout*, contains also a few *Foraminifera* of various species, ...	300 " =	690 "	390 to 690 feet. Richmond Diatom bed 300 feet thick.	
Miocene mollusks at 560 to 580 feet and at 660 to 690 feet.				
Clayey sand with *Miocene mollusks*, ...	30 " =	720 "		
Sand and gravel,.........	10 " =	730 "		
Clayey sand, ...	10 " =	740 "		
Coarse gray gravel with a moderate supply of water, ...	20 " =	760 "	Miocene.	
Sandy brown clay with *Perna* and other *Miocene mollusks*, ...	20 " =	780 "	780 to 860 feet. The Atlantic City 800-foot water-horizon.	
Dark brown clean sand,..	40 " =	820 "		
Light brown clean sand,..	40 " =	860 "		
Abundantly water bearing from 780 to 860 feet.				

Tough hard brown clay,.. Mollusks at 872 to 894 feet.	71 feet	= 931 feet	Miocene.	Tentatively Miocene 943 feet.±
Clay and sand with shells,	10 "	= 941 "		
Sand with a large admixture of greensand, slightly water-bearing, .	9 "	= 950 "		
Sand and clay with ponderous oysters, probably *Ostrea percrassa,* Conrad. These were found in the gas house well,..	2 "	= 952 "		
Hard tough brown clay with comminuted shell,.	22 "	= 974 "	Probably mostly if not entirely Miocene.	
Olive colored greensand marl with *Foraminifera* and small *mollusks,*....	16 "	= 990 "		
Hard brown clay with abundance of *mollusks* much comminuted, ...	12 "	= 1012 "		
Olive colored greensand marl, moderately fine,..	42 "	= 1054 "		
Olive colored greensand marl, considerably coarser, some comminuted shell, ...	21 "	= 1075 "		
Very clayey olive colored greensand, ...	21 "	= 1096 "		
Greensand marl, decidedly dark green in color,.... From within the greensands somewhere between 1012 and 1120 feet there were obtained from the Meadow well specimens of a cup *Coral* a *Flabellum*—Sp?	24 "	= 1120 "		
Light or ashen colored marly clay, ...	14 "	= 1134 "		
Light or ash colored greensand marl, ...	26 "	= 1160 "		
Brown micaceous clay,...	40 "	= 1200 "		
Dull yellow sand with *barnacles, Foraminifera,* small *Venericardia granulata,* Say, and other small *mollusks,* .... A little water rose to the surface from about this depth, probably from this stratum.	5 "	= 1205 "		
Clay with *mollusks,*......	10 "	= 1215 "		

Greensand marl, ...	25 feet	= 1240 feet	Possibly Eocene.	Eocene? 25 feet. +
Very hard and tough light and dark slate or ash colored clays with *Coccoliths* plentiful throughout and with a few *Textularia, Nodosaria* and other *Foraminifera*, ...	200 "	= 1440 "	Probably lower layer of the Upper Marl Bed.	Cretaceous 1066 feet. +
Yellowish calcareous rock sometimes moderately soft and sometimes quite hard, consists two-thirds of a nearly equal mixture of greensand and white quartz sand grains and one-third of carbonate of lime, the latter the cementing material; contains also the white calcareous shells of *Cristellaria* and other *Foraminifera*, ...	460 "	= 1900 "	Probably Vincentown limesand bed 460 feet thick.	
Glauconitic greensand marl, ...	40 "	= 1940 "	Middle and Lower Marl Beds.	
Clay mixed with a little greensand, ... Thin pebble layer at 2010 feet.	70 "	= 2010 "		
Indurated ash-colored clay "hard almost as rock,".. Large *Nodosaria* at 1230 to 1240 feet.	60 "	= 2070 "		
Glauconitic greensand marl similar to that at 1900 to 1940 feet,.......	80 "	= 2150 "		
Black or dark Micaceous sandy clays, ...	156 "	= 2306 "	Clay Marls.	

Tidal Rise and Fall of Water in the Well.—We have already noted that the water from the lower levels rose higher than that from the well-known 800-foot horizon. The water at 800 feet rises to about 10 feet above tide when not too strongly drawn upon as it is at times when the many wells at Atlantic City are pumping simultaneously, while that at 1,135 feet rises to about 20 feet above the same datum, or ten feet higher than that from the upper horizon. The fact of the difference of level to which the water from the two horizons will rise has been abundantly verified by the writer, who a few years since had a continuous series of tidal measurements made during three weeks for one well at Ventnor to the 800-foot stratum and during five weeks for the 1,135-foot well which is located at the gasworks on Michigan avenue. Incidentally we may mention that besides the verification of the difference of the natural water level from the two strata, we also learned that the water from both rises and falls with the tide, and that where wind or other conditions caused the ocean tides to be abnormally higher or lower the tide in the wells was similarly abnormally affected. While the rise and fall in the wells between tides may be stated to average one foot, the actual differences shown by the records made varied from 5 inches to 19 inches, both of which extremes indicated unusual conditions. These facts seem to indicate that the water-yielding sands have an outlet to the ocean probably a great distance off shore and that the oscillation of the water level in the wells is due to the balancing of two columns of water, one that of the ocean and the other that of the well.

The cup coral noted in the beds between the depths of 1,012 and 1,120 feet was also obtained by the writer from the same beds at Wildwood from the depth of about 1,200 feet. The specimens from the wells at both localities were referred to T. Wayland Vaughan, who in a letter received says they "cannot be determined positively. The genus is Flabellum and the species *probably* F. cuneiformis, Lons, variety wailesi Conrad. * * * The specimens are certainly Tertiary. But as I cannot be *sure* of the *species* I cannot express an opinion as to the *exact* horizon of the specimens."

The thicknesses of some of the geological formations as now indicated upon the right of the record differs somewhat from the thicknesses that were noted upon an oak tablet with a tube containing borings from this well that was prepared by the writer and placed in the exhibit of the State Geological Survey at the Pan-American Exposition at Buffalo. At that time, judging from the lithological resemblance of the specimens from this well to similar specimens from wells on the eastern shore of Maryland, the Eocene was then shown considerably thicker and the Miocene somewhat thinner. Recent careful examination of the borings has revealed quite a number of small shells in the sand noted as occurring at about 1,200 feet in this well and at 1,135 feet in the gashouse well, the most numerous of which was Venericardia granulata, a decidedly Miocene fossil. Hence, the present revision of the boundary line between the Miocene and Eocene beds.

A notable feature revealed by this well is the occurrence between the depths of 1,440 and 1,900 feet of a bed 460 feet thick of solid, uninterrupted sandy and glauconitic calcareous rock, the relative proportion of the constituents of which are noted in the record above. This, we apprehend, represents the Limesand that overlies the Middle Marl bed and typically occurs in outcrops near Vincentown. Along and near the line of its outcrops in this State this bed seldom exceeds twenty feet in thickness, except in Salem county, where it attains a thickness of about 100 feet, as shown by well-borings at Quinton and near Penton and Alloway. In the region of its outcrops the bed often consists of alternating layers of loose limesand and consolidated limesand rock, while some of the strata contain Bryozoa so plentiful as to cause it to be wrongly described by some as "coral" (?) rock, but in this well the Bryozoa were not observed, while the entire bed consisted of rock sometimes quite soft and again comparatively hard.

In confirmation of the equivalency of this bed with the limesand bed that outcrops above the Middle Marl the writer constructed to scale a vertical section directly from Woodstown to Atlantic City, and projected thereon in their proper places the wells at Quinton and Millville, both of which are comparatively near the line beween the points first named. This showed the top of the bed at Quinton, depth 38 feet, at Millville, depth 680 feet, and at Atlantic City, depth 1,440 feet, to be upon an even regular line of dip. It also showed the bottom of the bed at Woodstown, depth 50 feet*, at Quinton, depth 146 feet, and

* The elevation at Woodstown is 50 feet.

at Atlantic City, depth 1,900 feet, to be likewise upon an even line of dip, though one of greater amount. Our section would indicate the thickness at Millville to be about 275 feet; the boring there, however, was discontinued about five feet below the top of the bed. Its thickness at Quinton is 108 feet.

THREE ARTESIAN WELLS AT ATLANTIC CITY, TO THE 800-FOOT WATER-HORIZON.

Rear of Bartlett Building, north side Atlantic avenue, west of North Carolina avenue.
Elevation, 10 feet or less. Diameter, 6 inches. Depth, 843 feet.
At Champion Hotel, south side Atlantic avenue, east of Pennsylvania avenue.
Elevation, 10 feet or less. Diameter, 6 inches. Depth, 840 feet.
At Palace Royal Hotel, Ocean front, between Atlantic and Pacific avenues and north of Maine avenue.
Elevation, 10 feet or less. Diameter, 6 inches. Depth, 833 feet.

The three wells above noted were put down the past year by Uriah White. Each of these wells was furnished at the bottom with a screen 4½ inches in diameter and 50 feet in length, and, therefore, draw water from a vertical extent of 50 feet within the great 800-foot water-horizon midway in the Miocene deposits.

The well at the Palace Royal is about two blocks north of the lighthouse, and is upon ground that has in recent years been reclaimed from the sea. For this reason some mud or clay beds that have been found in the upper fifty feet of other well-borings at Atlantic City were not found in this well. With this exception, the strata penetrated by all three of these wells were the same and are likewise identical with the records published in past years for numerous other wells at this seaside resort. The first 860 feet of the preceding record of a deep well at Young's pier presents in detail the beds penetrated by these wells, with the exception, as already noted, of the first 50 feet of the Palace Royal well. After the last-named well was finished the writer collected from the dump some small, flat, flaky lumps of light weight and lightish-colored clay, which were quite numerous and which were richly diatomaceous when viewed under the microscope. A cleaning of the same was made for diatoms, while a study of the forms thus obtained showed the numerous characteristic species of the great 300-foot Miocene diatom bed of the Atlantic Coastal plain. This bed occurs between the depths of 390 and 690 feet at this place. (See the preceding record.)

TWO SHALLOW ARTESIAN WELLS AT ATLANTIC CITY.

Diameter of each, 4½ inches. Depth of each, 80 feet.
Water rises within 1½ feet of the surface.

These two wells were put down early in the year by Uriah White. They are at the plant of the Citizens' Ice and Cold Storage Company, and are located near the northwest corner of Baltic and Massachusetts avenues. This company had a well put down in the year 1894 to the depth of 805 feet, which they use for general supply. It was desired, however, to obtain an extra supply of water at the lowest temperature obtainable from wells to be used for cooling purposes. The more or less heavy gravels at the depth of about 80 or 90 feet furnish considerable water not generally deemed desirable for domestic use, but of a temperature a few degrees lower that that from the great 800-foot Atlantic City water-horizon. These wells were, therefore, sunk only to the depth of 80 feet so as to draw from this horizon. They obtained a supply satisfactory for the desired purpose.

II.—Wells Mostly in Northern New Jersey.

Sec. 1.—Wells Reported by W. R. Osborne.

Locality.	Owner.	Diameter.	Record.		Total Depth.	Remarks.
Metuchen,	John Power. Two wells,	4 inches,	Sand and gravel,	23 feet		
			Shale,	20 feet		
					43 ft.	Plenty of water.
			Gravel and sand,	35 feet	35 ft.	Water in sand.
Metuchen,	George D. Herron,	4 inches,	Red shale,	52 feet	52 ft.	
New Brunswick. Leverington avenue,	John Messeroll,	4 inches,	Red shale,	36 feet	36 ft.	
New Brunswick. Near Highland Park Hotel,	J. C. Anderson,	4 inches,	Shale,	100 feet	100 ft.	
Oak Tree. North of Metuchen,	Wm. Morrison,	4 inches,	Clay as mined near by,	30 feet		
			Red shale,	37 feet		
					97 ft.	
Oak Tree. Park Ave., towards Plainfield,	Hiram Steel,	2 inches,	Sand and gravel,	33 feet	33 ft.	Water in gravel on top of red shale.
			Stopped on red shale.			
Plainfield. Eastern city line on road to Dog's Corners,	J. B. D. Saybocker,	6 inches,	Hard deposits of sand and gravel belonging to the terminal moraine. No cobbles and no clay,	149 feet		Elevation of well, 218 feet. No water in sands and gravels.
			Gritty red shale,	56 feet		
					205 ft.	Plenty of water in red shale.
Sand Hills. Clay bank near,	M. A. Edgar,	4 inches,	Fire sand and then shallow vein of clay to	60 feet		
			Red shale,	32 feet		
					92 ft.	Water in red shale.
Valentine Station,	R. N. and H. Valentine,	4 inches,	Bottom of dug well,	10 feet		
			Fine sand,	20 feet		
			Plastic clay,	30 feet		
			Red shale,	37 feet		
					97 ft.	

