GEOLOGICAL SURVEY OF NEW JERSEY

ANNUAL REPORT

OF THE

STATE GEOLOGIST

For the Year 1900

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I. Congressional District.

EDWARD C. STOKES, ... MILLVILLE.
CLEMENT H. SINNICKSON, ... SALEM.

II. Congressional District.

EMMOR ROBERTS, ... MOORESTOWN.
WASHINGTON A. ROEBLING, ... TRENTON.

III. Congressional District.

HENRY S. LITTLE, ... MATAWAN.
M. D. VALENTINE, ... WOODBRIDGE.

IV. Congressional District.

FREDERICK A. CANFIELD, ... DOVER.
*GEORGE RICHARDS, ... DOVER.

V. Congressional District.

GEORGE W. WHEELER, ... HACKENSACK.
WILLIAM F. HALL, ... POMPTON LAKES.

VI. Congressional Dsstrict.

†THOMAS T. KINNEY, ... NEWARK.
FREDERIC W. STEVENS, ... NEWARK.

VII. Congressional District.

LEBBEUS B. WARD, ... JERSEY CITY.
SAMUEL B. DOD, ... HOBOKEN.

VIII. Congressional District.

ERNEST R. ACKERMAN, ... PLAINFIELD.
WENDELL P. GARRISON, ... ORANGE.

* Died April 3, 1900. † Died December 2, 1900.

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 1900.

Respectfully submitted,

JOHN C. SMOCK,

STATE GEOLOGIST.

TRENTON, N. J., November 30th, 1900.

Administrative Report.

Topographic Work.—Geology of the Surface.—Paleozoic Formations.—Artesian Wells.—Forestry.—Drainage of Wet Lands.—Mining Industry.—Mineralogical Work.—Chemical Work.—Geological Museum.—Publications.

The Geological Survey has continued its work in the same general direction as stated in the last Annual Report. The several divisions are: Topographic Work, in charge of Mr. C. C. Vermeule; Geological Work on the Surface Formations and Physiography, in charge of Prof. Rollin D. Salisbury; the work in the Paleozoic Formations, in charge of Mr. Stuart Weller; the collection of Artesian-well records, in charge of Mr. Lewis Woolman; the preparation of Notes on Mining Industry, in charge of Dr. Henry B. Kümmel, who, as Assistant State Geologist, has directed the work of distribution of publications and the sale of topographic maps. He has also given some time to the stratigraphic examination of the limestones and slates in the northern part of the State.

The sales of the old series of topographic maps, which had been in charge of Mr. Irving S. Upson, and at New Brunswick, from their first publication to the end of 1899, are now made directly from the office of the Survey in Trenton.

TOPOGRAPHIC WORK.

The topographic work has been in charge of Mr. C. C. Vermeule, the Topographer of the Survey. He has been assisted by Mr. Peter D. Staats in the field and by Mr. J. R. Prince and Mr. W. A. Coriell in the office. The revision of atlas sheets, where new editions have been necessary, and the surveys for the new series of maps have been a large part of the office work, and the drawings for the large-scale maps has engaged the steady attention of Mr. Prince. The progress in the publication of the large-scale and suburban sheets has been pushed to meet the demand for maps covering the districts of city advance and growth. The work can be reduced next year so as to give more of the appropriation to the geological mapping and and the preparation of geological reports. Mr. Vermeule's statement is here inserted:

"The field work of the topographic survey during the past season has included some reviewing and perfecting of the forest surveys on the head-waters of the Passaic and elsewhere in Northern New Jersey, but has been mainly directed to the extension of the new topographic survey for publication on a scale of 2,000 feet to the inch. The latter survey has been extended over the eastern portion of Monmouth county from Asbury Park northward, to include the area covered by the Long Branch and Navesink sheets. On completion of this work in Monmouth county the Morristown sheet was taken up. This sheet covers the territory along the Delaware, Lackawanna and Western Railroad from Summit beyond Morristown, all of which has been re-surveyed, and the field work is now in progress in the neighborhood of Atlantic City. At the close of the field season the Atlantic City sheet will be nearly completed.

"For all the territory covered by these four sheets the changes since the date of the original survey have been extensive and important, owing to the rapid advance of these sections in population and public improvements.

"Good progress has been made in drawing, photolithography and printing during the year. The drawing has been completed for the Elizabeth, Plainfield, Mt. Holly, Woodbury and Taunton sheets, and the Amboy sheet is also more than half done. Of the above the Elizabeth and Plainfield sheets have been printed and published, and the Mt. Holly, Woodbury and Taunton sheets are in press, and will shortly be ready for delivery. When they are done we shall have published in all ten sheets of the new series topographic maps, covering 776 square miles of the land surface of the State. In addition to the above the surveys are made for 267 square miles, making in all 1043 square miles of land surface re-surveyed up to the present time. Several of the completed sheets extend beyond the State limits, so that the actual area of land and water surfaces covered is considerably greater. More than one-eighth of the State has, therefore, been covered by the new survey at the present time, but the part completed is the most difficult, and represents a larger fraction of the labor of a complete survey. Probably more than one-sixth of the entire field work is now done.

"We have now in hand the material for seventeen sheets of the new series, including those already published. Those for which the field work is virtually done, but which have not yet been prepared for the printer, are the following: New York Bay, Lower Bay, Navesink, Long Branch, Amboy, Morristown and Atlantic City, seven in all.

"The usual work of revision of the maps on the scale of one inch to a mile, the furnishing of working maps for the field geologist, and preparation of illustrations for the Annual Report have occupied a part of the time employed in topographic work.

"Mr. C. C. Vermeule has continued in charge of topography, Mr. Peter D. Staats has been field assistant, and the drawing for photolithography has been done by Mr. J. R. Prince, assisted by Mr. William A. Coriell."

GEOLOGY OF THE SURFACE.

The work in the study of the Surface Formations has been continued through the year by Professor Salisbury, assisted by Mr. G. N. Knapp. The field surveys and examinations have all been made, and the data obtained for preparing the report and making the geological maps. While the ground has all been gone over, there will need to be some further work by way of reviewing and putting things together in the light of all that has developed in the first survey. The preparation of the Report on the Surface Formations is in progress, and is well advanced. Professor Salisbury was in the field for two months, in the early summer, reviewing some of the questions bearing on the stratigraphic relations of the several subdivisions of these formations. Mr. Knapp has spent a large part of the season assisting in the compilation of data from the field notes for the report and for the maps. The publication will be in two volumes, one on the general geology, and with particular application to the northern part of the State in its descriptive notes of localities. The second volume may contain a full account of the geological history of the State, as represented by the several successive formations, which make the surface in the Piedmont and the Coastal Plains zones of the State, or the red sandstone, the clay and marls and the southeastern divisions. The geological map, on a scale of five miles to an inch, illustrative of the report in the first volume, is in course of preparation. In the southern part of the State it will show the general relation of the several formations, but will not include all details of the geology of the Coastal Plain. The sectional maps are outlined, and in the scheme for the State there are thirty-four sheets, which do not overlap as in the atlas of topographic maps, but meet edge to edge. The scale is the same—one inch to a mile.

The use of the new large-scale suburban sheets as the base for another series of geological maps is also planned. The large scale, one inch = 2,000 feet, makes these new maps particularly valuable for the better illustration of details in geologic features and the geographic location of mines, quarries, clay banks, marl pits, glass-sand pits, gravel banks, openings for peat, artesian-well sites and other localities of natural products of economic importance and value. Hand-books containing descriptive notes of the topographic features of these areas, of the geological formations and on the occurrence of valuable economic materials, accompanying these new suburban maps will be helpful to the students of local geology as well as valuable to all who are interested in mining, quarrying or working mineral deposits of industrial importance.

The new series of large-scale maps will make a valuable base for the illustration of the surface formations in detail and have a greater value for purely geological studies, but the surface formations are so closely related to the practical development of the natural resources of the State that these maps will probably have a greater use in agriculture, in road construction, in questions of park locations and other suburban and municipal improvements, than in working mineral deposits and in illustration of geological features or purely as geological maps.

The further study of the surface formations, particularly in the southern part of the State, and of the geological history of the State as represented in these formations, contributes to our knowledge additional proofs of the accurate subdivision which has been made, and of which the reports on the progress of the work have given somewhat detailed descriptions. The central and southern parts of the State have been undergoing large changes of level relative to the ocean, and there have been alternating periods of elevation and of subsidence. The extent of these submergences of land, as measured by the depositions of sands, clays and gravels, has been so large as to make large sounds in the central part of the State, leaving small islands in what is now the southern interior; and again, to bring the shore line much further northwest than the present sea border. Between these periods of depression there were elevating forces at work and the general altitude was probably greater than it is now, and the shore line was further to the southeast than at present. These interesting changes have been referred to by Professor Salisbury in his work on the Physical Geography of the State.* The full discussion will be given in the forthcoming report on the surface formations of the State. Appended to this administrative report, Professor Salisbury has a note on the subdivisions of the formations in the southern part of the State, which gives in a few paragraphs a sketch of the geologic history, the nature and extent of the alternate epochs of subsidence and of elevation and land erosion, descriptions of the materials deposited, and the correlation of these New Jersey terranes with formations to the southwest, in Maryland and in the District of Columbia.

PALEOZOIC FORMATIONS.

The survey of the formations of what are known to geologists as belonging to the Cambrian, Ordovician, Silurian and Devonian ages of Paleozoic time was begun last year, and the last

* Vol. IV "Final Report" Series, Trenton, 1898.

Annual Report had in Part I a preliminary notice of the rocks of Walpack Ridge, in Sussex county, and their characteristic fossil forms of life, and some notes on the Magnesian Limestone and on Cambrian fossils. Mr. Weller has continued his work, and has made a short report on the work of the year. He was in the field about three months. Dr. Kümmel was with him, studying the structural relations of the limestones and slates in the Kittatinny Valley and in Sussex, Warren and Hunterdon and Morris counties. All of the sedimentary rocks in this valley can be classified in four formations, viz.: Hardiston Quartzite, Kittatinny Limestone, Trenton Limestone and the Hudson River Slate. They are well-marked horizons, and the rocks are generally characteristic and easily recognized. In the earlier Survey reports these divisions were known by other names, for the first and second in the series; the third and fourth being the same. The geological map did not, however, show the extent nor define accurately the limits. The work of the year has been to trace out these limits, to find out the positions of the beds and their displacements by foldings and faultings, and to discover the marks of life in the fossil forms characteristic of them. The investigations of the structure have demonstrated the presence of many faulting planes and of great disturbances since the original deposition, and careful searches have revealed many localities where fossils occur.

The work already done adds largely to our knowledge of the geology of this part of the State, and has a great deal of data for making a geological map. The correlation of the formations with like beds in the Great Valley to the southwest and to the New York State series is probably correctly made out. More work will establish the relations on a basis of demonstration by the tracing of the formations and the comparative study of the rocks themselves and the life-forms in them.

The results are of importance in an economic view also, because of the value of the pure limestones for lime and of the argillaceous members in the series of limestone for cement manufacture. Dr. Kümmel has made a special study of the rocks which occur in the *cement* district, and has prepared a report on their geological relations and their occurrence.

ARTESIAN WELLS.

Mr. Lewis Woolman has been requested to continue the record of artesian wells and of deep-well borings, and he has again brought together many facts of interest and of value to all who are about to put down wells or are engaged in the business of sinking wells. The public interest continues in the subject and these yearly reports attract attention. The wells for the present report are as suggestive as any of previous reports in the geological facts which they reveal, and also in their successful discovery of water-bearing beds; they are valuable evidences of the great resources in water which exist in these deep-lying strata.

The records are arranged in geological order: 1. Wells in a zone nearest the ocean; 2. Near the Delaware river and bay slope; and 3. Wells in northern and central parts of the State. Practically, however, these groups of the southern part of the State are in the Miocene and in the Cretaceous areas and in the more recent surface formations. The Parkdale, Bridgeton, Vineland, Cedarville and Millville wells are probably all in the water-bearing sands and gravels of the Beacon Hill formation. These sands and gravels are generally open enough to permit the flowing of water through them, and are, therefore, water-bearing. There is a large area in the southern and southeastern part of the State, where wells either dug or bored can get an abundant supply of good water from these Beacon Hill formations. The location of these areas is already known, but the surveys are not yet represented on the published maps of the State. The new series of geological maps may be of considerable importance in showing the extent of water-bearing beds, their depths beneath the surface and their relation to water-supply. Where these porous sands and gravels lie upon the impervious chocolate-colored and astringent clays, the conditions are highly favorable for yielding large volumes of water. The records of the wells are not, however, in all cases conclusive evidence of the place of the beds of clays, sands and gravels in the geological series, and the references to their position is to be regarded as probable, but not demonstratively certain.

Five new artesian wells are reported in Atlantic City, 830 to 850 feet deep. All pass through the great diatomaceous clay bed and are stopped in the 800-foot water-bearing bed. The abundant supply of water whch is found at this depth in Atlantic City is of great importance, as it furnishes so much excellent water within practicable depth for individual domestic consumption. The multiplication of wells drawing from this horizon must have some influence finally upon the quantity of the water to be had from it and result in some interference and losses of supply, but so far no such interference of one well on another has been observed. The existence of higher water-bearing beds nearer the surface indicates additional available supplies of water by borings to these horizons. During the year steady progress has been made in a deeper boring on Young's pier, about 1,000 feet from the board-walk, and a depth of 2,000 feet has been reached in search for a water-bearing bed which shall give a flowing well. The results are thus far unsatisfactory.

The report summarizes the data concerning wells in Cape May, and notes two artesian or bored-well horizons of water, and the probable existence of two deeper ones, one of which appears to be at 350 feet, as shown by the well at Holly Beach, and the other, the extension southward of the Atlantic City 800-foot water-bearing beds. The boring of wells at Cape May to a depth of 800 or 900 feet will test the ground, and verify or disprove the presumption in favor of this lower water-horizon. The advantages of deep wells, giving a large flow of water, at Cape May City and in the southern part of the county, would be so great as to suggest the importance of putting down test borings in search of this deeper water-supply. The geological interest in deeper borings is great, on account of our ignorance of the stratigraphic relations of the Cape May peninsula, and need of more facts such as deep wells can give. The records of the Sewell's Point and Wildwood wells show that there is a diatomaceous clay bed in Cape May county which is not recognized north of it. The existence of later diatomaceous clay beds in this southern peninsular part of the State, and above the Miocene diatomaceous clay bed consists with the theory of its later origin and of its recent geological age. The wells at Cape

May City have a historic interest, in that they were the first which were put down on the Atlantic coast side of the State, and the record of cedar stumps so deep beneath the surface was regarded as suggestive of the recent origin of this peninsula of Cape May.

The well records from the lower valley of the Delaware, at Fort Mott and Fort Dupont, Delaware, indicate a remarkably thick clay and sand series of beds, which are probably of the Raritan Clay Formations. These records, however, agree with some wells bored in Burlington in showing a greater thickness of clay than to the northeast, in the Woodbridge and Amboy clay district.

In the record of the second deep boring at the League Island Navy Yard the rock is found to be 260 feet below the surface, and is overlain by clays, sands and gravels of the Raritan Formation. The fresh-water and marine diatoms in the overlying mud represent the later formations of an older river, but with a broader channel-way than that of the Delaware. The well at the foot of Penn street, Camden, also struck the rock, but at less depth—only 76 feet.

The geological structure is the key to the water-supply question where the artesian-well system is used, showing the place of the open or porous beds and their relation to the impervious beds. In the southern part of the State these water-bearing beds make the horizons where water is found, and determine the depth of the wells. The sands and gravels in the Beacon Hill formations; the sandy beds in the Greensand Marl series, and in the Raritan Clay Formations; the sand bed under the great diatomaceous clay bed at Atlantic City are all more or less water-bearing and horizons of artesian-well sources. In the central part of the State the more sandy beds of the Newark system of rock, or the Red Sandstone belt, afford water, but position is not always located from the surface outcrops. The glacial drift of the terminal moraine and the stratified sands and gravels of the overwash plains near it afford abundant volumes in wells at Plainfield and Netherwood and eastward to Springfield and Perth Amboy, and also near Chatham and Madison. These wells in the drift beds are all comparatively shallow, few being more than 200 feet deep. The wells in the red sandstone are generally deeper, but no water-horizons are as yet recognized. There are many wells in the valley of the Passaic from Paterson south to Newark, and particularly in the vicinity of Passaic and in the city of Newark, which supply large manufacturing establishments and individual home consumption. The borings in the sandstones and shales at the base of the Palisades range and in Jersey City and Hoboken have not all been successful in getting the desired supplies of water. The trap-rock of the Palisades Mountains also has been barren of a water-supply. Further study of the borings for water in the red sandstones and shales and in the trap-rocks, after more wells have been put down, will no doubt enable us to locate the depth of the water-bearing beds, and indicate the localities and depth of wells.

The new wells reported from the Highlands and from the limestone and slates of the valleys in the Highlands and of the Kittatinny Valley do not offer great hopes of getting large quantity of water from either the crystalline schists or the sedimentary limestones and slates, although the many springs of excellent water in the slate hills, as well as in the gneissoid rocks, would lead to the belief that wells bored in such geological formations would yield water in large quantity. The absence of excessive volumes of water in the iron mines generally, indicates that there is not so great quantity of water as to justify boring wells in order to get a large flow.

FORESTRY.

The work in Forestry during the year was limited to the publication of the Report on Forests, which was ordered printed as a part of the Annual Report for 1899. From the applications for this report, and from the letters which have been received bearing on the subject, and making inquiry about timber tracts and supplies of lumber to be had in the State, it is evident that there is a growing sentiment in favor of protecting our forests against fires and of the judicious care and scientific management of forested lands so that they may produce crops of wood of value and remunerative to the landholder. The want in these directions appears to be great, and to be an urgent call for State help in protection and in the education of foresters who may be able to take the management of forests. The province of the Survey in this direction is to indicate the lines of work to be done and to suggest State help and to give information to those interested in these lands. The report just published is full of suggestions in regard to the need of protective measures against fires, and hints as to possible means which are available, and describes the great forested districts where they are needed urgently and at once. The areas which may be devoted to forest reservations also are mapped, and their geographic and topographic features are shown, with the location of forests. In the Highlands of northern New Jersey the maps show the forests and their topographic relations and the water-sheds of the several large streams issuing from this district, and their location with particular reference to the cities which may probably get their supply from these Highlands' stream.

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 differences 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 landholders 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.

FOREST RESERVATIONS.

In the Report on Forests it was said in reference to forest fires and their ravages that "some system of protection must be adopted if ever these terrible forest fires are to be stopped," and also that "in the southern part of the State the necessity of public protection is imperative if there is to be any production of timber or lumber in that part of the State."* Any system of protection against forest fires to be thoroughly effective must be under the control of the State, and a forest system with State control necessitates either State ownership or the relinquishment of rights of private ownership, which is not to be expected in our country. The great pines district of Southern New Jersey is a compact body of timbered lands which would make a valuable State forest reservation. Its importance as gathering ground of an abundant supply of excellent water for the public use in the seaside cities and settlements, and in the towns in the interior and on the Delaware river was discussed by Mr. Vermeule in a report on the Pine Belt of Southern New Jersey, and Water-Supply, published in the annual report for 1898. The problem of water-supply is paramount; that of forestry and forest management subordinate in importance, but under an efficient system of control and with State ownership these woodlands should become valuable in producing pine and cedar lumber and other forest materials, and eventually should be self-supporting. The imponderable assets in the tonic effects of the pine woods and in the benefits of their winter health resorts are not to be neglected in this consideration of values and incomes. The opportunities for the creation of large game preserves and of private parks (under certain restrictions) in these oak and pine lands also may be here noted as of great possibilities in the way of game and fisheries.