Sec. 2.—Wells Reported by P. H. & J. Conlan.

Locality.	Owner.	Diameter.	Record.		Total Depth.	Remarks.
Arlington,	Arlington Co.,	10 inches,	Depth to rock, Blue trap rock, Red shale,	45 feet 55 feet 700 feet	800 ft.	100 gallons per minute.
Arlington,	Arlington Copper Co.,	8 inches,	Depth to rock, Red shale rock with strata of blue trap rock which varied from a few feet to 20 feet in thickness,	8 feet 355 feet	363 ft.	275 gallons per minute. Quality of water excellent.
Belleville,	Maas & Waldstien,	8 inches,	Depth to rock, Red shale,	35 feet 415 feet	450 ft.	75 gallons per minute.
Hoboken,	Bavarian Glass Works,	6 inches,	Clay and sand, Red shale,	80 feet 120 feet	200 ft.	50 gallons per minute.
Harrison,	Bimbler & Van Wagenen,	8 inches,	Clay and sand, Red shale,	125 feet 475 feet	600 ft.	50 gallons per minute.
Lake Hopatcong,	Three wells,	10 inches,	Red sandstone,	215 feet	250 ft.	325 gallons per minute per well.
	American Forcite Powder Co.,	8 inches,	Sand and gravel,	113 feet	113 ft.	60 gallons per minute.
Newark,	Spence Degreasing Co.,	6 inches,	Clay and sand, Red shale,	50 feet 150 feet	200 ft.	150 gallons per minute.
New York Harbor. Governors Island,	U. S. Government,	12 in. to 400 ft., 8 in. to 1150 ft.	Hard clay, Gneiss rock,	75 feet 1,075 feet	1,150 ft.	Drilling not completed.

Locality.	Owner.	Diameter.	Record.		Total Depth.	Remarks.
New York,	Grand Union Hotel, 42d street,	12 in. to 200 ft., then 8 in. to the bottom,	Micaceous gneiss rock,	420 feet	420 ft.	30 gallons per minute.
New York,	Astor Hotel, 55th street and Fifth avenue,	12 in. to 300 ft., then 8 in. to 650 ft.,	Rock as elsewhere on Manhattan Island,	650 feet	650 ft.	
Passaic,	U. S. Finishing Co.,	6 inches,	Quicksand,	130 feet		75 gallons good potable water per minute.
			Red shale rock,	270 feet	400 ft.	
Pompton,	Metallic Cap Mfg. Co.,	6 inches,	Gray rock,	75 feet	75 ft.	25 gallons per minute.
Paterson,	Auger & Simon Silk Co.,		Clay and sand,	35 feet	35 ft.	
Plainfield,	Plainfield Water Supply Co.,	10 inches,	Clay, sand & gravel,	100 feet		
			Red shale,	300 feet	400 ft.	150 gallons per minute.
Waverly,	George Stengel,	6 inches,	Clay and sand,	60 feet		
— "			Red shale,	217 feet	277 ft.	80 gallons per minute.

Sec. 3.—Wells Reported by Stotthoff Bros.

Locality.	Owner.	Diameter.	Record.		Total Depth.	Remarks.
Alpha,	Walter and Davis,	6 inches,	Earth,	10 feet		
			Limestone,	88 feet		
			Decomposed limestone,	30 feet		
			Yellow limestone,	17 feet	145 ft.	20 gallons per minute at 100 feet from the surface.
Bayonne,	Tide Water Oil Co. Well No. 1,	8 inches,	Red clay,	76 feet		
			Red sandstone,	127 feet		
			Gray rock,	28 feet	231 ft.	No water.
	Well No. 2,	8 inches,	Red clay,	23 feet		
			Gray sand,	42 feet	65 ft.	No water.
Belvidere,	A. F. Morris,	6 inches,	Earth,	3 feet		
			Cement rock, high percentage of lime,	322 feet		
			Very hard limestone,	137 feet	462 ft.	3 gallons per minute.
Elizabeth, near the Post Office,	American Steam Laundry,	8 inches,	Light gray sand,	32 feet		
			Red shale,	140 feet	172 ft.	100 gallons per minute at 42 feet from the surface.
Elizabeth, near N. J. C. R. R. depot,	L. F. and H Hirsch,	8 inches,	Earth,	5 feet		
			Red shale,	163 feet	168 ft.	45 gallons per minute.

Locality.	Owner.	Diameter.	Record.		Total Depth.	Remarks.
Lodi,	Alexander Dye Works,	8 inches,	Red sand,	55 feet		
			Red sandstone,	154 feet	209 ft.	30 gallons per minute.
Martins Creek, Pa., 7 miles north of Easton,	Martins Creek Cement Co.,	6 inches,	Sand and gravel,	20 feet		
			"Cement rock high in lime,"	105 feet	125 ft.	10 gallons per minute.
New Orange,	American Circular Loom Co.,	8 inches,	Red sand and quicksand,	55 feet		
			Red shale,	183 feet	238 ft.	50 gallons per minute.
New Orange,	Monarch Pipe Covering Co.,	8 inches,	Earth and sand,	65 feet		
			Red shale,	90 feet	155 ft.	55 gallons per minute at 60 feet from the surface.
Oxford,	Empire Steel and Iron Co.,	Test borings for ore—				
		No. 1,	Clay and boulders,	193 feet	193 ft.	No ore.
		No. 2,	Yellow clay and boulders,	30 feet	30 ft.	
		No. 3,	Clay,	104 feet		
			Rich magnetic ore,	18 feet		
			Loam or earth,	9 feet		
			Magnetic ore,	49 feet		
			Clay mixed with ore,	24 feet	204 ft.	
		No. 4,	Earth,	26 feet	26 ft.	
		No. 5,	Clay,	30 feet		
			Ore and clay,	3 feet		
			Clay,	107 feet	140 ft.	

Locality.	Owner.	Diameter.	Record.		Total Depth.	Remarks.
Elizabeth,	United Electric Co.,		Earth and sand, Red shale,	26 feet 291 feet	317 ft.	160 gallons per minute.
Elizabethport,	Herman Jentsch,	6 inches,	Earth, Red clay, Soft red shale,	3 feet 32 feet 345 feet	400 ft.	10 gallons per minute at 30 feet from the surface.
Elizabethport,	A. and F. Brown,	8 inches,	Earth and clay, Red shale,	50 feet 100 feet	150 ft.	40 gallons per minute at 120 feet from the surface.
Elizabethport,	Riker Motor Co. Well No. 1,	8 inches,	Earth and clay, Soft red shale,	56 feet 444 feet	500 ft.	No water.
	Well No. 2, 400 feet from No. 1,	8 inches,	Earth and clay, Red shale,	60 feet 140 feet	200 ft.	65 gallons per minute.
Elizabethport,	Frederick Klophaus,	6 inches,	Earth and sand, Red shale,	62 feet 98 feet	160 ft.	35 gallons per minute.
Elizabethport,	Margaretta and William Herlich,		Earth and clay, Red shale,	63 feet 59 feet	122 ft.	50 gallons per minute.
Flemington,	Wm. Suydam,	6 inches,	Red shale with "layer of copper ore,"	74 feet	74 ft.	10 gallons per minute.
Linden,	Malm Winans,	6 inches,	Earth, Red shale,	22 feet 78 feet	100 ft.	25 gallons per minute.

Locality.	Owner.	Diameter.	Record.		Total Depth.	Remarks.
Passaic,	Hygeia Brewing Co.,	8 inches,	Earth and sand, Red sandstone,	16 feet 234 feet	250 ft.	100 gallons per minute at 60 feet from the surface.
Pennington,	E. B. Allen,		Earth, Red shale,	22 feet 113 feet	135 ft.	10 gallons per minute at 30 feet from the surface.
Sandts Eddy, 5 miles north of Easton. Pa.,	Mrs. Jane Sandts,	6 inches,	Sand, gravel and boulders,	52 feet	52 ft.	6 gallons per minute.
Tranquility,	Sugar Loaf Dairy Co.,	6 inches,	Gravel,	34 feet	34 ft.	30 gallons per minute at 16 feet from the surface.
Westfield,	J. T. Tubby,		Earth, sand and gravel,	93 feet	93 ft.	
Westfield,	Gidney W. Beatty,	6 inches,	Earth, Sand, Red shale,	6 feet 44 feet 51 feet	101 ft.	20 gallons per minute at 22 feet from the surface.
White Hill,	Standard Ammonia and Chemical Co.,	8 inches,	Dug well, Blue clay, Sand with water, Clay,	15 feet 14 feet 59 feet 20 feet	108 ft.	40 gallons per minute.

Sec. 4.—Wells Reported by Harry Estes, Ridgewood, N. J.

LOCALITY.	OWNER.	Feet to Rock.	Kind of Rock.	Total Depth.	Gal. per Min.	Comments.
Allendale,	J. Willard,	21	Sandstone,	77	10	
"	M. Davis,	12	"	156	10	
"	Geo. Cook,	....	"	100	20	
"	John Winters,	....	"	48	....	
Bogota,	Bogota Paper Co.,	....	"	....	....	Flowed at surface.
Belleville,	Sissum Machine Works,	30	"	136	21	
Demerest,	F. F. Travis,	14	"	160	20	
"	A. Demerest,	16	"	65	3	
"	R. Stillfox,	86	"	238	20	
Englewood,	Englewood Hygeia Ice Co.,	....	"	355	120	Flowed at surface.
Fairlawn,	....	30	"	145	40	
"	....	35	"	156	32	
Hillsdale,	Mr. Ayers,	105	"	150	7	
"	G. Boulard,	108	"	152	....	
"	Mrs. Mack,	96	"	160	20	
"	E. Taylor,	105	"	155	26	
Hohokus,	J. H. Bogert,	....	"	78	8	
"	John Magill,	9	"	50	6	
"	N. Orr,	32	"	128	30	
"	Mrs. Northrup,	16	"	86	3	
"	Mr. Kiefer,	17	"	104	14	
Harrington Park,	W. Walters,	40	"	80	6	
Hoboken,	Franklin Paper Mills,	....	"	303	357	Air lift.
"	Palisade Paper Mills,	....	"	500	427	Air lift.
"	Hudson Gas Co.,	58	"	410	65	
"	Steven & Campbell,	52	"	208	100	
"	" " "	54	"	386	350	
Midland Park,	Otto Walthey,	21	"	45	6	
" "	Holt Bros.,	21	"	52	4	
" "	T. Banta,	4	"	108	12	
Maywood,	O. Weisbeyher,	....	"	90	20	
"	Dr. Schaffer,	21	"	400	120	
"	Mr. Beaton,	12	"	59	5	
"	Mr. Doxsid,	21	"	80	12	
"	Mr. Menzel,	19	"	52	7	
"	Mr. Weinz,	26	"	80	8	
"	Mr. H. Sewell,	21	"	100	20	
"	O. J. Teeple,	21	"	58	12	
Mahwah,	Rev. A. King,	68	"	105	12	
"	G. S. Rowe,	57	"	57	4	Did not penetrate rock.
"	Mr. Banta,	65	"	65	12	Did not penetrate rock.
Montvale,	Mrs. Blelock,	48	"	160	60	
"	R. R. Deme,	21	"	108	....	
North Paterson,	Mr. Knouse,	16	"	55	9	
" "	Standard Co.,	16	"	56	13	
" "	A. Post,	27	"	33	6	

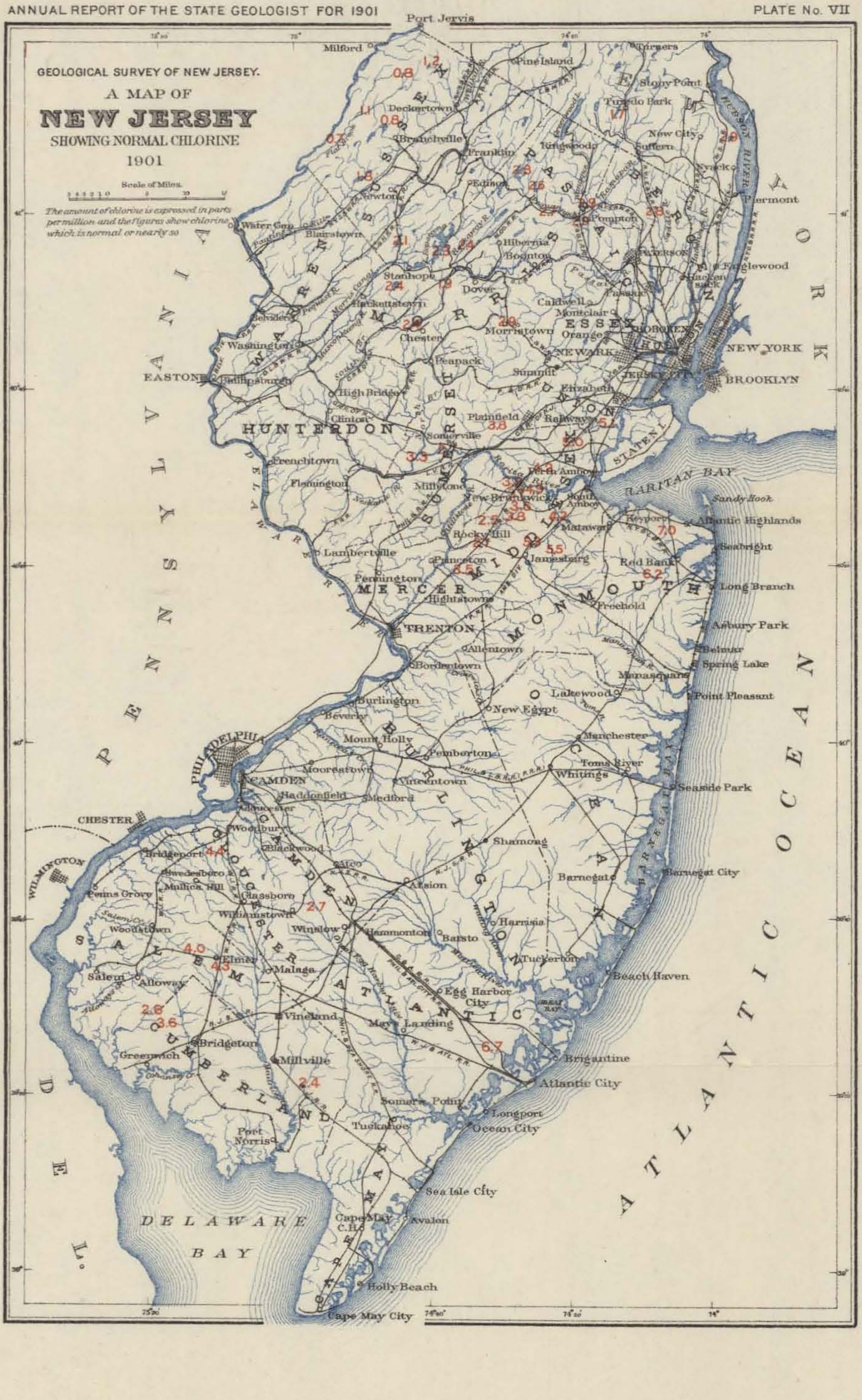
LOCALITY.	OWNER.	Feet to Rock.	Kind of Rock.	Total Depth.	Gal. per Min.	Comments.
North Paterson,	J. Meyers,	21	Sandstone,	90	12	
" "	Donald Mains,	76	"	170	40	
Oradell,	P. Van Buskirk,	86	"	97	....	
"	G. Van Dubergh,	58	"	110	....	
"	Mrs. Van Dubergh,	21	"	106	....	
Paramus,	Widow Zabrisee,	....	"	32	2	
"	Mr. Conklin,	35	"	45	25	
"	James Zabriskee,	32	"	40	4	
"	Mrs. Bennett,	50	"	82	....	Flowed at surface.
"	Mrs. Hawley,	26	"	120	21	
"	Chas. Hutchinson,	21	"	83	12	
Paterson,	Mrs. Masaker, 501 Mkt. St.,	....	"	64	5	
Palisade Park,	J. Stiblitz,	26	"	90	20	
Park Ridge,	Mr. Fisher,	60	"	100	6	
" "	Miss Campbell,	21	"	130	28	
Ridgewood,	J. E. Hutton,	51	"	152	11	
"	" " "	76	"	186	12	
"	" " "	78	"	178	15	
"	P. Akerman,	84	"	154	20	
"	Paramus Church,	38	"	45	4	
"	" " Parsonage,	21	"	86	20	
"	H. Houston,	14	"	115	10	
"	Miss Seers,	55	"	74	6	
"	S. H. Bunn,	21	"	48	6	
"	J. R. Knowlton,	28	"	127	26	
"	Mr. Reed,	27	"	73	12	
"	M. L. Hendrickson,	26	"	131	30	
"	B. Van Derbergh,	48	"	54	20	
"	L. Johnston,	6	"	192	4	
"	E. Winans,	17	"	117	17	
"	T. Winans,	30	"	96	20	
"	Mr. Parker,	16	"	200	100	
"	S. Villa,	32	"	126	12	
"	C. Edsall,	21	"	80	8	
"	A. H. Post,	14	"	60	4	
"	N. Zabriskie,	6	"	55	5	
"	S. Yeomans,	7	"	70	20	
"	" "	21	"	90	14	
"	H. Estes,	13	"	70	19	
"	" "	21	"	86	9	
"	C. Hennas,	21	"	70	12	
"	Mr. Bender,	16	"	200	20	
"	C. S. Keyser,	16	"	85	21	
"	Henry Remsen,	26	"	80	12	
"	C. Phelps,	3	"	182	21	
"	Thos. Morrison,	21	"	90	20	
"	Mrs. Snyder,	36	"	115	5	
"	H. White,	33	"	88	21	
"	M. Phillip,	28	"	42	12	

LOCALITY.	OWNER.	Feet to Rock.	Kind of Rock.	Total Depth.	Gal. per Min.	Comments.
Ridgewood,	Henry Orne,	55	Sandstone,	165	21	
"	C. Raymond,	30	"	152	6	
"	Mrs. A. A. Blauvelt,	32	"	72	20	
"	" "	13	"	58	4	
"	" "	14	"	92	12	
"	F. Vogler,	21	"	90	7	
"	A. H. Balliett,	21	"	....	121	Overflowed at surface.
"	A. H. Balliett,	28	"	123	15	
"	J. L. Bruck,	13	"	197	21	
"	Mrs. Holmes,	26	"	127	12	
"	Robt. Dunlop,	16	"	108	16	
"	Wm. Martin,	38	"	100	40	
"	Mrs. Miller,	2	"	125	12	
"	G. R. Younge,	52	"	132	4	
"	Village School,	52	"	113	21	
"	Mrs. Weisse,	53	"	100	10	Flowing well.
"	R. Ackerman,	44	"	132	30	
"	Mrs. Conway,	26	"	47	10	
"	P. Zabriskie,	26	"	150	30	
"	R. Bassett,	25	"	80	12	
"	R. Henshall,	90	"	225	10	
"	D. J. O'Neil,	13	"	213	21	
Saddle River,	Mr. Craig,	14	"	154	20	
" "	P. Wilson,	20	"	55	6	
" "	A. Ackerman,	2	"	130	12	
Tenafly,	Mr. Tettemanti,	21	"	62	6	
Woodcliff,	C. Neulson,	4	"	52	4	
"	C. Cronk,	21	"	27	3	
"	Lord's Farm,	4	"	92	25	
"	Miss aunders,	16	"	172	5	
"	John Weiss,	2	"	86	4	
"	Miss Hopkins,	12	"	56	20	
"	Mr. Collingwood,	26	"	140	20	
"	C. Mitchell,	28	"	90	12	
"	Mrs. Hall,	21	"	80	3	
Waldwick,	John Hopper,	109	"	135	10	
"	John V. Smith,	26	"	82	12	
Westwood,	Westwood Water Works,	32	"	147	147	
"	H. Vanderbilt,	52	"	109	7	
"	W. Keiser,	21	"	60	12	
"	Geo. Hopper,	22	"	82	12	
"	Mrs. Mathews,	105	"	340	14	
	" "	16	"	86	15	

PART III.

Chlorine in Natural Waters.

By WILLIAM S. MYERS.


GEOLOGICAL SURVEY OF NEW JERSEY.
A MAP OF
NEW JERSEY
SHOWING NORMAL CHLORINE
1901
Scale of Miles.
The amount of chlorine is expressed in parts per million and the figures show chlorine which is normal or nearly so
PENNSYLVANIA
NEW YORK
ATLANTIC OCEAN
DELAWARE BAY
DEL.
HUNTERDON
MERCER
MONMOUTH
ESSEX
OCEAN
BURLINGTON
CAMDEN
GLOUCESTER
SALEM
CUMBERLAND
ATLANTIC
CAPE MAY
Port Jervis
TRENTON
CAMDEN
PHILADELPHIA
NEWARK
BROOKLYN
EASTON
CHESTER
WILMINGTON
RARITAN BAY
Atlantic City
Cape May City

Chlorine in Natural Waters of the State.

BY WILLIAM S. MYERS.

The work of securing data for a Chlorine map of the State showing the Chlorine content in parts per million in the natural surface waters has been continued and numerous data have been obtained. In view of the considerable monthly and seasonal variations now well established in the Chlorine content of rain-waters and other natural waters the world over, it has not been deemed advisable to lay down any lines for normals on the map published herewith. It would be easy to fix lines on the map which would probably not have to be changed greatly by future observations, but it is not believed that such lines would add to the usefulness of the data published in this and previous reports.

The selected Chlorine figures have been printed on the map at the place where the sample was taken, and while it is not claimed that the figure printed represents the mathematical normal for that place, nevertheless it is sufficiently near for all practical purposes. Closer results could only be obtained by making continuous and very frequent observations for all points for a series of years. The variations already observed in the New Brunswick, Somerville, Long Branch, Morristown supplies and elsewhere in the State are so great as to suggest a question as to whether the Iso-Chlors laid down so rigidly for Massachusetts, Connecticut and Long Island are by themselves as valuable guides as many take them to be.

I desire to call attention again, as last year, to the futility of claiming to secure wholesome water-supplies by means of chemical or engineering devices, and thereby causing our citizens to believe that these last resorts can yield such wholesome conditions as an originally pure and uncontaminated supply affords. I wish to emphasize the necessity of such prompt action on the part of our State authorities as will conserve all water-sheds likely to be drawn upon by our own future great populations as well as those of our adjoining large cities.

The numerous data and the suggestions published under this title in this and previous reports will, it is earnestly hoped, be of value in the future to our Boards of Water Commissioners and sanitary experts for the rapid and accurate diagnosis of water-supplies. If the labors of these three past years serve in any way to help the communities of our State in securing for their use wholesome and abundant supplies of this most important natural product, the writer will feel amply recompensed for the time spent upon this most interesting and vital subject. In making the character of this mineral resource better known to the people of the State an important duty of our Geological Survey will have been accomplished, and its possibilities for usefulness further exemplified. Below are additional data secured since the publication of the previous report.

	Parts per Million.	
	Total Solids.	*Chlorine.*
Fries Mills, South Jersey,	49.60	2.40
Seven Mile Run, road to Princeton, near Franklin Park,	61.40	2.50
Marlboro, near boundary Salem and Cumberland,	87.61	2.60
Raritan river above Somerville,	120.00	2.70
New Brooklyn, Camden county,		2.70
South Branch Raritan, near mouth,	63.00	3.30
Stream one mile east of Plainsboro,	58.69	3.50
New Brunswick, Parsons Mills,	53.00	3.50
Shiloh, east of Roadstown,	83.92	3.60
New Brunswick Supply,	56.08	3.70
De Russy Lane Creek, one mile west New Brunswick,	78.40	3.90
Creek two miles east of New Brunswick,	84.00	4.20
Daretown, stream near,	96.11	4.00
Tributary Maurice river near Elmer,	96.80	4.30
Sucker Brook, Iselin, on P. R. R.,	40.00	5.00
Stream one mile east of Rahway,	75.60	5.10
Hop River at Phalanx,		6.20
Stream at south extremity of Union county,	93.00	6.40
Absecon creek, Doughty's Mill,		6.70
New Monmouth, near Middletown,	76.10	7.00

PART IV.

THE MINING INDUSTRY.

By HENRY B. KÜMMEL.

The Mining Industry.

BY HENRY B. KÜMMEL.

The Iron Mines.

The iron-mining industry in New Jersey during the year 1901 has been in a prosperous condition—much better in fact than was anticipated by many at the beginning of the year. This has been due to the extraordinary demand for pig-iron which has prevailed throughout the country at large, particularly during the closing months of the year. In consequence of this demand for iron the demand for ore has kept up, and the mines have been able in all cases to dispose of their product promptly. In fact, shipments as reported by the railroad companies exceed by over 18,000 tons the production as reported by the mine managers, showing that there is less ore on the docks at the mines than a year ago. By far the greater portion of the ore mined in the State is shipped directly to furnaces under the same management as the mines themselves. Comparatively little is produced by the independent miner to be sold in open market.