Reference to the Highlands, the Kittatinny Mountain and to the Palisades Mountain range as sites for State forest reservations has been made in our annual reports and in the Report on Forests, and the location of the forested lands has been shown on the maps accompanying these reports. The large cost of the land

* Report on Forests, 1899, p. 11.

on the Palisades and in parts of the Highlands would perhaps make it impossible for the State to acquire large holdings in compact areas, suitable for State reservations. On the Kittatinny Mountain the land is less valuable, forest fires are common and protection is wanted, such as might be had through the ownership by the State and the creation of a public forest reservation.

On this question of forest reservations it is well to repeat what was said in the Report on Forests, "The control of the forests by the State is a subject of great public importance and demands the careful study of the wise legislator, in order to avoid the error of excessive paternalism in government on the one hand and the reckless and riotous excesses of individual liberty and license on the other side."

DRAINAGE.

The drainage laws of the State provide that "on the application of at least five owners of separate lots of land, included in any tract of land in this State, which is subject to overflow from freshets, or which is usually in a low, marshy, boggy or wet condition, the Board of Managers of the Geological Survey is authorized to make surveys of such tract or tracts and to submit a plan of drainage to the Supreme Court of the State, by whom commissioners may be appointed to carry into effect the work of drainage in accordance with the provisions of said plan of the Geological Survey." The general drainage laws apply to both salt marshes and to fresh-water meadows.

The subject of the improvement and reclamation of wet and drowned lands has received a large share of attention from the Board of Managers of the Survey, and the annual reports have contained many descriptive notes of tracts of wet lands and arguments for their improvement or reclamation. The drainage of the wet lands in the Pequest Valley, in Warren county, was an example of successful work under the provisions of the law and following the plan prepared by the Survey. The work in the Upper Passaic Valley, referred to in the last report, has lain dormant for want of the necessary funds to carry it forward to completion. The large expenditure of money (which was raised by the sale of bonds) in removing the reef of rock at Little Falls and providing a free passage for the flood waters below the Beattie dam, left nothing for the continuation of the work in the removal of the reef above the dam and of the bar at Two Bridges. A large part of the work, as indicated in the drainage plan, remains to be done before there can be any benefit to the agricultural lands in the valley or any improvement of the general sanitary conditions. The prevalence of malarial disease in the wet-meadow districts and the mosquito-breeding, stagnant pools of water, which favor the further transportation of malarial poison, are strong arguments for the effective drainage of these lands, and having a much wider significance and more important bearing than the enhanced agricultural values resulting from the drainage. The burden of the expenses necessary to finish the work will be heavy, and more than many of the farmers owning these wet lands can bear, equivalent to a confiscation of their holdings. Inasmuch as the benefits will probably reach beyond the immediate limits of the drowned or wet lands, promoting the healthfulness of the whole valley, it seems as if in a proper adjustment of the assessments of the cost some of the adjacent lands and the municipalities immediately affected also might share in bearing these assessments.

The Passaic drainage has been referred to at length in our annual reports, so that it is unnecessary to do more than call attention to the condition of the work, the arguments for its completion, and also the difficulties in the way. It should here be stated that the benefits of the work will be had only after the completion of a thorough drainage system, which shall include lateral ditches and their tributary drains, so that in times of flood there shall be ample water-ways and a rapid discharge of the flood waters through a net-work of ditches and channel-ways. So flat a surface as these meadows must be treated as that of the polder-lands of the Netherlands.* The opening of the main channel of the river by the removal of the obstructions is a part only of the work to be done. The failure in the Pequest Valley drainage to draw off the water from the borders of the meadows and at the sides of the valley and to realize the full benefits of the lowering of

*See An. Rep. of State Geologist for 1902, pp. 331, et seq.

the river channel is due to a lack of lateral canals and drains, and emphasizes the necessity for ample provision for complete drainage in the case of the Passaic Valley. The maintenance of these open ditches and of the deepened main channel may make necessary some permanent control by the associated authorities or by the State.†

THE MINING INDUSTRY.

The metalliferous ores of the State are practically limited to iron, zinc and copper. Lead and silver occur, but there are no lead mines now worked, and silver is not known to occur in quantity to make it a possible metal to be won by mining. The occurrences of arsenical and nickeliferous ores are of mineralogical importance only and no veins or deposits of such ores of any workable extent are known.

The iron mines continue to produce large amounts of rich ore and to maintain the place of the State in the rank of iron mining.

The total output for the year was 342,390 tons and 73,000 tons in excess of that of 1899. This aggregate includes 10,000 tons of concentrates produced at Edison.* The total shipments, as reported to the Survey by the carrying companies, is 39.057 in excess of the amount shipped in 1899. Referring to the tabular statement on page 216 of this Report, it will be noted that the production has been increasing since 1896, and that the year's output is larger than that of any year since 1892. Among the more notable facts reported is the continued working of the Hurd Mine at Hurdtown, and the search for other large shoots of ore like that which was worked for so many years. The valuable statistics of the Richard Mine so kindly furnished the Survey by Mr. B. F. Fackenthal, and given on page 200, make an interesting exhibit of steady working, the rapid increase in the yearly output and the grand total and the undiminished capacity of this remarkable iron mine.

† An. Rep. State Geologist, 1893, pp. 14-15.

* The table on p. 216, in its total of 407,596 tons, includes 75,206 tons of crude material See p. 206.

The re-opening of the mines at Mount Hope by the Empire Steel and Iron Company, once so large producers of iron ore, is evidence of an advance in the mining industry of the State and of confidence in our iron-ore mines as good business enterprises.

The change in the ownership at Hibernia and the control of the whole of the Hibernia iron-ore range by Mr. Joseph Wharton marks a concentration of management which must produce a more systematic and far-reaching plan of working and a thorough exploration of the ore-shoots, both in depth and to the northeast, on the strike of the ore *vein*. It is a most-to-be desired condition that this long range of ore, remarkable for the regularity of the dip and the *pitch* of the *shoots,* may be so worked and tested that we shall secure much additional information regarding the nature of the rock walls, the form and extent of the *ore-shoots,* and the structural relations of the several shoots, one to another, and to the adjacent country rock. Important suggestions bearing upon the questions of the age and origin of the iron-ore beds in the Highlands region and valuable hints of great help to those who are working on such iron-ore shoots elsewhere in this part of the State are looked for in the further systematic development of this great iron-ore range.

The geological studies in the Highlands, and particularly in the iron-ore mines, will no doubt find in the deeper and longer workings of these old historic mines a great many facts about the mode of occurrence of the ore, in verification of the descriptions which have been given in the "Geology of New Jersey," and in the later publications of the Survey, and probably many others, illustrating in detail and making clear the obscure and unknown in the complex structural relations of these iron-ore masses.

COPPER MINING.—Work in further exploitation of the copper-ore-bearing beds, in the foot of the mountain near Somerville, has been continued during the year, and the mine has been opened to permit of working on a large scale. The finding of native copper in the deeper slopes and drifts, and replacing apparently the oxide and carbonate near the surface, is new in the history of copper mining in New Jersey, and is noteworthy and suggestive of richer ore beds at greater depths than any yet reached. The steady following of the ore beds and the systematic opening by slopes and drifts have developed a mine capable of producing a large amount of ore.

The experiments in the concentration and in the leaching of the ore have taken shape in the erection of a small metallurgical plant.

The development of the mine will be awaited with interest by the owners of copper-ore property elsewhere in New Jersey. The re-opening of other copper mines in the red sandstone and trap-rock district of the State is made probable by the success of this Somerville mine.

The construction of the large plant at North Arlington and the re-opening of the famous old Schuyler Mine mark an era in the history of this mine. The results of the developments in mining and in the metallurgical treatment of the ores will be important in testing the practicability of working successfully the lean copper ores of the Middle Atlantic States when most favorably situated for cheap and easy transportation of materials and near markets.

MINERALOGICAL WORK.

Two excursions have been made during the year for the purpose of collecting minerals, and also for a thorough examination of known localities, and in search of minerals new to the State or hitherto unknown in these localities. They have been under the direction of Professor Albert H. Chester, and the parties in the field have been Andrew Manley and W. S. Valiant, of New Brunswick. The examination has been in Sussex and Warren counties and along the Jenny Jump Mountain and at Andover and Roseville. The results of these field trips are collections of minerals for addition to the general collection of the Survey and material for use in making exchanges and for distribution in the State as may be desired to State institutions and schools. The mineralogical species new to the State are six in number, and, among others, are Jamesonite and a new hydrous dolomite.

CHEMICAL WORK.

The chemical examinations necessary for the proper studies and investigations of the Survey have been continued by Prof. William S. Myers, of New Brunswick. The subjects of chemical work have been the investigation of the chlorine in the natural waters of the State; the analyses of minerals in order to determination of species, and miscellaneous assays and analyses of economic natural products. These lines of investigation are really the same as made last year, and are, therefore, continuation of the chemical work which was begun in 1899. A new subject of study, taken up during the year, is the examination of the limestones and slates of the Kittatinny Valley, in Warren and Sussex counties.

The mineralogical studies are referred to and the analyses are given in the report of Professor Chester. The importance of chemical work in the determination of mineralogical species is shown by the chemical composition of the minerals and by the absence of distinctive physical marks or characteristics, as stated in Professor Chester's report.

The value of the chlorine determination in the natural waters of the State was mentioned in the report for 1899. It may be repeated here that the amount of the chlorine in the natural waters of any given locality and the isochlor map of the State, showing the areas of equal chlorine content, are of vital importance as a guide to the examination of waters which are suspected as being contaminated by sewerage liquids, and, therefore, dangerous for public water-supply or private use. The results of the examinations made during the year, with those of last year, serve as basis for a map of the State which shows the range in the amount of chlorine in natural waters. The large amount in the spring and stream waters near the ocean and the lesser content of chlorine, going away from it, westward and northwest, to the Highlands and the Kittatinny Valley and the valley of the Upper Delaware are worthy of the attention of chemists and of all who have occasion to inquire about the composition of waters and their use for public and private supplies as drinking water. These figures of chlorine become a guide to the normal amount of chlorine which is to be looked for in the water of any given locality. An excessive amount found in a water is at once an index of some source of pollution, and of danger to health in its use for the household. The examination for chlorine has gone far enough to indicate the amounts normal in the several great districts of the State, but not far enough to enable us to make an accurate map showing chlorine content of waters. Further analyses will be necessary to make a detailed report, including all the sections and subdivisions of these great natural divisions and an isochlor map of the State.

The analyses of limestones and shales which have been collected by Dr. Kümmel in the course of his studies of these rocks of the Kittatinny Valley, have been made to determine the occurrence of pure limestones and the extent of dolomitic limestones and the relation of these rocks to one another, and the possible gradation between these dolomitic or magnesian limestones and the pure limestones. The results of the analyses confirm the field work in the large increase in the number of localities where pure limestones are to be found, and their wide distribution in the Kittatinny Valley.

The analyses of the limestones which are used in the manufacture of Portland Cement at the several cement works in the Musconetcong Valley, near Phillipsburg, and northeast to Stewartsville, show the chemical composition of stone which is thus used, and a comparison of these analyses with those of rocks of like appearance and of similar geological relation, elsewhere in this Kittatinny Valley, in Warren and Sussex counties, is evidence of the wide range of rock which may be used in this industry. The economic importance of these chemical examinations of the limestones, and of their nature and composition, is such as to emphasize the attention of the readers of this report to the results as they are given by Dr. Kümmel in Part II.

GEOLOGICAL ROOMS.

The State Museum continues to attract many visitors and to serve as an educational agency in giving information about the natural products of the State. During the year the additions have been mainly collections of ores and rocks made in the course of the geological work by Dr. Kümmel in the northern part of the State, and of fossils from the limestones in Sussex and Warren counties collected by Mr. Weller. They are now being studied by him, and the fossil forms of life, when properly labelled, will illustrate the nature of organic life in the seas when these rocks were deposited. Among the Paleozoic fossils there will be some types illustrating descriptions of new species or of new varieties.

The additions of minerals to the Museum collections consist of many specimens from the Jenny Jump Mountain range, from Marble Mountain on the Delaware, and Andover and Roseville in Sussex county, collected by Mr. John Manley and Mr. Wm. S. Valiant under the general direction of Prof. A. H. Chester, of Rutgers College, who has studied carefully the specimens and had them all labelled.

The collection of Hoboken minerals from George F. Kunz has been sorted and labelled by Professor Chester and placed in the storage rooms of the Survey. It contains many duplicates of value for exchanges.

MUSEUM.

The arrangement of the exhibition cases remains as it was last year, and few specimens have been placed in the collections as arranged in the room.

A collection of 436 minerals has been purchased for the illustration of the species as described in Dana's Mineralogy, and it is proposed to place them on exhibition as soon as possible. The value of a synoptic collection may be understood by reference to the collection of New Jersey minerals, and particularly to many species which are not represented in the State collection. By the exhibition of these minerals the relation of the species to the localities here represented from the State will be understood and the true mineralogical association be better appreciated than is possible by local collections only.

The gift of 50 species of woods from the southern part of the State by Benjamin Heritage, of Mickleton, Gloucester county, is a valuable contribution. The notes of Mr. Heritage as to locality and condition of tree growth, which are given with the specimens, make them still more valuable as representing typical tree growth in that part of the State.

Fourteen specimens of woods were given by Charles D. Lippincott, of Swedesboro, at the request of Mr. Heritage. An interesting fact in this work is the occurrence of a grove of hemlock (*Tsuga Canadensis*) on Salem creek, below Sharptown.

It is desirable that an equally large collection of woods be had from the northern part of the State for completing the tree flora and for comparison of specimens from so diverse conditions of geological formations and general habitat.

The new extension of the State House affords room for the Museum in the third story, where the space on floor is nearly twice that of the existing room, and where the windows on each side and at the end and also skylights in the roof give ample openings for the inlet of light for the exhibition of the collections. The removal to the new room is to be made as soon as it is ready for the material, and probably early in the winter. Under good light, and with ample space and in new cases, the State collections can then be seen readily and can be studied advantageously by all who are seeking information about the natural products of the State. A synoptic collection of minerals and the collections of minerals from localities in the State, and representative of the ores, marls, clays, building stones and fossils, will make a useful museum.

PAN-AMERICAN EXPOSITION.

Application for an appropriation for the expenses of making an exhibit at the Pan-American Exposition, to be held in Buffalo next year, has been made to the Governor and the Commissioners for the State. It is proposed to put in this exhibit of the Survey the geological and other maps which have been published, including the two series of topographic maps and relief maps of characteristic topographic features of areas: 1, stratified drift at Newton and vicinity; 2, of the drift at Ogdensburg; 3, of the Hamburg drift banks, and of the terminal moraine at Hackettstown, and of districts on the Atlantic slope and on the Delaware river side of the State. These relief maps or models, on a large scale, will show some of the more characteristic features of the surface as seen in different parts of the State and as determined by geological forces.

Collections of metallic ores, building stones, limestones, cement rocks, clays, marls, sands and minerals of use in the industrial arts are to be made to exhibit the natural resources of the State. A mineralogical collection will show the large number of mineral species to be found in the State. The additional material to be collected for the Exposition may be a large part of the whole exhibit, and be of much value in filling gaps in the collections which are now in the Geological Rooms.

PUBLICATIONS.

The publications of the year have been the Annual Report for 1899, and the Report on Forests, the former an 8 vo., containing xliii + 192 pages; the latter, xvi + 327 pages, illustrated with a State map, showing the density of the forests, and a six-sheet map, showing the forests and their relation to the topographic features and the water-sheds of the northern part of the State. These reports have been distributed to the libraries of the State and of the country generally, and to many individuals. The applications for the Report on Forests continue to be received, and indicate an increasing interest in the cause of Forestry here as well as generally throughout the country.

The maps of the new series published are the following-named sheets: Camden, Elizabeth, Plainfield, Woodbury, Mount Holly and Taunton.

The demand for the maps on large scale is proof of the want filled by them and of their usefulness. There is also a renewal of interest in the older series of the Atlas of New Jersey, and the sales are in evidence of the appreciation of both the old series and of the large-scale new maps. The sales are attended to here, and on application at this office. The sheets are sold at a uniform price of twenty-five cents and are sent free of further charges to the applicant. The price barely covers the cost of paper, printing and mailing or express charges. The aggregate sales of the year exceed considerably that of 1899.

The Surface Formations in Southern New Jersey.

ROLLIN D. SALISBURY.

The Annual Reports for 1892, 1893, 1894, 1895, and 1896 contained statements concerning the progress of the work on the surface formations of the southern part of the State. In the first of the reports mentioned, the suggestion was made that the "yellow gravel" was probably not one formation, but three. In the following years Mr. Knapp gave some time each season to the detailed mapping of these formations, and the study of their general relations was continued by myself, in connection with the detailed work of Mr. Knapp. As the work progressed, it became evident that the southern part of the State had had an even more complex history than was at first conjectured, and modifications of the classification first suggested were found to be necessary. In 1897, when the detailed work of Mr. Knapp was well advanced, a classification was proposed which seemed to cover the principal stages in the post-Miocene history of that part of the State which is often known as the Coastal Plain. This classification now seems to be applicable, in its essential features, to the Coastal Plain farther south. It is in essential harmony with the classification proposed earlier for the District of Columbia, though the names which had been applied farther south were not used in New Jersey, since the relations of the northern formations to the more southern had not been established.

There seems to be occasion at this time for re-stating in brief terms the general conclusions which have been reached, and for adding a few words concerning the correlation of the several formations. At the same time it should be said that the final report on the geology of this part of the State is not yet published, or ready for publication. The surface has been studied in detail by Mr. Knapp, and his manuscript maps and accompanying reports are essentially done, but before maps or reports are published, both will be reviewed in the light of all the knowledge which has been gained in the prosecution of the work.

The classification proposed in 1897 recognized four principal stages of deposition within the non-glaciated area of the State in post-Miocene time, and the separation of these four stages from one another by epochs of erosion. During the epochs of deposition, the surface of the southern part of the State was lower than now, relative to sea level, but the extent of the submergence in the several epochs was successively less as the present time was approached. During the epochs of erosion which intervened between those of deposition, the land was higher, relative to sea level, than during the epochs of deposition, and at times at least, it was somewhat higher than now.

The four epochs of deposition are represented by four formations, which, commencing with the oldest, have been described under the following names: 1. The Beacon Hill formation (pre-Pleistocene); 2. The Bridgeton formation, now regarded as earliest Pleistocene; 3. The Pensauken formation or mid-Pleistocene, and the Cape May formation, or late Pleistocene.

The Beacon Hill Epoch and Formation. The Beacon Hill formation has never been certainly differentiated from the Miocene. If it be Miocene, it represents the deposits of the last part of that period. No unconformity between it and the known Miocene has been demonstrated, and in the present state of the formations and their exposures, is probably not demonstrable. The formation often consists of two parts, a gravel member above, and a coarse sand member below, though these two divisions are by no means hard and fast. Locally it contains beds of clay. The hypothesis has all along been entertained that the lower part of the formation may be Miocene, and the upper part younger.