The most noteworthy features of the year's work have been, first, the increase in production over 1900, 401,151 tons, as against 342,390 for 1900; second, the marked increase in the output of the Richard mine, which in its tonnage far outranks any other iron mine in the State; and third, the extensive improvements instituted by Joseph Wharton at his Hibernia property, and by the Empire Steel and Iron Company at the Mount Hope mines. The introduction at Hibernia of a magnetic sorter or cobber to take the place of hand cobbing is an important step, since it promises not only more enconomical handling of the ore, but a more even run of ore for the furnace.

During the year the following mines were in operation, but not all of them continuously: At Oxford, Slope No. 3, Washington and Osmun; at Stanhope, the Hude and Wolfe; at Hurdtown, the Hurd; at Weldon, the Weldon; at Mine Hill, the Brotherton; at Port Oram, the Irondale group; at Mt. Pleasant, the Richard; at Mount Hope, the Elizabeth and Taylor; at Hibernia, Beach Glen, Crane, Upper Wood, and Wharton; the Ringwood mines.

The following notes indicate the work at the various mines during 1901:

THE OXFORD MINES, OXFORD FURNACE.

Empire Steel and Iron Co., Catasauqua, Pa., owners and operators; Mr. S. Norton, Superintendent.

Washington Mine.—This mine as at present worked has a maximum daily capacity of 150 tons, but with the completion of the improvements now in progress its productive capacity will be largely increased. According to the Superintendent, Mr. Norton, the vein has been located for a distance of 4,000 feet along the strike, which is in general a little west of north. The present slope, which descends diagonally to the strike of the vein and cuts into it from the foot wall, is now so long that any great increase in the production is impossible.

A new double compartment slope is now being constructed about 1,400 feet south of the old one. This slope, known as the Chapman, is expected to strike the ore body at a depth of about 150 feet. It will then follow down the foot-wall and connection will be made with the workings now reached only through the old slope.

The Washington ore is high in sulphur and is therefore roasted, by which process the sulphur is reduced to 7 per cent. and the ore made more porous and open. The roasting plant is now composed of seven Gjers' kilns capable of handling about 100 tons daily. Of these four have been set up during the past year and another is now under construction. They are continuous in operation, the ore and anthracite coal being fed in above, the roasted and cooled ore being removed below. Experience has shown that about 50 lbs. of coal are sufficient for a ton of ore.

Slope No. 3.—This mine lies about one-half a mile east of the Washington mine and along the road from Oxford to Washington. It has been worked steadily all the year, the workings being now about 700 feet deep along the slope, or about 500 feet vertical. The ore is reported to run 54 per cent. metallic iron, 1 per cent. phosphorus and practically no sulphur.

During the year a vertical "prospect" shaft No. 4 was started at a point about 1,000 feet south of Slope No. 3. At the close of the year it was not yet deep enough to reach the ore body.

On an average two hundred and fifty men are reported to have been employed at the mines and furnaces, and the production of ore during the year has been 48,519 tons.

OSMUN-ROBESON MINES.

Basic Iron Ore Co., operators; J. W. Allis, President; L. R. Allis, Secretary and Treasurer, Oxford Furnace, N. J.

About December 1st, 1901, work was commenced on this group of mines which are situated about a mile northwest of Oxford Furnace. A shaft has been sunk 70 feet in glacial drift, and it is planned to go 50 feet farther and then drift southward to the ore body. The ore, as shown by earlier workings, is a soft powdery magnetite, more or less altered to limonite, and said to run from 45 to 50 per cent. metallic iron and 4 to 7 per cent. manganese. Development work has not progressed sufficiently to show the manner of occurrence of the ore nor the nature of the country rock.

HUDE MINES, STANHOPE.

Musconetcong Iron Works, Philadelphia, lessees; John S. Kennedy, Stanhope, Manager.

These mines which had not been worked for several years were leased during the past year by the Musconetcong Iron Works, of Philadelphia. Mining operations were commenced about October 1st, although some work was done previously in cobbing the old ore piles. Up to the close of the year 1,006 tons had been hauled to the company's furnaces at Stanhope.

The ore occurs in a number of distinct shoots which, where well developed, vary in width from 6 to 20 feet, and in height from 20 to 30 feet. The pitch is in general to the northeast, sometimes at rather steep angles, so that the shoots resemble "chimneys." There are also some irregularities due to offsets and squeezes.

The new work has consisted in drifting in the two tunnels, both of which were opened years ago, and in taking out ore from the old shoots. In No. 1, the ore of which contains some molybdenite, the ore-body was found to pinch out and offset to the east for a few feet, beyond which it opened out in a fine breast of ore.

A recent analysis of this ore by the company was as follows.

Iron,	53.77
SiO_2,	14.86
Phos.,	0.084
Sulphur,	1.342
Molybdenum,	undet.

The ore is all hauled by teams to the company's furnace at Stanhope, a mile distant, each team hauling ten gross tons daily when the roads are good.

WOLFE MINE, NEAR NETCONG.

Salmon Bros., of Ledgewood, report that during the year about 500 tons of ore were mined at the Wolfe mine near Netcong. The ore is reported to be soft and of good quality, samples from vein averaging 59 per cent. metallic iron, traces of sulphur, and low in phosphorus, although above the Bessemer limit. The vein, however, is small, and work was finally stopped.

HURD MINE, HURDTOWN.

New Jersey Ore Company, Philadelphia, lessees; T. M. Williams, Mine Hill, Manager.

During this past year some ore has been taken by "robbing" from the upper workings of the northeast shoot, which for the most part had been abandoned and is full of water. On the southern side of the great offset, which separates the northeast from the southwest shoot, considerable prospecting has been done. As was pointed out many years ago, the ore-body here forms a synclinal fold the northwestern limb of which is composed of several shoots separated by masses of rock.

A fourth shoot has been located lying apparently just to the westward of the three shown by Dr. Cook in his diagram.* It has been sunk upon to a depth of 125 feet and a rich body of ore about nine feet in width exposed. The bottom of the shoot has not yet been reached. Northward it probably extends to the offset, whereas the normal pitch would speedily carry it to the surface towards the southwest. In the direction of the dip it may unite with the closely adjoining ore-shoots in the bottom of the syncline.

North of the offset, the side-shoot southeast of the old open cut (see Annual Report for 1883, p. 130) has been drifted on about twenty feet and some ore taken out. The ore-body is here horizontal as seen in cross-section, about four feet high, and with the customary northeast pitch. This is believed to be the crest of an anticline lying just east of the syncline, and the behavior of the ore-body where now exposed lends some support to this view. A small offset has been found in this slope which has dropped the ore-body a few feet. Various prospects suggest that south of the great offset the eastern limb of the syncline arches over to form an anticline on the southeast in a similar manner, but the case has not yet been demonstrated.

Although no great amount of ore has been in sight at any time during the last two years, yet mining has been steadily carried on without exhausting the known deposits. During the year the production amounted to between 8,000 and 9,000 tons.

THE WELDON, NORTHEAST OF HURDTOWN.

O. K. Moore, lessee.

This mine was operated in a small way for six or seven months during the past year, and about 250 tons of ore are reported to

* Geology of New Jersey, 1868, p. 608.

have been mined. Work was carried on in a shaft near the southwestern line of the property. About the close of the year a small offset was encountered, which threw the vein into the hanging wall for a distance equal to its own width. In stripping this offset portion the water from the old mine was tapped and work had to be abandoned. As this report goes to press we learn that an effort is being made to lower the water by means of larger pumps and to resume work.

BROTHERTON MINES, MINE HILL, MORRIS COUNTY.

Bethlehem Steel Co., lessees.

The mine was operated by the Bethlehem Steel Company until about August 1st. The main slope was sunk about 75 feet and about 200 tons of ore was mined and shipped. Since August 1st the mine has been idle.

HACKLEBARNEY MINES, CHESTER.

These mines were not in operation during the year, but a small amount of ore from the dock was shipped.

HURD AND NEW STERLING MINES, IRONDALE, PORT ORAM.

New Jersey Iron Mining Company, owners.

During the past year these mines have been operated continually, but the work has been done chiefly at the Hurd slope which now has a depth on the incline of 45° of 950 feet. The present workings are northeast of the slope on a breast of ore 65 feet high and from 2½ to 6 feet in width.

Work has been commenced on a new "sink" at the bottom of the slope, revealing the continuation downward of good ore. Upon the completion of the sink and consequent lengthening of the slope 60 feet, new stopes will be started both to the southwest and northeast. The hanging-wall is firm and even and but few stulls are necessary. The foot-wall rolls somewhat, causing the usual swells and pinches in the vein.

During the past year the production of these mines was 20,317 tons 13 cwt.

RICHARD MINE, MT. PLEASANT.

This mine continues to be the largest producer of iron-ore in the State, and during the past year its production of 121,763 long tons has exceeded even its own previous best record of 112,386 tons, from July 1st, 1895, to July 1st, 1896. Not only has this splendid record been made, but there is no indication of exhaustion of the ore-body, and developments of the year show that there is still a large amount of ore untouched. There is, therefore, every reason for believing that this high rate can be maintained, or even exceeded, if the market warrants it.

The body of ore discovered in 1896 in the foot-wall near slope No. 2 has continued to yield largely during the year. That this vein probably extends a considerable distance towards the old No. 3 slope is indicated by a short cross-cut made near the bottom of the mine about two-thirds of the distance from slope No. 2 to No. 3. Here a cut of four or five feet in the supposed foot-wall revealed a large body of ore corresponding in position to that previously found.

The discovery of a body of ore in the hanging-wall of the northeastward workings was made in 1889, but its extent down the dip was unknown. Within the last two years the chief vein in this vicinity was found to terminate downward somewhat abruptly and be replaced by the bed-rock. But during the past year slope No. 5, situated between slopes 2 and 3, and northwest of the vein, was sunk 100 feet below the level of this bed-rock, that is, to a depth of 875 feet on the incline, and a cross-cut made 90 feet southward towards the hanging-wall. Here a large ore-body was found with a width of from 3 to 25 feet. Levels have been driven 150 feet in both directions along the vein and sufficient overhead stoping done to show that this ore-body is the same as that previously discovered in the hanging-wall 100 feet above. In reality what had been supposed to be the bed-rock of the vein was only a trough in the foot-wall underlying a shallow fold or short branch on the foot-wall side of the ore while the vein itself continued downward uninterruptedly after making a somewhat abrupt end into the hanging-wall. For a width of two feet along the hanging-wall this newly-opened portion is exceedingly rich, running to 69.43 per cent. metallic iron.

Towards the close of the year slope No. 4, which is west of No. 1, and reaches the northwest or Mount Pleasant vein, has been deepened, and beneath the lean ground a new ore-body has been found which is now 8 to 9 feet in width.

TEABO MINE.

Joseph Wharton, owner.

No ore was mined here during 1901, but preparations were made to sink a new shaft early in 1902, so that there is a good prospect that this mine may again be an active producer after a period of idleness since 1891.

MOUNT HOPE MINES, MOUNT HOPE, N. J.

Empire Steel and Iron Company, Catasaqua, Pa., owners; Mr. M. Peckitt, Superintendent.

Both the Elizabeth and Taylor mines have been worked during the past year and have produced 34,895 tons of ore, including a small amount of contract ore from old workings on this property. In both these mines the working shafts are located so far to the southwest that with increasing depth the northeastern pitch of the shoots carries the larger part of the ore to the northeast of the shaft, leaving but little ore to the southwest. The mines are therefore constantly worked at increasing disadvantage.

The Taylor Mine.—This disadvantage was so great in the Taylor mine that in 1900 a new slope was commenced farther to the northeast. It is now down about 275 feet at an angle of about 68°, but since it has not yet reached the ore-body, the old shaft and tunnel are still used in taking out the ore.

At the northeastern end of the bottom workings of this mine an offset has been encountered about 200 feet eastward of where the new slope will strike in. This fracture crosses the ore-body obliquely to the east and hades southward 41° from the vertical, or what is the same thing, dips 49° from the horizontal. This is supposed to be the same offset as that described years ago as existing between the Mt. Hope veins and the Hickory Hill veins. In the shallower workings it was struck further northeast, but its southward dip of 49° carries it somewhat rapidly to the southwest in the deeper workings, thus cutting out the ore-body in that direction. On the assumption that this offset is the same as that already known, the northeastward continuation of the vein ought to be found from 160 to 200 feet along it to the eastward.