Both gravel and sand are essential quartzose. The gravel contains, in addition to quartz pebbles, much chert and some hard sandstone and quartzite. The gravel is generally not coarse, but it now and then contains large cobbles. It is coarser to the north, nearer the old shore line, and becomes finer to the south. The formation has nowhere been seen to contain water-worn pieces of ferruginous conglomerate or sandstone, such as might have been derived from the cemented layers of the Cretaceous formation. Its original northward extension is not known, but it probably reached the Sourland and Watchung Mountains.

The general distribution of this formation was outlined in the

Report for 1897, in which a small *preliminary* map, from which many details were necessarily omitted, was published.

After the deposition of this formation, there was uplift of the land, or sinking of the sea level, resulting in the emergence of much or perhaps of all of that part of the State which this formation covered. There followed a prolonged period of erosion, during which much of the northern part of the Beacon Hill formation, especially north of the present Miocene area, was carried away by erosion, the material being deposited chiefly in the sea, but probably subordinately, especially in the later part of the erosion interval, in the valleys of the land as well. The position of the shore line during this interval of erosion is not known, but it was probably well east of the present coast for a considerable distance south of Raritan Bay.

The Bridgeton Epoch and Formation. Later, there was another period of submergence, due either to the sinking of the land or to the rise of the sea level, letting the sea in over much of the area which had been land. The submergence was probably slow, but when it reached its maximum, there was a broad sound between Raritan Bay and Trenton, and south of this sound all that remained above the water was a series of islands, some of which were large, but most of which were small. South of the islands lay the open sea, which extended well up the Delaware Bay to some point above Trenton. The extent of the submergence of the land, at its maximum, was such that the larger part of the State, which is now 200 feet and less above the sea was beneath the water.

Over the submerged area deposition was in progress. The sediments were derived partly from the islands which remained above the water and partly from the main land to the north and west. The sediments were brought to their position of deposition partly by the waves of the sea and partly by rivers.

The sediments deposited during this submergence constitute the Bridgeton formation. It differs from the Beacon Hill formation in being more heterogeneous, both physically and lithologically. Bowlders of large size are of occasional occurrence, and from them the material ranges to sand. Gravel and coarse sand predominate. The formation contains materials which appear to have been derived from the Beacon Hill, the Miocene, the Cretaceous, the Triassic, and the Crystalline schist formations, and below the mouth of the Schuylkill, from certain Paleozoic formations as well. The proportions of material from these various sources vary notably in different localities.

The material from the crystalline rock is usually decayed, small pieces completely, and large bowlders deeply. Among the bowlders are some of soft shale and sandstone from the Triassic formation, which could hardly have stood transportation to their present position except by the help of floating ice. The large bowlders, the bowlders of non-resistant rock far from their sources, the association of bowlders with fine material, and the great amount of material derived from the crystalline formations far to the north, is taken to mean that when the formation was in process of deposition, glaciation was in progress to the north, and that the rivers coming down to the sea were laden with material borne out from the ice by its melting waters. The ice may have reached the sea (sound) in the eastern part of the State.

In the report of 1895 the question of the separation of this formation from the Pensauken was raised. In the report of 1896 it was stated that two should be regarded as different, and the suggestion was made that what is now regarded as the Bridgeton formation might perhaps belong with the Beacon Hill formation; but in 1897 it was separated from the Beacon Hill formation, as it had been from the Pensauken before.

Following the deposition of the Bridgeton formation, there was uplift of the land, or withdrawal of the sea, and the newly deposited beds, as well as all others above the sea, were subjected to erosion. During some part of this epoch of erosion the land was at least as high as now, as shown by the depth of the valleys excavated at this time. This interval of erosion was long enough to allow of the removal of much of the Bridgeton formation north and west of the present outcrop of the Miocene. The amount removed farther southeast is less easily determined. The eroded material, together with that from other formations suffering erosion at the same time, was largely carried to the sea, but subordinately, especially in the later parts of the epoch, some of it was probably deposited in the valleys of the land.

The Pensauken Epoch and Formation. Submergence followed, and that part of the present area of the State which has an elevation of less than 130 feet was under water. The water may, at a maximum, have reached somewhat higher. For the second time a sound stretched across the State from Raritan Bay to the Delaware at Trenton, and south of it, as in the Bridgeton epoch, were islands large and small. In the waters of this sea, and to some extent in the low lying valleys of the land, deposition was in progress. The same formations which yielded materials for the Bridgeton were again laid under contribution, and to their number the Bridgeton formation itself was added. In this stage, as in the preceding, the waters flowing into the sound from the north seem to have brought the products of glaciation, but they belonged to a glacial epoch which antedated, by a long period of time, that during which the Perth Amboy-Belvidere moraine was made.

The formation made at this time is the Pensauken formation. Under this name the Bridgeton, as well as the Pensauken, was included, before the two were differentiated (1895 and earlier). This differentiation was first made in Burlington county, but when the *preliminary* map accompanying the Report of 1897 was published, the separation of the two formations had not been attempted in Monmouth county. No work has been done in that county since the differentiation of the two formations was made; but from the time the differentiation was effected in Burlington county, it has been recognized that Monmouth county would need to be re-studied with this subdivision in view. It is certain, however, that the differentiation in some parts of Monmouth county will be difficult, if possible, and the same will be true in the pine belt. In both these areas of difficulty the two formations, if present, are not clearly differentiated in their topographic distribution. In both areas the base of the Bridgeton, if it is present, is often well below the top of the Pensauken.

So long as the Pensauken and Bridgeton formations were regarded as one, certain difficulties in its topographic distribution were recognized, and crustal warping was suggested as the explanation. The separation of the two formations made this suggestion unnecessary, or, at least, unnecessary to the extent which had hitherto been supposed.

Following the deposition of the Pensauken formation, there was another period of uplift (or sinking of the sea level) when the altitude of the land was comparable to that of the present time. The rise was doubtless gradual, and at its maximum may have exceeded somewhat the present stand of the land. Erosion accompanied and followed the rise. Again the eroded material was carried to the sea, but in the latter stages of the period more or less of it was deposited on the land which had been brought low by erosion. The interval of erosion was long enough to allow of the removal of much of the Pensauken formation in areas favorably situated for erosion.

Cape May Epoch and Formation. At a later time there was a slight submergence to the extent of 40 to 50 feet below the present stand of the land. During this time deposition was in progress along some parts of the coast, as in the Cape May peninsula, and erosion in others. Deposition was also in progress in many of the valleys which were not submerged. The deposits of this stage constitute the Cape May formation.

This stage of deposition is believed to correspond measurably with the last glacial epoch, or possibly with its later stages. It may have continued somewhat after the ice retreat began. Since the deposition of the Cape May formation there has been elevation of the land, or sinking of the sea level, and the land has stood somewhat above its present level. Still more recently, subsidence has been in progress, and is, perhaps, now going on.

Correlation. The Beacon Hill formation, or, at least, the gravel portion of it, is very likely the equivalent of the Lafayette formation (McGee and Darton) farther south. This is undemonstrated, and in the present fragmentary condition of the formation is hardly demonstrable. The Bridgeton is believed to be the equivalent of what has been described in the District of Columbia (McGee and Darton) as the Earlier or High Level Columbia, and in Maryland (Shattuck) as the Sunderland formation. The correlation of the Bridgeton with the Lafayette was suggested, but not affirmed, in the report of 1897. The Pensauken formation is believed to be the equivalent of the Later or Low Level Columbia of the District of Columbia, and of the Wicomico of Maryland. The Cape May formation has not been recognized in the District of Columbia, and in the immediate vicinity of Washington, at least, it has little, if any, development. The equivalent of this formation has been recognized in Maryland under the name Talbot.

In the way of this correlation, there seems to be one difficulty. Locally, at least, the Pensauken has suffered more extensive erosion than the Later Columbia farther south, and the Bridgeton more than the Earlier Columbia. On the other hand, the Bridgeton has not suffered erosion to an extent comparable with that suffered by the Lafayette. An alternative interpretation of certain areas in New Jersey has recently been suggested by Dr. Shattuck, who is working on the corresponding formations Maryland. This interpretation, if it proves to be correct, will relieve this point of difficulty, though it will involve others.

In addition to the above formations there is a widespread loam, or series of loams, the age and relations of which are not satisfactorily accounted for in the preceding classification. This loam was at one time described under the name of Jamesburg, but this name was dropped some years since, because of doubt of the unity of the loams originally grouped under it.

The loams in question affect not only the coastal plain, but parts of the Triassic area to the north, and parts of the glacial drift as well. If they all belong together, and constitute a formation in any proper sense of that term, it is a post-glacial formation, or a formation which dates from the closing stages of the glacial period. Locally, the loam overlies the Cape May formation, and seems to be continuous above it over older formations, to an elevation of 150 feet or more. With interruptions, it occurs at still higher levels. No definite upper limit has ever been found to the loams here referred to, but they seem to run up to levels beyond 200 feet, and to fall short of 300. On the whole, the loam is better defined at low levels than at high, though to this general statement there are exceptions. Locally, it seems to be clearly marked off from its sub-stratum, but much more commonly it is not, and it is often wanting altogether. The hypothesis that the loams are a unit, and that they represent a brief post-glacial (Cape May) submergence, is entertained as a working hypothesis, and much may be said for it, as well as against it. If it be true, many minor phenomena of the glaciated area, other than the loam itself, would be explained. They are not, however, of such a decisive character that the hypothesis of submergence can be said to be demonstrated by them. The hypothesis is also entertained that these loams may be of various ages and origins, and that they do not constitute a formation in any proper sense of the term. Neither of these hypotheses has been out of mind at any time in the progress of the work. The former has, perhaps, sometimes been too boldly stated.

PART I.

A Preliminary Report on the Paleozoic Formations of the Kittatinny Valley in New Jersey.