A winze has been sunk in good ore 60 feet below the lowest level at a point in line with the new slope. Upon the completion of this slope, stoping both ways can proceed rapidly from the bottom of the winze and thus greatly increase the production of the mine. Since in places in the old workings the ore-body was 30 feet wide and the pitch carries this swell into the part still to be opened up, a large amount of ore is assured for the future.

The Elizabeth Mine.—This mine lies southwest of the Taylor and on a vein which if extended would pass southeast of the Taylor vein, and probably southeast of any vein exposed in the Taylor tunnel. It is also entered through a tunnel in the hill-side and then down a steeply inclined slope or shaft.

The sinking in the main shaft reported last year was continued 15 feet farther through a vein of ore 6 to 8 feet thick. On this level, 305 feet below the tunnel, stopes have been driven a considerable distance northeastward and a less distance southwestward, but owing to the pitch of the ore the shaft in its deeper portion is approaching nearer and nearer to the southwestward limit of the workable ore.

Test drill-holes at the bottom of the mine, 12 feet in the footwall, showed some very rich ore, samples of which are said to analyze as high as 70 per cent. metallic iron.

In December explorations with a diamond drill were commenced in the foot-wall on the 250-feet level, but at the close of the year nothing had been revealed.

BEACH GLEN MINE, BEACH GLEN, N. J.

Joseph Wharton, lessee; Edward Kelley, Port Oram, Manager.

The open-cut workings on this property were abandoned in October, 1900, owing to the increasing thickness of the covering. A double skip-way shaft was started late in that year and during 1901 continued to a depth of 425 feet. At about 395 feet a narrow seam of ore was struck which widened rapidly to 5 feet. It is said to average 63 or 64 per cent. metallic iron and 9 per cent. phosphorus. Where first struck the foot-wall dipped steeply to the northwest but at greater depths, it swung over to the more normal position of 75° dip to the southeast. It is intended to continue the shaft to a depth of about 525 feet and then work the vein in levels about 45 feet apart. During the past year the only ore mined was that taken out in sinking the shaft.

HIBERNIA MINES, HIBERNIA, N. J.

Jos. Wharton, owner and operator; Edward Kelley, Port Oram, Manager.

By the purchase of the holdings of the Andover Iron Company early in 1901, Mr. Wharton obtained possession of the Hibernia vein throughout its entire known extent, so that all the mines upon this important ore deposit are now under one management.

The progressive policy of permanent improvements on the surface and development work underground, indicated in the Annual Report for 1900, has been continued during the past year, so that the whole plant is in a better condition than ever before, and a largely increased output of ore during the coming year may be expected. Owing to the attention given to this development work during the past year, the output of the mines has been somewhat curtailed.

The following notes indicate in detail what has been done on these various properties, the old names being retained for the sake of convenience.

Lower Wood and Crane or Church Mine.—No ore is mined in the Lower Wood proper, but it continues to be the outlet for all the ore from the adjoining Crane lot on the northeast. During the year the remaining portion of stope 21 was worked to the line on the northeast, a distance of 150 or 200 feet. Stope 22, which was commenced in 1900, was also worked out to the lean ground on the southwest and the De Camp line on the northeast, about 800 feet in all being removed. No. 19 shaft, which although sunk from No. 16 level, is used chiefly below No. 19 level, was sunk from slope 22 to 23, a distance of about 45 feet. The new stope was opened up 280 feet northeast of the shaft and 160 feet southwestward. Owing to the pitch of the bed-rock or barren ground found in the bottom of the shaft these deeper stopes are continually driven to the northeast, each stope extending farther in that direction than the one above it. There is no intention, however, in spite of the common ownership, of cutting through to the adjoining workings. On the contrary, it is intended that there shall always be a solid wall between these and the workings on the northeast, so that in the event of either mine being abandoned and flooded, the other will not be affected.

From the most easterly workings the ore is hauled up an incline, plane 16 E. to No. 16 level, thence several hundred feet west to the foot of the main incline and then to the surface. From the more westerly breasts the ore is hoisted through shaft 19 to that level, hauled on tram cars to the foot of a third incline, extending from the 19th to the 16th level, then westerly along this level to the foot of the main hoisting shaft, which is 700 feet deep. The deepest workings are now about 940 feet below tunnel level and 358 feet below sea level. The production during 1901 fell slightly below that for 1900.

De Camp Mine.—During the past year the tunnel of the Hibernia underground railroad was extended an additional 1,000 feet in the foot-wall about thirty feet back from the vein, and the corresponding portion of the old tunnel in the vein was abandoned. This supplements the similar work done several years ago, so that the railroad now has a rock cut from the entrance across the Lower Wood, Glendon and De Camp lots, and the constant expense attendant upon keeping in repair the old tunnel along the vein is avoided.

On this property also a new skip-way was put down about 325 feet at a pitch of about 70° S. E. No ore was taken in this mine directly, but in working westward on No. 5 level in the Upper Wood mine the line was passed and some ore taken from the De Camp lot.

Upper Wood Mine.—Mining was resumed here in July on one stope, No. 5 west. Starting from a point about 300 feet southwest of the skip-road, stoping has been carried in that direction for 300 to 350 feet on a breast of ore about 45 feet high and 9 feet wide. As indicated above, a large portion of this stope lies on the De Camp lot, but the ore was mined from the Upper Wood side. On No. 5 east nothing was done in 1901, the stope having been carried 500 feet or so east of the skip-road in previous years.

On level No. 6, which is about 70 feet below No. 5, earlier work had driven the stope 140 feet westward from the skip, and in January, 1902, work was beginning here. Northeast from the skip about 200 feet had previously been taken out, and late in the year a little work was done on this stope.

On level No. 7, 80 feet below No. 6, the breast of ore is at present just west of where the skip-road will be when extended to this level. Northeastward the level has been cut through so as to connect with level No. 1 of the Wharton mine, 300 feet of the 900 to 1,000 feet which separates the Upper Wood skip and Shaft 9 (formerly No. 1, the Wharton mine), having been taken out this past year.

Wharton Mine.—This mine now has a depth of between 1,200 and 1,300 feet, or 300-400 feet below sea-level, and has fourteen working stopes, only a few of which were operated in 1901, owing to the meager hoisting facilities.

With the installation of the new hoisting engine which was contracted for early in the year this difficulty will be largely removed. The two new boilers of 250-horse power capacity each have already been set up.

During the year a crushing and magnetic sorting plant has been erected at Shaft 11, which is 400 feet eastward from Shaft 9. Ore from this shaft is now dropped into a chute and thence fed into a jaw-crusher. It is then carried by an elevator to a screen with three-inch mesh. The fragments too large to pass the screen are carried automatically to be re-crushed, while that which passes is carried on belts to a magnetic separator or sorter consisting of a rotating drum about three feet in diameter against which the crushed ore is fed. The rock falls off at once, while the ore clings to the drum until it revolves beyond the magnetic field, when it also falls off. Both the ore and rock are then carried by belts, the one to bins the other to the dump piles.

As a result of this sorting the heads run about 58 per cent. metallic iron and the tailings carry considerably less iron than the tailings from hand sorting. It has been demonstrated that by this process a more constant run of ore can be obtained and at much less cost than by hand cobbing.

This sorter has been running since the 1st of October, and the results so far attained have been so satisfactory that the erection of another crusher at Shaft 9 is now in progress. At present, however, only the ore from No. 11 is thus treated. That from No. 9 is sorted by hand.

During the past year the concentrating mill, which was formerly at work on ore from Lower Hibernia and the Beach Glen mines, has been working entirely on the hand-picked refuse of the Wharton mine, and since October entirely on that from Shaft 9. This has been hauled on cars to a shaft directly over the Hibernia underground railroad, where it was dumped into a chute 300 feet below, and then fed into the cars of the underground railroad by which it could be hauled to the concentrator.

The work underground has been as follows:

In the previous year (1900) the new shaft, No. 12, which is 1,000 feet northeast of No. 11, had been sunk to a depth of 225 feet, but as the inclination 27° was too gentle and no great amount of ore had been found, it was determined to go back to the foot of the 80-feet vertical section and sink from there on an angle of 80°. This has been done to a depth of 330 feet and a cross cut of 102 feet made to the southward, and a vein 7 feet wide found. No. 2 level from Shaft 11 has already been run to within about 45 feet of the projected position of Shaft 12.

At No. 9 shaft No. 2 level was run about 240 feet southwesterly, the breast being now 60 feet high, 6 to 7 feet wide and 600 feet west of the shaft. In No. 3 west the breast of ore is 80 feet high and about 240 feet from the shaft, about 150 feet of which were worked out during the year. A 10-foot pillar is being left between these stopes. In No. 4 west, which is at present below the level of the skip-road of Shaft 9, no work was done during the year, the breast of ore being about 25 feet west of the bucket shaft. Eastward from Shaft 9 all these levels had in previous years been stoped out to connect with the levels run from Shaft 11. These latter levels are not numbered the same as those from Shaft 9, but begin from a point nearer the surface so that No. 1 level in Shaft 9 corresponds with No. 6 in Shaft 11. In this part of the mine the work of the year has been as follows:

No. 3 east has been driven about 180 feet, the stope being now about 60 feet high and 360 feet from the shaft. The vein here has a width of about 6 feet, but judging by the experience in the higher workings it will probably widen somewhat. On levels 4, 5, 6 and 7 no mining was done during the year. On No. 8 east the breast of ore is between 400 and 500 feet from the shaft, about 200 feet of which were driven during the year. No. 9 was carried 240 feet east of the shaft and has a working face of about 80 feet, the vein being 10 to 12 feet wide. The skip-road reaches only slightly below No. 9, but the bucket shaft was sunk 45 feet to a new level, No. 10, which was driven about 30 feet northeastward and nearly 400 feet southwestward during the year. The southwest breast of ore is now about in line with the extension of Shaft 9. These stopes are each about 45 feet high and 10 feet wide. In general in this mine either one or both walls of the vein are rough and more or less rock is taken out near the margin. The vein is nearly vertical and not infrequently dips slightly northward. During the year the Wharton mine considerably exceeded its production for 1900.

RINGWOOD MINES, RINGWOOD, N. J.

Cooper, Hewitt & Co., owners.

Mr. Hewitt reports that the Ringwood mines were operated continuously during the past year, and 13,472 tons were produced, 1,000 tons being from the Cannon mine and the remainder from the Peters mine. During the latter part of the year the production fell off somewhat owing to the sinking of a new shaft which is now 180 feet deep and which has reached the ore-body. With the better facilities afforded by this shaft it is expected that a greatly increased production will be insured for the coming year.

The Zinc Mines.

The zinc mines at Franklin Furnace, owned by the New Jersey Zinc Company, have been in active operation during the past year.

The Superintendent, Mr. James B. Tonking, reports that the principal work in the Parker mine has been the extension of the several levels noted in the Report for 1900 in a southwesterly direction. This work will be continued until they intersect the bed-rock or basin of the ore-body.

The Trotter mine has been inactive during the entire year, but the main portion is practically clear of water, since it is drained by a diamond drill-hole into the Buckwheat mine.

On the southwest end, commonly called the Buckwheat mine, the general stripping work referred to in last year's notes has been vigorously continued so that at the present time all of the rock down to the level of the old Buckwheat mine-tunnel and up to the large trap-dike has been nearly removed. A portion of the ore on the west leg has also been removed, but a goodly portion of it still remains in place. The slope which was sunk from this trap-dike down underneath the limestone arch has been continued throughout the year, and is now at a point in depth where it will be possible to cross over and open into the Parker mine, thus connecting the two ends of this lens of ore, giving two outlets to both mines and furnishing the necessary pure air. Connection will probably be made during the year 1902.

The total number of tons mined during the year, and principally sent to the mills for separation, is 191,221.43 tons.

The Stirling Hill mines at Ogdensburg have been inactive during the entire year. These mines are filled with water, no pumping going on.

Mill No. 1 was operated for the first five months of the year. Since then it has been closed down, being held as an auxiliary to Mill No. 2.

Mill No. 2 was operated during the entire twelve months of the year, the first five months on the hard black ore from the west vein from the southwest end of the deposit, *i. e.*, the Taylor mine. The other seven months it was supplied with the richer ore of the deposit.

These two mills have taken the principal part of the ore mined for the year excepting some crude ore that was shipped direct.

The Copper Mines.

The copper mines of New Jersey are not yet beyond the development stage, but there is no longer any doubt but that in certain localities at least there are large quantities of low-grade ore, which with modern methods of mining and ore-treatment, can probably be worked profitably, even with the price of copper somewhat below that which prevailed previous to the slump at the close of the year. In order, however, that this may be done, operations must be conducted on a large scale. Some method must be adopted of treating the ore at the mine, either by concentration, leaching, smelting or other process, in order to save heavy freight charges. This necessitates the investment of a very considerable sum of money in a plant, and in sufficient development work underground to afford facilities for mining large amounts of ore cheaply and rapidly. It is not possible to make the development work pay for itself; nor even under the most favorable conditions known to prevail in the State can this preliminary work be done for a few hundred or even a few thousand dollars. Persons contemplating re-opening any of the old copper workings of the State, or developing any new localities, would do well to keep these self-evident facts clearly in mind.

More or less prospecting for copper was done in the early part of the year, but the depression which prevailed in the copper market during the closing months was not encouraging to new enterprises. In spite, however, of this depression, it is believed that in the future copper mining in the State will be much more successful than in the past.

THE AMERICAN COPPER MINE, SOMERVILLE.

Mr. J. C. Reiff, President; Josiah Bond, General Manager.

Work has been steadily carried on at this mine during the past year. The main slope which coincides with the old tunnel as far as the first bend, and follows down the dip of the shales at the base of the trap-sheet, has been extended 655 feet, and now has a length of 1,112 feet, equivalent to a depth of about 600 feet from the surface. Beyond the bend the old tunnel has been abandoned. The Spencer slope, 500 feet distant from the main slope, has been lengthened 160 feet to give better ventilation in the main slope. In addition to this 740 feet of side-drift work has been done, the drifts being run alternately on either side of main slope and at right-angles to it, at intervals of 30 feet, so that the intervals between two drifts on the same side is 60 feet. There are now a total of 1,270 feet of slope and 1,800 feet of side drifts, without including the abandoned portion of the old tunnel, along all of which the ore is exposed as indicated in previous reports.

Incidentally to this development work several thousand tons of ore have been mined, of which a portion has been concentrated with good results. Several trial smeltings have also been made, both of concentrated and mine ore, and a high grade of ingot copper produced, while the slag was very low in that metal.

As indicated in previous reports the ore is somewhat irregularly distributed along the contact of the shale and trap, the upper two and a-half feet of the shale and the lower foot of the trap being mineralized. There is considerable variation in the per cent. of copper within short distances, but when wider areas are considered the averages do not vary greatly. In the deeper workings the ore is chiefly native copper instead of the oxides, sulphides and carbonate, which occurred nearer the surface. Only along joint faces, etc., where there has been ready access by surface waters is the native copper changed to the oxide or carbonate. It is very evident that the mineral, probably at first minutely disseminated in the trap, was afterwards concentrated here as native copper. In these deeper workings masses of mineralized rock several feet in diameter are found which carry 20 to 25 per cent. of copper, but of course this by no means represents the average, which is very much less.

During the year a 20-ton brick and steel-jacketed smelter has been erected for experimental purposes. It is designed particularly for low-grade ores and is fitted with a draught induced by compressed air, by which a large in-rush of the surrounding air is caused. This style of smelter has been found to work very successfully with highly siliceous ores which do not carry much iron, although they demand more fuel than other styles.

In the report for 1900 some minor errors were made in regard to the details of the power employed. The plant now consists of (1) A 5-drill Rand Compressor plant with 80-horsepower boiler. The air not used for the drills is used in pumping. (2) A hoisting plant with one 12-horsepower Lidgerwood engine. (3) Mill plant of one 60-horsepower boiler and engine, a crusher, two sets of roughing rolls, drier, screen, sizers, and two Wilfrey tables. As at present constituted its capacity is 50 tons daily.

Large specimens of the copper ore from this mine were a part of the Survey's display at the Pan-American Exposition.

During the year an elaborate series of chemical tests were undertaken with a view of determining the best methods of leaching such of the ores as could best be treated in this way. The results of these experiments are of more than passing interest, since they have a decidedly practical bearing upon methods of treating many of the New Jersey copper ores. The President of this mine and his associates are certainly to be commended for their enterprise in instituting and carrying forward these experiments, even after it was evident that the bulk of their own ore could probably be better treated mechanically. Through the kindness of Mr. Reiff, Mr. Josiah Bond, the General Manager, has prepared a discussion of these experiments which we take pleasure in printing, hoping it may be of assistance to others.

COPPER LEACHING AT THE AMERICAN COPPER MINE.

BY JOSIAH BOND.

There are known to exist in the Triassic area of New Jersey extensive bodies of copper ore, which as far as developed have not proved to be such as can be economically sent from the mine to the smelter without intermediate expense. They will, however, probably prove to carry enough copper to form a paying ore where treated mechanically or chemically, so as to increase the copper contents of the material saved, and by throwing away a large proportion of the waste rock, cut down the ultimate expense of melting to a profitable point. Some ores can best be treated chemically, while others, such as most of that found at the American mine near Somerville, can be best saved by mechanical concentration. At this mine, however, there is near the surface a rim of highly oxidized ores which will occasionally furnish tailings rich enough in copper to leach with a profit, owing to the abundance of carbonates and silicates which do not separate readily by gravity.

In view of this fact an exhaustive series of experiments was carried out on these and other copper ores, by all the commonly accepted methods and combinations of them. Many conditions exist here favorable to the extraction of copper in the wet way. The low price of chemicals and fuel, cheapness of construction, favorable climatic conditions, low freights, the certainty of securing reliable and intelligent labor at reasonable rates, ease of access for purposes of supervision and inspection, all combined to tempt to trials of any method proposed. A short description of the method adopted in making these experiments, and some notes on the results obtained may be of interest to future copper miners in New Jersey, which State, I venture to predict, will cut some figure in the copper supply in years to come. In publishing these notes I wish to express my appreciation of the ability and painstaking fidelity of Messrs. James E. Thompson and Henry Huntington Miller, the chemists in charge of the work on the ground, as well as to the very numerous chemists who from time to time have assisted by suggestions and information in making the experiments successful.

The experiments have been applied to all grades of ores and tailings, and so far as these came from the American mine they belonged to some one of the types represented by the following analyses:

	Ores.		Ore and Shale.	Tailings.				
	1	2	3	4	5	6	7	8
SiO_2,	55.28	56.82	51.32	69.70	65.25	70.10	53.10	71.40
Fe_2O_3,	5.71	4.53	6.87	3.25	5.20	4.06	5.70	2.75
Al_2O_3,	15.84	14.95	16.79	16.90	14.35	13.21	16.20	17.10
$CaCO_3$,	9.73	9.40	2.75	2.45	1.10	9.00	6.20	2.80
MgO,	2.75	2.90	2.91	3.10	1.50	4.50	15.30	2.30
Nickel,	trace	trace	trace					
Cobalt,	trace		trace					
Copper,	2.83	2.66	.47	.50	.44	.30	.15	.22
Silver (oz. per ton),	.84	.50	.11		trace			
Gold,	.01		trace					

Numbers 1 and 2 are ores; 3 is a mixed ore and shale; 4, 5 and 6 are tailings; 8 is the shale lying below the mineralized zone, and 7 is tailings of slime; that is, slime from which the copper has been separated by concentration.

The average contents of the various ores are about the same, the principal variants being lime and iron, which are present in the calcite and hematite amygdules found in the trap on the contact; these cause most of the waste of reagents, and must, therefore be given some consideration.

With a few exceptions, all the material used in the experiments was crushed to 16 mesh in the ordinary course of milling and taken from the mill run of the day. In the laboratory tests generally one-half a kilo of ore was covered with 200 c.c. of solution. For large tests we had a set of barrels with a capacity of 200 pounds. For commercial tests tanks with a capacity of 25 tons each were used. Steam for heating solutions, compressed air for agitation, etc., and other necessities were at hand.

First of all a series of tests was made for the purpose of determining the amount of ore ground to various sizes by our method of grinding, and the proportion of the total copper carried by each size. These tests were many, and were repeated from time to time. Occasionally samples were ground finer for the purpose of determining whether a finer grinding would aid in securing a greater extraction. The following tabulated results may be taken as a characteristic, a few being adduced to show the substantial conformity of the whole:

Classification.			*Percentage of total copper in each size.*			
	1	*2*	*4*	*5*	*6*	*7*
Between 16 and 20 mesh, ...	37.50	34.50	37	55.4	57.4	72
" 20 " 40 "	18	17	35	16.4	13.6	
" 40 " 60 "	15	17.50	4.7	8.2	9.8	4.70
" 60 " 80 "	18	19	6	5.4	5.2	6
" 80 " 100 "	3.50	2.50	1.5	3.2	2.4	1.50
Smaller than 100 "	8	9.50	15.8	11.4	11.6	15.80

Columns 1 and 2 show the percentages of material of different sizes in two instances, while columns 4, 5, 6 and 7 show the percentage of total copper in each size in four different cases. It will readily be seen that the coarse particles of crushed ore carried the greater part of the copper. The meal, from 16 to 40 mesh, carries over 70 per cent. of the total copper, although comprising only from 51 to 53 per cent. of the whole material; the pulp, from 40 to 100 mesh, had but comparatively little copper, while the slime, which made but 8 or 9 per cent. of the whole, carried much in proportion to its weight (from 11 to 15 per cent. of the total). It, therefore, received the benefit of much experimenting as to the best methods of handling it mechanically. Chemically it responded practically as did the coarser material, except that there was a large consumption of acid. However, it was found that the greater part of the slime was amenable to concentration, so that, as will be perceived from No. 7 of the analyses in the first table, the proportion of copper left in the tailings of the slime was so small and the actual quantity so little that it was more economical to drain it off from the tailings than to treat it chemically, since it interfered with the percolation of the solutions by forming impervious layers. This, therefore, was generally done, although in many ores the slime may be found to carry sufficent values to warrant the separate chemical treatment.

When inaugurating an experiment with a solution, as, for instance, sulphuric acid, a series of leachings was made with a view to determining the time necessary to secure the best extraction with various strengths of acids. The result of such a series is here tabulated:

Hours.	*1*	*2½*	*5*	*8*	*12*	*24*	*36*
Solution, 1 %, ...	4	2	1	3	5	6	7
" 2 %, ...	3	2	1	4	5	6	7
" 3 %, ...	3	2	1	4	5	6	7
" 4 %, ...	3	2	1	4	5	6	7
" 5 %, ...	3	2	1	4	5	6	7

The figure 1 indicates the most copper in solution, figure 7 the least. The table shows all the solutions best at 5 hours and deteriorating after 8 hours; but as they were next best in 2½ hours a series of tests was made to determine the necessary time more exactly. These are graphically represented in the following table, in which A represents the time at which each particular solution contained the most copper, D the least, while the figure 1 shows the solution which made the best extraction of copper at each hour:

Hours.	*4*	*4½*	*5*	*5½*	*4*	*4½*	*5*	*5½*
Solution 1 %, ...	D	A	B	C	2	1	1	1
" 2 %, ...	A	B	C	D	1	2	2	2
" 3 %, ...	C	A	B	D	3	3	5	3
" 4 %, ...	A	B	C	D	4	4	3	4
" 5 %, ...	B	A	C	D	5	5	4	5

As shown by the above tables, the solutions, of whatever strength, contained the most copper in from four to four and a-half hours, while the weaker solutions made the best extraction of copper at all times. The stronger solutions attacked the other elements of the ore more than the copper, even finally surrendering up part of the copper already conquered. A variety of such tests with sulphuric acid gave maximum extraction in a little over 4 hours by a solution of a little above 1 per cent. From results obtained in this way data were gathered for experiments on a larger scale.

The above tables represent merely a portion of the work done for the purpose of determining the action of sulphuric acid solutions, and in a similar manner numerous tests were made with each reagent to obtain as nearly as possible the exact strength of the solution and the exact time necessary to secure the extraction of the greatest amount of copper.

The principal reagents are ammonium, chlorine and sulphur compounds. What was wanted was a reagent which would take the most copper and the least of anything else, in the shortest time, and would be cheap. Its success was gauged by these requisites.

Of ammonium hydroxide, choride, carbonate, oxalate, nitrate, sulphate and acetate, all of which were tried, the ammonium sulphate appears the best. Yet while none of these attack other matter fiercely, evaporation is so continuous as to render necessary closed receptacles for the solution, and since the best extraction with this reagent was obtained at 48 hours, there was time to waste the reagent. On addition of time the nascent ammonia acts quickly enough on a carbonate, but all forms of ammonium compounds act slowly on oxides, and with extreme slowness on native copper. For a purely carbonate ore in a siliceous gangue nothing will approach the ammonium hydroxide in a concentrated solution, as it can be recovered and used repeatedly. Our tests on such an ore indicated a loss of only 3 cents per ton of 1 per cent. ore when proper precautions were taken. But as our mine ore was mixed, oxides, carbonates and silicates, the extraction was neither good nor uniform.