By STUART WELLER.

A Preliminary Report on the Paleozoic Formations of the Kittatinny Valley in New Jersey.

BY STUART WELLER.

All the sedimentary rocks of the Kittatinny Valley in New Jersey are of Cambrian and Ordovician age. The formations into which the entire series can be differentiated are but four in number, and these will be discussed in order from the lowermost up.

Hardiston Quartzite.—This formation was called the Hardistonville Quartzite by Wolff and Brooks,* but an abbreviation of the name to Hardiston seems desirable. The formation is exceedingly variable in thickness and in lithologic character, ranging from a coarse arkose rock to a fine-grained sandstone containing a considerable proportion of calcareous matter. A detailed description of the physical characters of this formation may be found in Dr. Kümmel's report, published elsewhere in the present volume.

The age of this quartzite has been well established as Cambrian. Beecher † first found Cambrian trilobites, belonging to the genus *Olenellus*, in the formation at Hardistonville, and later Foerste ‡ discovered additional fossil localities, *Olenellus* being the most conspicuous form in all cases. During the past field season several additional fossil localities have been discovered, one at the foot of the mountain east of Tranquility, another at Oxford Furnace, and a third in the railroad cut at Washington. In all cases the genus *Olenellus* was the commonest and almost the only recognizable genus. The observa-

* 18th Ann. Rep. U. S. Geol. Surv., pt. 2, p. 442.
† Ann. Rep. State Geol. N. J. for 1890, p. 49.
‡ Am. Jour. Sci. (3), vol. XLVI, p. 438.

tions of the past season lead to the conclusion that wherever this formation is a fairly fine-grained sandstone with a considerable proportion of calcareous material, fossils can be found more or less abundantly in the rusty-brown weathered portions of the rock.

Kittatinny Limestone.—Overlying the Hardiston quartzite, and usually not sharply separated from it, is the great magnesian limestone series of the Kittatinny Valley, to which the name Kittatinny limestone may be applied. No accurate estimate of the thickness of this formation can yet be made, although the field observations of Dr. Kümmel during the past season indicate that it must be twenty-five hundred feet or more.

In the course of a reconnaissance during the field season of 1899, a single fossil locality, near Carpentersville, was observed in the Kittatinny limestone. During the past season a large portion of the time was spent in an almost fruitless search for fossils in this formation. Only three additional localities of note were discovered. The first of these, at Newton, has afforded a considerable fauna of trilobites and brachiopods. A species of *Dikelocephalus* is the commonest member of this fauna, indicating the upper Cambrian age of the sediments at this locality. Another locality near Blairstown afforded a large number of cranidia, free-cheeks and pygidia of trilobites, belonging, however, to but a small number of species, all of which indicate the Cambrian age of the beds in which they occur. A third locality, in the railroad cut of the Delaware branch of the N. Y., S. and W. Railroad at Columbia, in a bed but a few hundred feet from the top of the formation, afforded a fauna with *Ophileta complanata* Van., *Eccyliomphalus* sp., *Cyrtoceras* sp., *Asaphus canalis* Whitf., *Illaenurus* n. sp., etc., the whole complexion of which is that of the Calciferous or Beekmantown limestone of lower Ordovician age. The evidence of the fossils, therefore, indicates that the age of the Kittatinny limestone covers the whole of the Cambrian and extends into the lower Ordovician.

Trenton Limestone.—This formation was described by Prof. Cook* as the fossiliferous limestone, and its Trenton age has long been recognized. In almost every exposure of the forma-

* Geol. N. J., 1868, p. 131.

tion fossils occur, and in several localities large faunas have been secured. The fauna of the lower beds of the formation indicates the Black River horizon which is the extreme basal portion of the Trenton limestone series in its more typical localities in New York, so that the Trenton limestone in New Jersey may be considered as being the basal portion of the formation.

Repeated estimates in the field by Dr. Kümmel, indicate the average thickness of the Trenton limestone to be from 135 to 150 feet. The basal conglomerate in the lower portion of the formation, mentioned in the report for 1899,* was found to be practically co-extensive with the formation in the State.

Hudson River Formation.—Lying upon the Trenton limestone there is a monotonous series of slates and sandstones. The slates are usually black in color, the sandstone layers being brownish upon weathered surfaces. This formation is not sharply separated from the Trenton limestone below, there being a gradual transition from the limestone through calcareous shales to the slate beds.

Fossils are exceedingly rare in this formation. Near Branchville, however, a graptolite fauna was found in the lower portion of the formation, about fifty or seventy-five feet above a Trenton limestone outcrop upon the same hillside. The graptolites at this locality are pyritized and are poorly preserved, the following species being recognized.†

1. *Diplograptus foliaceus* Murch.
2. *Diplograptus* sp. cf. *angustifolius* Hall.
3. *Lasiograptus mucronatus* Hall.
4. *Corynoides calycularis* Nich.

In addition to the graptolites a few fragments of brachiopods, probably *Dalmanella testudinaria*, were found at this locality. The fauna is the equivalent of the Norman's Kill graptolite fauna, near Albany, N. Y., and this occurrence of the fauna in New Jersey is of especial interest, because it affords additional evidence as to its true stratigraphic position. The Trenton limestone outcrop, from fifty to seventy-five feet beneath the graptolite bed, contains the following species:

* Ann. Rep. State Geol. N. J. for 1899, p. 49.

† The writer is indebted to Dr. R. Ruedemann, of Albany, N. Y., for revising the identifications of these graptolites, and also those found near Jutland.

Streptelasma profunda Hall.
Columnaria sp.
Prasopora lycoperdon (Say.).
Crinoid stems.
Orbiculoidea lamellosa Hall.
Plectambonites sericeus (Sow.).
Strophomena incurvata (Shep.).
Dalmanella testudinaria (Dal.).
Dinorthis pectinella (Emm.).
Platystrophia biforata (Schl.).
Parastrophia hemiplicata Hall.
Rhynchotrema ? sp.
Cyclonema ? sp.
Calymene senaria Con.
Pterygometopus sp.
Asaphus sp.

Parastrophia hemiplicata is one of the most characteristic species of the fauna, and this *Parastrophia* zone has been observed at several localities in New Jersey. A well-marked and quite constant *Parastrophia* zone has been recognized by White* at the top of the Black River horizon in eastern New York and on Lake Champlain, and this occurrence in New Jersey may be a continuation of the same zone in New York. In New Jersey, *Parastrophia* is always associated with one or both of the low Trenton species *Dinorthis pectinella* or *Orthis tricenaria*. The low Trenton age of this fauna seems to be assured, and the Norman's Kill graptolite fauna which lies but a short distance above it would thus be carried well down beneath the upper limit of the Trenton horizon.

In the typical exposures of the Trenton limestone at Trenton Falls, N. Y., 270 feet have been recognized by Prosser and Cummings,† and 268 feet by White,† but neither the bottom nor the top of the formation is exposed at this locality. Dana‡ gives the thickness of the Trenton limestone at Montreal as 600 feet, and west of Lake Ontario as nearly 1,000 feet.

* N. Y. St. Mus., Rep. of Director, p. r 28.

† 15th Ann. Rep. N. Y. State Geol., p. 626. † Rep. Director N. Y. State Mus., p. r 31.

‡ Man Geol., 4th Ed., p. 493.

The thickness of the Utica slate, given by Dana,* is 15 to 35 feet at Glens Falls, 250 feet in Montgomery county, and 300 feet in Lewis county, New York. Walcott† gives the thickness of the same formation in its typical locality at Utica, New York, as over 600 feet. The Lorrain shales have a thickness of 700 feet in Schoharie county, New York, and a similar thickness in western Canada, according to Dana.‡

<table>
<tr><th>New York and Canada.</th><th>New Jersey.</th></tr>
<tr><td>Lorrain, 600.</td><td rowspan="2">Hudson River Slate.</td></tr>
<tr><td>Utica, 400.</td></tr>
<tr><td rowspan="2">Black River and Trenton, 300.</td><td>Norman's kill * * * * Fauna.</td></tr>
<tr><td>Black River and Trenton, 135.</td></tr>
</table>

If we tabulate the thicknesses of these several Ordovician formations as they occur in their more typical New York and Canadian exposures, comparing them with the New Jersey section, some such relations as are exhibited in the accompanying table may be shown. The thicknesses of the New York and Canadian formations used are somewhat arbitrarily chosen, but in all cases they have been under rather than over estimated.

It will be seen that the Hudson river formation is probably the equivalent of the upper portion of the Trenton, the whole of the Utica and the Lorrain shales of New York, the New Jersey evidence supporting that which has been collected by the New York geologists.§ This relationship of the Hudson river slates to the other Ordovician formations should be deemed sufficient to exclude the term Hudson river as a time name in geology co-ordinate with Trenton and Utica. The name Lorrain is being used more and more for this youngest time division of the Ordovician, and merits universal adoption.

* Loc. cit., p. 494.
† Trans. Albany Inst., vol. 10, p. 1.
‡ Loc. cit., p. 494.
§ Science, N. S., vol. 10, No. 259, p. 877.

The age of the upper limits of the Hudson river slates in New Jersey has not yet been determined from fossil evidence. Aside from the graptolites found near Branchville, and others at Jutland indicating the same Norman's Kill fauna, the only fossils secured in the formation were found at Deckertown. In the flag-stone quarry within the limits of the village, a thin calcareous band was observed, crowded with small brachiopods. The species, however, *Leptæna sericea* and *Dalmanella testudinaria*, are not such as to signify any definite horizon. Neither could the stratigraphic position of the fauna be determined, as the locality occurs in the midst of a broad slate area which has been subjected to a great amount of folding and faulting.

No Paleozoic rocks of younger age than the Hudson river slates occupy the Kittatinny valley. The immediately overlying formation is the Oneida conglomerate which forms the crest of the Kittatinny mountain, and this, with the superjacent Silurian and Devonian formations, occupy the Delaware valley.

PART II.

Report on Portland Cement Industry.

By HENRY B. KÜMMEL.

Report on the Portland Cement Industry.

By HENRY B. KÜMMEL, Ph. D.

CONTENTS.

INTRODUCTION.

This report is the outgrowth of work upon the Paleozoic formations of the State, undertaken preliminary to the revision of the Geological Map. At first the differentiation of the formations and their structure and areal relations were the chief points of investigation. As the work progressed it became evident that the occurrence of limestone, probably suitable for Portland cement, was more widespread than had been supposed, and the importance of a prompt report in detail upon these rocks, without waiting for an exhaustive study of the whole region, was apparent. Thereupon the scope of the work was slightly changed. Attention was directed chiefly to the limestone formations which were carefully mapped, and samples were collected from the most promising areas.

In Chapter I the composition of natural and Portland cements is given with a statement of various raw materials. There is no attempt at an exhaustive treatise on the composition and manufacture of Portland cement. For that, the reader is referred to the numerous technical works and to the trade journals. But it is hoped that the chapter may prove helpful as an introduction to the description of the available raw materials in the State.

In Chapter II the rock formations of the Kittatinny valley and their structural relations to each other are described. The characteristics of the cement beds and pure limestones are given and comparison with the Magnesian limestones made so that the two may be readily distinguished. The local details as to the occurrence of the beds suitable for cement are given in Chapter III. Brief description of the shell marl deposits, compiled from the earlier reports of the Survey, are also given.

During a part of the season I had the co-operation of Mr. Stuart Weller, who had charge of the Paleontological work. The chemical analyses, unless otherwise stated, were made by Prof. William S. Myers, of Rutgers College. Thanks are due to Mr. Thomas A. Edison, Mr. W. S. Mallory and others of the Edison Cement Works, to Mr. A. F. Gerstell of the Alpha Portland Cement Company, to officials of the Vulcanite Portland Cement

Company, to Mr. George A. Large of Flemington, Mr. Chester Tomson of Clinton, Mr. Clarence L. Murphy of Plainfield, Mr. William Siefert, editor of the "Cement and Engineering News," Mr. J. B. Millard of Lebanon, Pa., Mr. E. Duryee of Colton, Cal., and Mr. George Marshall of Trenton, all of whom have kindly furnished analyses or assisted in other ways in the accumulation of data for this report.

Mr. Myers furnishes the following statement of the method of analysis used by him:

One gram of the properly prepared sample was taken for analysis, and after being treated with boiling dilute hydrochloric acid and a little nitric, was evaporated to dryness on the water bath in order to render all the silica insoluble. After taking up the residue in hydrochloric acid of Sp-Gr. 1.10 and gently warming, the whole was filtered and the insoluble siliceous residue was washed, dried, ignited and reported as such.

The oxides of iron and alumina were precipitated in the usual way by means of ammonia and re-precipitation was made in such cases as required it. The lime was precipitated as oxalate, re-precipitated when necessary, filtered and converted into oxide by means of a blast lamp. The magnesia was determined in the usual way as pyrophosphate. The carbonic acid was calculated on the assumption that the lime and magnesia were all present as carbonate and was not determined in any case.

In certain cases the insoluble siliceous residue was examined for silica, oxide of iron, alumina, lime and magnesia. In a few cases the soluble silica was determined by means of a boiling sodium carbonate solution.

CHAPTER I.

The Constitution of Portland Cement.

Lime and cement are two important building materials. Both are mixed with water and used in a more or less plastic condition. Both possess the important property of hardening or *setting* in a shorter or longer time after mixing.

Lime, as is well known, is made by burning more or less pure carbonate of lime, which occurs widely in the form of limestone. Pure limestone consists of 56 per cent. of oxide of calcium (CaO) or "lime," and 44 per cent. of carbonic acid. It rarely occurs absolutely pure, however, but contains greater or less quantities of magnesia, silica, alumina, iron and other ingredients. In burning the carbonic acid is driven off, leaving the lime and other constituents. Pure limestone will, therefore, in burning lose 44 per cent. of its weight, or even more, if the rock contained much water. Impure limestone contains a relatively smaller proportion of carbonic acid, and therefore its loss by burning is somewhat less. Freshly burnt lime, before it has absorbed any water, for which it has a great avidity, is known as *quick-lime.* When water is added to quick-lime it is rapidly absorbed, heat is generated, the lime swells to twice or three times its original bulk and slowly disintegrates, finally forming a fine white powder. The lime is then said to be *slacked.* Slacked lime mixed with proper amounts of sand and water sets slowly when exposed to dry air. It will not harden under water, nor in damp places, but can be used only in places where dry air may have free access to it.

Cements are compounds of lime and the elements of clay, *i. e.,* silica, alumina and iron, with commonly a few other ingredients in minute and variable quantities. The lime, silica and alumina must be present in such proportions that the mixture, when properly burned, ground to an impalpable powder and mixed with water, has the power of setting under water and out of contact with the air as well as in the air. In this power of setting under water—hydraulicity—cements stand in marked contrast to lime-mortars. They differ, also, in their behavior after burning. Quick-lime disintegrates to a powder upon slacking. The burnt cement-rock—*clinker,* as it is called technically—will not slack and disintegrate, but has to be ground to an impalpable powder before it can be used.

Intermediate between ordinary lime and cement is the material called hydraulic lime. It is made by burning limestone containing from 10 to 25 per cent of silica, alumina and iron, at a slightly higher temperature than that needed for making quicklime. It is slacked before using and disintegrates in the process, but more slowly than in the case of quick-lime. It has the power of setting under water, but to a less degree than the cements.

As the percentage of silica, alumina and iron in a lime increases, it gradually acquires the power of hardening beneath water and becomes an hydraulic lime. With greater increase in the proportions of these substances the burned product slacks less readily until at last a point is reached when it becomes a cement. The clinker must then be ground by machinery and the hydraulicity becomes the important characteristic.

Although the hydraulicity depends upon the amount of silica, alumina and iron present, increasing for a time as these increase, there is a limit beyond which the proportion of these substances cannot go. Experience has shown that there are certain narrow and well-defined limits within which the proportions of the lime, silica and alumina with the iron must not vary in order to obtain the best results in cement manufacture. These limits will be given below.

KINDS OF CEMENTS.—Cements, as has been said, are mixtures of lime, silica and alumnia with iron and a few other materials, generally in minute quantities, which harden under water. Commercial cements can be divided into three general classes—slag, natural and Portland.

Slag Cements.—Slag cements are made by mixing a granulated blast-furnace slag of suitable composition with slacked lime. A natural volcanic scoria is sometimes used in place of the furnace slag. The resulting cement is then called Puzzolana.

Natural Cements.—Natural cements are made from a limestone containing a high proportion of silica and alumina, with or without considerable magnesia. This rock is burned at a relatively low heat, 1000° to 1200° F., and then ground to a fine powder. The following table* illustrates the variable composition of some rocks used for making natural cement in America:

AMERICAN CEMENT ROCKS.

	1.	2.	3.	4.	5.
Lime,	17.2	23.4	38.64	23.66	26.05
Magnesia,	16.7	4.1	1.61	15.22	12.57
Carbon dioxide (calculated),	31.91	22.9	32.14	35.35	34.30
Silica,	19.64	24.74	15.65	....	16.41
Alumina,	7.52	16.74	6.80	22.18	5.44
Oxide of Iron,	2.38	6.30	2.50	undet.	3.38
Alkali,	4.10	6.18	undet.	undet.	undet.

1. Ulster county, New York.
2. Cumberland, Maryland.
3. New Lisbon, Ohio.
4. La Salle, Illinois.
5. Bellaire, Ohio.

The following table† shows the constitution of numerous natural cements, both native and foreign:

COMPOSITION OF NATURAL ROCK CEMENTS.

Locality.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.
Lawrenceville,	29.00	10.40		32.35	19.92
Norton's Rosendale,	24.30	7.22	5.06	33.70	20.94
Old Newark Rosendale,	24.42	8.16	3.96	36.30	16.93
Lawrence,	22.77	10.43		34.54	21.85
Utica, N. Y.,	35.43	9.92		33.67	20.98
Cumberland,	28.30	10.12	4.42	49.60	3.76
Milwaukee,	25.16	6.33	1.71	36.08	18.38
Lehigh Valley, Pa.,	26.50	9.40	2.00	53.50	2.40
Louisville, Ky.,	21.10	7.51		30.16	7.00
Cumberland,	36.60	14.58	5.12	37.50	2.73
"	25.70	12.28	4.22	52.69	1.44
Round Top,	30.02	13.55	3.00	44.58	2.76
"	28.36	9.85	3.07	45.04	2.82
Potomac,	26.65	12.38	2.14	33.20	12.56
Vassy (Fr.),	22.60	8.90	5.30	52.69	1.15
Yonne,	23.40	12.90	3.30	47.70	1.05
Argentenie (Fr.),	29.55	8.35	4.10	47.50	3.85
Tsckerkasoff (Russ.),	24.29	6.53	5.80	42.10	10.15

* Geological Survey of Ohio, Vol. VI, p. 673.
† Report of the State Geologist of New York, 1897, p. 401, quoted by Ries from Lewis.

It will be seen from the above table that natural cements vary considerably in chemical composition. In these analyses the lime varies from 30 per cent. to 53.5 per cent.; the silica from 21.1 to 36.6 per cent.; the alumina from 6.33 to 14.58 per cent., and the magnesia from 1.05 to 21.85 per cent. It is to be expected, therefore, that the cements themselves will vary considerably in rapidity of hardening, ultimate strength, tendency to expand or contract, and consequent durability. Moreover, the temperature at which the rock is burned affects these qualities to a greater or less extent, so that two cements of the same chemical composition may give somewhat different results in use because of different burning. It often happens, moreover, that different beds in a quarry vary in composition, and are not equally valuable for cement-making. Not uncommonly variations in constitution occur in the same bed, so that the resulting cement is almost sure to be of uneven grade, the variations often being great enough to cause serious variations in its essential qualities. It is highly requisite that a good cement be uniform in its action. Owing to their lesser strength, variability in action, and quick-setting properties, the natural cements are not, on the whole, so highly esteemed as the Portland cement. But their low price makes them the best cement for some kind of work.