Sulphate of iron, sulphate of iron and salt, chloride of iron, salt and sulphate of ammonia, were efficient in action, but the iron solutions produced a low-grade cement and a large excess of each was necessary. A solution of salt, permanganate of potash and sulphuric and nitric acids proved too expensive, being too hungry for other matter than the copper. Bleaching powder alone gave fair extraction.

Cupric chloride in solution takes up another atom of copper to make cuprous chloride, and from the latter the extra atom of copper can be released in several ways, thus restoring the original cupric chloride for use again. This gives almost complete extraction, but the action is slow, and there is a tendency to form oxychlorides of copper, which are insoluble.*

* A unique feature of this process, I think, not pointed out before, is its ability to take up gold and silver in lieu of and in preference to copper, and it was proved to secure a good extraction of gold from a quartzose ore. It may under certain circumstances be cheaper than the cyanide solution as the gold can be extracted readily by a feeble electric current. Chemically this acted well on our ore.

Hyposulphite of soda gives fair results in 24 hours when heated to 40° C. (about 100 F.). The copper may be precipitated in two ways and the solution regenerated for further use. With an ammonia salt better extraction is secured and not so much foreign matter dissolved.

A solution of saltpeter, salt and sulphuric acid was tried, but it dissolved too much of the rock. Hypochlorite of soda with an excess of chlorine gives good extraction, but costs too much. A nitre cake or salt cake solution would be economical on ores free from soluble salts, but with us seemed even more grasping than sulphuric acid alone, probably on account of its slower action.

Sulphurous acid applied either in liquid form, or as gas developed at the time, has the power of dissolving native copper as well, but too much foreign matter is taken up, and the extraction is not complete. Sulphuric acid is open to these objections in little less degree, and on low-grade tailings the operation increases in cost in proportion to the preponderance of the other foreign matter attacked by it.

Hydrochloric acid, especially applied hot, is extremely satisfactory in its chemical action, and, where sulphuric acid and salt are cheap, is feasible. An excess of salt should be used, producing the acid in solution, and making in addition a hot brine to protect the cuprous chloride from precipitation. After this is drawn off the ore is washed with ammonia with the effect of increasing extraction, and if the ore is placed in a tank and one solution and then the other allowed to percolate through it several times in succession, the extraction is as complete as mechanically possible. The copper can be extracted from the solutions and both the hydrochloric acid and ammonia can be recovered for continuous use, the latter with but small loss, and the former until it becomes so fouled with foreign matter as to be slow in action, when it can be utilized so as to obtain about one-third of its first cost. The only ingredients required in full strength for each lot of ore are the salt and a little lime, used for the purpose of releasing ammonia compounds with the other elements of the ore. This process will recover silver, and, with an addition of permanganate of potash, gold also. But as our gold and silver values were very completely saved by concentration, this phase of the question was not gone into exhaustively.

My experience indicates that tailings, against which the main costs of mining and milling have been charged, can be economically leached when they run above one-half of one per cent. When the ore to be leached must be mined and pulverized it is necessary to add enough percentage of copper to this half of one per cent. to cover these costs. In New Jersey, where mining conditions are of the easiest, it is safe to say that a one and one-quarter per cent. ore can be treated profitably by leaching if it occurs as carbonates and silicates. If in other forms, it will probably be better handled by concentration, which should be adopted if possible, as it is much the cheaper process.

Since the ores of the American mine are chiefly native copper, and a peculiarly satisfactory ore to concentrate, the tailings have been generally too low to leach, so that up to this time we have had no opportunity to apply any method commercially in continuous run. Even our surface ores have turned out to be concentratable, owing to nuclei of native copper, red oxide or sulphide found in every concretion of silicates and carbonates, and, in all probability, no leaching process will be applied to any ores as they come from the mine, but only to tailings should these at times be high enough in copper to show true economy in making the further saving.

The mechanical difficulties of all leaching processes are considerable, and great care was found necessary in timing the leaching, so as not to re-precipitate the copper; in agitating the ore in the solution and in thoroughly washing the ore after treatment, so as to retain with the solution all the copper extracted. The former difficulty disappears in treating quartz ores, the second would not be so necessary with them, but the latter difficulty will be found with every ore.

The recovery of the copper from the solutions was in every case readily accomplished. Copper in solution with acid reagents will be deposited in the presence of iron; ammonia solutions can be distilled, the ammonia recovered and copper oxide produced, and various other methods have been proposed which will act perfectly chemically; the cements from the acid solutions will run from 50 per cent. to 60 per cent. and those from ammonia solutions 70 per cent. to 80 per cent. These cements are readily reduced to a metallic copper by established methods. Our experimenting in this direction was principally with the electric current, the aim being to produce refined copper at one operation. This was feasible, and we are now in the midst of experiments on a continuous process in which the solution can be placed on the ore or tailings and the copper extracted as fast as taken into solution. This I believe to be perfectly feasible, and we have already done this on a small scale; the difficulties are mostly mechanical, and as there are many chemists working on this problem, its solution is imminent.

While the above summary of our methods of determining strength of solutions, time required and results obtained is fragmentary, I trust that these notes may assist in solving the problem of handling the low-grade copper carbonate ores of the State.

THE ARLINGTON COPPER COMPANY.

During the past year considerable work has been done on the plant, which was described in the Annual Report for 1900, and some work was done underground. The material has not proved as susceptible to the proposed chemical treatment as was expected. Work was suspended late in the year, but the mine is kept open and the company report that active operations will be resumed in the spring.

PAHAQUARRY MINE.

The Survey has been informed that during the past year the Montgomery Gold Leaf Mining Co., of which H. D. Deshler, of Belvidere, is Secretary and Treasurer, has acquired the mineral rights of 1,028 acres of land in Pahaquarry township, Warren county, in the vicinity of the old copper workings there. Some prospecting work has been done and new deposits exposed, about a hundred tons of ore being mined. A tunnel is being driven to cross-cut the deposits and afford better drainage. The ore as found at present is low grade and not sufficiently rich to warrant a long haul to the railroad—seven miles—and subsequent freight charges to a smelter, and sufficient development work has not yet been done to determine whether the amount of ore available will warrant a concentrating plant at the mine.

Dr. George H. Cook, in 1868, in his Geology of New Jersey, page 680, said of this mine: "Some of the mine holes here are supposed to have been opened prior to 1664 by the emigrants from Holland, who entered this valley from the Hudson river through Ulster county. The settlement known as the Minnisink settlement had a good road for one hundred miles to the Hudson river, and the ore from these workings was taken that way." About 1862 a Philadelphia company did some work there, but little ore was obtained.

GRIGGSTOWN MINE.

Some work has been done towards re-opening the old Griggstown copper mines, but as work was commenced late in the year not much was accomplished. The old shaft has been cleared out to a depth of 100 feet and an incline about 400 feet distant has been started. Work is expected to continue in the spring of 1902.

Mineral Statistics

For the Year 1901.

Iron Ore.

The total production of the mines, as reported by the several mining companies, was 401,151 tons.

The total shipments from mines in the State, as reported by the railway companies, to the office of the Geological Survey, plus a small amount hauled by wagons to furnaces, amounted to 419,762 tons.

The table of statistics is reprinted, with the total amount for 1901 added.

TABLE OF STATISTICS.

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

* From statistics collected later.

Year.	*Iron Ore.*	*Authority.*
1885,	330,000 tons,	Annual Report State Geologist.
1886,	500,501 tons,	" " "
1887,	547,889 tons,	" " "
1888,	447,738 tons,	" " "
1889,	482,109 tons,	" " "
1890,	552,996 tons,	" " "
1891,	551,358 tons,	" " "
1892,	465,455 tons,	" " "
1893,	356,150 tons,	" " "
1894,	277,483 tons,	" " "
1895,	282,433 tons,	" " "
1896,	264,999 tons,	" " "
1897,	257,235 tons,	" " "
1898,	275,378 tons,	" " "
1899,	300,757 tons,	" " "
1900,	342,390 tons,*	" " "
1901,	401,151 tons,	" " "

Zinc Ore.

The production of the New Jersey Zinc Company's mines is reported by Mr. James B. Tonking, Superintendent, to be 191,221 tons of zinc and franklinite ore. It was chiefly separated at the company's mills. The amount of separates and ore shipped by the railroad is reported to be 170,225 tons. Both reports show a slight falling off in production over 1900.

The statistics for a period of years are reprinted from the last annual report.

ZINC ORE.

1868,	25,000 tons,†	Annual Report State Geologist.
1871,	22,000 tons,†	" " "
1873,	17,500 tons,	" " "
1874,	13,500 tons,	" " "
1878,	14,467 tons,	" " "
1879,	21,937 tons,	" " "
1880,	28,311 tons,	" " "
1881,	49,178 tons,	" " "
1882,	40,138 tons,	" " "

* The figures, 407,596 tons, given in the report for 1900, included 75,206 tons of crude material, which should have been reduced to its equivalent in concentrates.

† Estimated for 1868 and 1871. Statistics for 1873–1890, inclusive, are for shipments by railway companies. The later reports are from zinc-mining companies.

Year.	*Iron Ore.*	*Authority.*
1883	56,085 tons	Annual Report State Geologist.
1884	40,094 tons	" " "
1885	38,526 tons	" " "
1886	43,877 tons	" " "
1887	50,220 tons	" " "
1888	46,377 tons	" " "
1889	56,154 tons	" " "
1890	49,618 tons	" " "
1891	76,032 tons	" " "
1892	77,298 tons	" " "
1893	55,852 tons	" " "
1894	59,382 tons	" " "
1895*		
1896	78,080 tons	" " "
1897	76,973 tons	" " "
1898	99,419 tons	" " "
1899	154,447 tons	" " "
1900	194,881 tons	" " "
1901	191,221 tons	" " "

* No statistics were published in the Annual Report for 1895.

Publications.

The demand for the publications of the Survey is continuous and active. So far as possible requests for the reports are granted.

It is the wish of the Board of Managers to complete, as far as possible, incomplete sets of the publications of the Survey, chiefly files of the Annual Reports in public libraries, and librarians are urged to correspond with the State Geologist concerning this matter.

By the act of 1864 the Board of Managers of the Survey is a board of publication, with power to issue and distribute the publications as they may be authorized. The Annual Reports of the State Geologist are printed by order of the Legislature as a part of the legislative documents. They are distributed by the State Geologist to libraries and public institutions, and, as far as possible, to any who may be interested in the subjects of which they treat.

Four volumes of the Final Report series have been issued. Volume I, published in 1888, has been very scarce for several years, but all the valuable tables were reprinted in an appendix of Volume IV, which can still be supplied.

The appended list makes brief mention of all the publications of the present Survey since its inception in 1864, with a statement of the editions now out of print. The reports of the Survey are distributed without further expense than that of transportation. Single reports can usually be sent more cheaply by *mail* than otherwise, and requests should be accompanied by the proper postage as indicated in the list. Otherwise they are sent *express collect*.

The maps are distributed only by sale, at a price, 25 cents per sheet, to cover cost of paper, printing and transportation. In order to secure prompt attention requests for both reports and maps should be addressed simply "State Geologist," Trenton, N. J.

CATALOGUE OF PUBLICATIONS.

Geology of New Jersey. Newark, 1868, 8vo., xxiv+899 pp. Out of print.

Portfolio of Maps accompanying the same, as follows:

1. Azoic and paleozoic formations, including the iron-ore and limestone districts: colored. Scale, 2 miles to an inch.

2. Triassic formation, including the red sandstone and trap-rocks of Central New Jersey; colored. Scale, 2 miles to an inch.

3. Cretaceous formation, including the greensand-marl beds; colored. Scale, 2 miles to an inch.

4. Tertiary and recent formations of Southern New Jersey; colored. Scale, 2 miles to an inch.

5. Map of a group of iron mines in Morris county; printed in two colors. Scale, 3 inches to 1 mile.

6. Map of the Ringwood iron mines; printed in two colors. Scale, 8 inches to 1 mile.

7. Map of Oxford Furnace iron-ore veins; colored. Scale, 8 inches to 1 mile.

8. Map of the zinc mines, Sussex county; colored. Scale, 8 inches to 1 mile. A few copies are undistributed.

Report on the Clay Deposits of Woodbridge, South Amboy and other places in New Jersey, together with their uses for fire-brick, pottery, &c. Trenton, 1878, 8vo., viii+381 pp., with map.

A Preliminary Catalogue of the Flora of New Jersey, compiled by N. L. Britton, Ph.D. New Brunswick, 1881, 8vo., xi+233 pp. Out of print.

Final Report of the State Geologist. Vol. I. Topography. Magnetism. Climate. Trenton, 1888, 8vo., xi+439 pp. Very scarce.

Final Report of the State Geologist. Vol. II. Part I. Mineralogy. Botany. Trenton, 1889, 8vo., x+642 pp. (Postage, 25 cents.)

Final Report of the State Geologist. Vol. II. Part II. Zoölogy. Trenton, 1890, 8vo., x+824 pp. (Postage, 30 cents.)

Report on Water-Supply. Vol. III of the Final Report of the State Geologist. Trenton, 1894, 8vo., xvi+352 and 96 pp. (Postage, 21 cents.)

Report on the Physical Geography of New Jersey. Vol. IV of Final Report of the State Geologist. Trenton, 1898, 8vo., xvi+170+200 pp. (Postage, 24 cents.)

Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1886, quarto, pp. 338, plates XXXV and Map. (Paleontology, Vol. 1.) (By express.)

Gasteropoda and Cephalopoda of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1892, quarto, pp. 402, plates L. (Paleontology, Vol. II.) (By express.)

Atlas of New Jersey. The complete work is made up of twenty sheets, each 27 by 37 inches, including margin, intended to fold once across, making the leaves of the Atlas 18½ by 27 inches. The location and number of each map are given below. Those from 1 to 17 are on the scale of one mile to an inch.

No. 1. Kittatinny Valley and Mountain, from Hope to the State line.

No. 2. *Southwestern Highlands,* with the southwest part of Kittatinny valley.

No. 3. *Central Highlands,* including all of Morris county west of Boonton, and Sussex south and east of Newton.

No. 4. *Northeastern Highlands,* including the country lying between Deckertown, Dover, Paterson and Suffern.

No. 5. *Vicinity of Flemington,* from Somerville and Princeton westward to the Delaware.

No. 6. *The Valley of the Passaic,* with the country eastward to Newark and southward to the Raritan river.

No. 7. *The Counties of Bergen, Hudson and Essex,* with parts of Passaic and Union.

No. 8. *Vicinity of Trenton,* from New Brunswick to Bordentown.

No. 9. *Monmouth Shore,* with the interior from Metuchen to Lakewood.

No. 10. *Vicinity of Salem,* from Swedesboro and Bridgeton westward to the Delaware.

No. 11. *Vicinity of Camden,* to Burlington, Winslow, Elmer and Swedesboro.

No. 12. *Vicinity of Mount Holly,* from Bordentown southward to Winslow and Woodmansie.

No. 13. *Vicinity of Barnegat Bay,* with the greater part of Ocean county.

No. 14. *Vicinity of Bridgeton,* from Allowaystown and Vineland southward to the Delaware bay shore.

No. 15. *Southern Interior,* the country lying between Atco, Millville and Egg Harbor City.

No. 16. *Egg Harbor and Vicinity,* including the Atlantic shore from Barnegat to Great Egg Harbor.

No. 17. *Cape May,* with the country westward to Maurice river.

No. 18. *New Jersey State Map.* Scale, 5 miles to an inch. Geographic.

No. 19. *New Jersey Relief Map.* Scale, 5 miles to the inch. Hypsometric.

No. 20. *New Jersey Geological Map.* Scale, 5 miles to the inch.
At present out of stock.

The maps comprising THE ATLAS OF NEW JERSEY are sold at the cost of paper and printing, for the uniform price of 25 cents per sheet, either singly or in lots. *Payment, invariably in advance.*

TOPOGRAPHIC MAPS, NEW SERIES.

The new series topographic maps of the Survey, on a scale of one inch to 2,000 feet, are sold at 25 cents per sheet. The following sheets are ready: JERSEY CITY, NEWARK, MORRISTOWN, HACKENSACK, PATERSON, ELIZABETH, PLAINFIELD, CAMDEN, MOUNT HOLLY, WOODBURY, TAUNTON, AMBOY, NAVESINK, LONG BRANCH. They may be had by addressing the State Geologist, Trenton, N. J., with remittance for amount of order.

ANNUAL REPORTS.

REPORT OF PROFESSOR GEORGE H. COOK upon the Geological Survey of New Jersey and its progress during the year 1863. Trenton, 1864, 8vo., 13 pp. Out of print.

THE ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to his Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1864. Trenton, 1865, 8vo., 24 pp. Out of print.

ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to his Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1865. Trenton, 1866, 8vo., 12 pp. Out of print.

ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, on the Geological Survey of New Jersey, for the year 1866. Trenton, 1867, 8vo., 28 pp. Out of print.

REPORT OF THE STATE GEOLOGIST, Prof. Geo. H. Cook, for the year of 1867. Trenton, 1868, 8vo., 28 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1869. Trenton, 1870, 8vo., 57 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1870. New Brunswick, 1871, 8vo., 75 pp., with maps. Very scarce.

ANNUAL REPORT of the State Geologist of New Jersey for 1871. New Brunswick, 1872, 8vo., 46 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1872. Trenton, 1872, 8vo., 44 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1873. Trenton, 1874, 8vo., 128 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1874. Trenton, 1874, 8vo., 115 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1875. Trenton, 1875, 8vo., 41 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1876. Trenton, 1876, 8vo., 56 pp., with maps. Out of print.

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ANNUAL REPORT of the State Geologist of New Jersey for 1881. Trenton, 1881, 8vo., 87+107+xiv pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1882. Camden, 1882, 8vo., 191 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1883. Camden, 1883, 8vo., 188 pp. Scarce.*

ANNUAL REPORT of the State Geologist of New Jersey for 1884. Trenton, 1884, 8vo., 168 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1885. Trenton, 1885, 8vo., 228 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1886. Trenton, 1887, 8vo., 254 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1887. Trenton, 1887, 8vo., 45 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1888. Camden, 1889, 8vo., 87 pp., with map.

ANNUAL REPORT of the State Geologist of New Jersey for 1889. Camden, 1889, 8vo., 112 pp.

ANNUAL REPORT of the State Geologist of New Jersey for 1890. Trenton, 1891, 8vo., 305 pp., with maps. (Postage, 10 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1891. Trenton, 1892, 8vo., xii+270 pp., with maps. (Postage, 10 cents.) Scarce.*

ANNUAL REPORT of the State Geologist of New Jersey for 1892. Trenton, 1893, 8vo., x+368 pp., with maps. (Postage, 10 cents.) Very scarce.*

ANNUAL REPORT of the State Geologist of New Jersey for 1893. Trenton, 1894, 8vo., x+452 pp., with maps. (Postage, 18 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1894. Trenton, 1895, 8vo., x+304 pp., with geological map. (Postage, 11 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1895. Trenton, 1896, 8vo., xl+198 pp., with geological map. (Postage, 8 cents.)

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ANNUAL REPORT of the State Geologist of New Jersey for 1897. Trenton, 1898, 8vo., xl+368 pp. (Postage, 12 cents.)

ANNUAL REPORT of the State Geologist for 1898. Trenton, 1899, 8vo., xxxii+244 pp., with Appendix, 102 pp. (Postage, 14 cents.)

ANNUAL REPORT of the State Geologist for 1899 and REPORT ON FORESTS. Trenton, 1900, 2 vols. 8vo., Annual Report, xliii+192 pp. FORESTS, xvi+327 pp., with seven maps in a roll. (Postage, 8 and 22 cents.)

ANNUAL REPORT of the State Geologist for 1900. Trenton, 1901, 8vo., xl+231 pp. (Postage, 10 cents.)

ANNUAL REPORT of the State Geologist for 1901.

* These reports can be supplied only to libraries.

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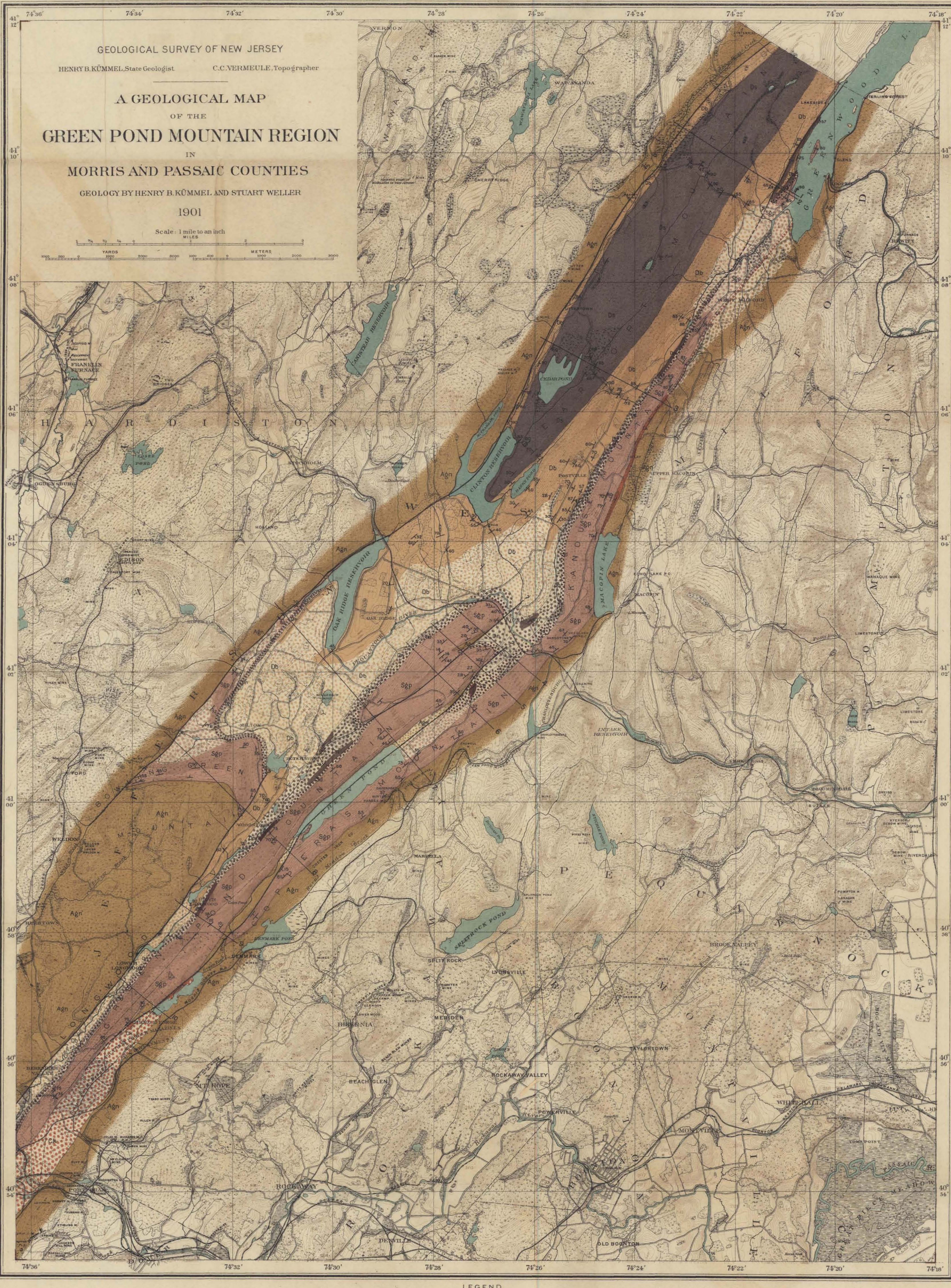

LEGEND

DEVONIAN			SILURIAN		CAMBRIAN	UNCLASSIFIED PRE-CAMBRIAN	
Ds	Db	Dn	Sd	Sgp	Ck	Agn	
Skunnemunk conglomerate (*Chemung-Catskill?*)	Bellvale flags and Monroe shales (*Hamilton*)	Newfoundland grit (*Oriskany-Corniferous*)	Decker Ferry limestone (*Niagaran*)	Longwood shales and Green Pond conglomerate and quartzite (*Oneida & Medina*)	Kittatinny limestone and Hardyston quartzite	Chiefly gneiss	Dotted areas show heavy drift deposits with underlying rock doubtful or unknown

30 Dip (normal) — 58 Dip (overturned) — Faults — 1 Section lines, 2, 3, etc.