In 1898 there were manufactured in the United States 8,161,078 barrels (300 lbs.) of natural rock cement, worth, on the basis of the selling prices at the mills, $3,819,995. This amount was 59.6 per cent. of all the cement used in this country. In 1899 the amount rose to 10,186,447 barrels,* and in 1900 fell to 8,832,240 barrels.†

Portland Cements.—Portland cement is made by preparing an artificial mixture of the necessary materials in the proper proportions, and burning the mixture at a white heat. A much higher temperature, above 2000° F., and more thorough burning is necessary for Portland cement than for the natural rock cements. The term Portland was first given the cement because of its resemblance, when set, to Portland stone. As used at the

*Mineral Industry, Vol. VIII. 1900.
† The Engineering and Mining Journal's Estimate, Jan. 5, 1901.

present time the name signifies a cement made from an artificial mixture, and according to a generally accepted formula, in contrast with cement made from rock, in which the necessary materials are naturally mixed together.

Composition.—The composition of modern Portland cements is quite uniform, as may be seen from the accompanying table.* In this they form a marked contrast to the natural rock cements (see above).

American Brands.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	SO_3.	*Authority.*
Alpha, ...	22.62	8.76	2.66	61.46	2.92	1.53	Booth, G. B.
Atlas, ...	21.96	8.29	2.67	60.56	3.43	1.43	"
Giant, ...	19.92	9.83	2.63	60.32	3.12	1.13	"
Saylors, ...	22.68	6.71	2.35	62.30	3.14	1.88	"
Vulcanite, ...	21.08	7.86	2.48	63.68	2.62	1.25	"
Empire, ...	22.04	6.45	3.41	60.92	3.53	2.73	"
Jordan, ...	21.84	7.17	3.73	61.14	2.34	1.94	"
Diamond, ...	21.80	7.95	4.95	61.90	1.64	.79	"
Sandusky, ...	23.08	6.16	2.90	62.38	1.21	1.66	"
Bronson, ...	20.95	9.74	3.12	63.17	.75	.86	Mfr's analysis.
White Cliffs, ...	22.93	10.33		64.67	.94	1.05	"
European Brands.							
Dyckerhoff (Gr.),	20.64	7.15	3.69	63.06	2.33	1.39	Booth, G. B.
Germania (Gr.),.	22.08	6.84	3.36	63.72	1.32	1.82	"
Candlot (Fr.), ..	22.30	8.50	3.10	62.80	.45	.70	Candlot.
Boulogne (Fr.), .	22.30	7.00	2.50	64.62	1.04	.75	"

The essential elements are the lime and the clay materials, *i. e.*, the silica and alumina. Iron and magnesia are always present, as shown by the above analyses, but careful experimental tests seem to indicate that they are not important in small amounts, and that in large amounts the magnesia is detrimental, while the iron serves the same purpose as the alumina.

The quality of a cement, however, cannot be determined from a chemical analysis alone. Two cements may have the same chemical composition and still have very different values in use. The value of a cement depends also upon the degree to which the various chemical elements have combined in the burning to form those compounds which experience has shown are essential to a good cement.

* Heinrich Ries, loc. cit.

There has been considerable difference of opinion as to what these compounds are, but the excellent work of Prof. Spencer B. Newberry* seems to have established certain conclusions. The lime unites with the silica in the proportion of three molecules of lime to one of silica, forming the tri-calcium silicate ($3\ CaO.\ SiO_2$). The best results are obtained when the remaining lime unites with the alumina in the ratio of two molecules to one, forming the di-calcium aluminate ($2\ CaO.\ Al_2O_3$). Experiments indicate that the tri-calcium silicate is slow-setting, but that the ultimate strength of the cement is due to changes in this compound on the addition of water. The di-calcium aluminate, on the contrary, is quick-setting, and the first set of the cement is due to changes in this compound.

It is now generally agreed that the setting of Portland cement is due to the formation of crystallized calcium hydrate ($Ca(OH)_2$), and a hydrated calcium monosilicate ($CaO.\ SiO_2.\ 2\frac{1}{2}H_2O$).

Studies of hardened cement by Le Chatelier showed that it consisted of hexagonal plates of crystallized calcium hydrate, imbedded in a white mass of interlaced needle-shaped crystals of hydrated calcium monosilicate. These studies indicate, therefore, that the chief reaction in the hardening of cement may be represented as follows: $3CaO.SiO_2 + xH_2O = 2CaO.(OH_2) + CaO.\ SiO_2.2\frac{1}{2}H_2O$.

In order that the right proportion of lime, silica and alumina may be present to form the maximum amounts of tri-calcium silicate and the di-calcium aluminate, Newberry has proposed the following formula for the mixing of raw materials:

"Multiply the percentage of silica by 2.8 *and the percentage of alumina by 1.1, add the products; the sum will be the number of parts of lime required for 100 parts clay."*

This formula represents the maximum amount of lime which can be used with safety, a result attainable only by most thorough grinding and mixing of the raw materials. Moreover, the higher the lime content the harder it is to burn the cement properly, the higher the temperature necessary and the longer the heat is

* Newberry. The Composition of Hydraulic Cements. "The Cement and Engineering News," Nov., 1897.

required. High-limed cements, also, are more destructive of the kiln linings, necessitating their frequent renewal. So, too, the difficulty in causing complete combination of the lime with the silica and alumina is increased as the maximum lime limit is approached. But with all these conditions properly fulfilled, the nearer the amount of lime approaches that demanded by the formula the better the resulting cement. In actual practice it has been found necessary to use somewhat less lime than the maximum, but the best commercial Portland cements do not depart widely from the proportions demanded by the formula.

Newberry's other conclusions are summarized as follows:*

"Iron oxide combines with lime at a high heat, and acts like alumina in promoting the combination of silica and lime. For practical purposes, however, the presence of iron oxide in a clay need not be considered in calculating the proportion of lime required.

"Alkalies, so far as indicated by the behavior of soda, are of no value in promoting the combination of lime and silica, and probably play no part in the formation of cement.

"Magnesia, though possessing marked hydraulic properties when ignited alone, yields no hydraulic products when heated with silica, alumina or clay, and probably plays no part in the formation of cement. It is incapable of replacing lime in cement mixtures, the composition of which should be calculated on the basis of lime only, without regard to the magnesia present."

It is commonly believed that an excess of 4 per cent. of magnesia is injurious to a cement, causing a steady falling-off in its strength, and rendering it liable to crack as it ages, even after several years. The subject, however, is still under investigation, and the final word on this phase of cement-making has not yet been said.

Sulphate of lime in quantities exceeding 2½ per cent. is generally regarded as injurious, particularly in cements to be exposed to the action of sea-water.

If the proportion of lime is too high, or if through imperfect mixing or underburning a part of the lime remains free, that is uncombined with the silica or alumina, the cement deteriorates.

* Newberry, loc. cit.

The free lime in time slacks, and the cement mortar swells and cracks. If the cement is kept for a considerable period before using, there is less danger from the free-lime, as the latter slacks in seasoning. In so far as the amount of lime falls short of the proportion demanded by Newberry's formula, there is a decrease in the ultimate strength of the product, so that the problem constantly before the manufacturer is to approach as close to those proportions as is consistent with the limitations imposed by the difficulties and cost of manufacture.

The ratio of silica to alumina may vary somewhat without materially affecting the value of the cement. In the analyses of the American cements given above it varies between 2 to 1 and 3.9 to 1. Newberry's experiments indicate that the alumina may vary from 2 to something over 7 per cent., and still the cement be sound. With increasing amounts of alumina the fusibility of the mixture is increased, and the difficulty of burning properly is greater. The clinker is very hard to grind, and the resulting cement is quick-setting. A quick-setting cement is not, as a rule, so strong as one which sets more slowly, but increases in strength for a considerable period. Cements too high in alumina have, also, a tendency to expand and crack.

Raw materials.—A great variety of raw materials can be used in the manufacture of Portland cement, but they are not all equally available from a commercial standpoint, in which the cost of production is a most important factor. Raw materials to be available must possess certain requisites, the most important of which are these:

1. A correct chemical composition. Not only must the lime, silica and alumina be present in such proportions that the raw materials can be united in a mixture approximating to the formula of Newberry, but deleterious substances, such as excess of magnesia and sulphur, must be absent.

2. They should be sufficiently homogeneous to run evenly without marked fluctuations in the composition. With fluctuating materials much bad cement may be made before the error is discovered.

3. The location must be suitable. Here a large number of factors must be considered, chief of which are cost of quarrying,

cost of fuel and shipping facilities. However good and abundant the raw material, its location in reference to a railroad, actual or potential, is all-important.

4. Since the raw materials must commonly be finely ground and thoroughly mixed before burning, the cost of these operations must be considered. A pure limestone must be ground so fine that it will pass a sieve having 150 meshes to a linear inch, whereas a clayey limestone in which the silica and alumina are already mixed with the lime, does not need to be ground so fine. The cost and difficulty in grinding large quantities of a very hard rock may be prohibitory, even though its composition be correct. Doubtless other factors will at once suggest themselves to cement manufacturers, and only these need be mentioned here.

The best raw material would be a soft, clayey limestone of constant composition, in which the lime, silica and alumina were present in the right proportions. In such a case the mixing of the materials would have been done in a most thorough manner by nature, and the subsequent process of manufacture would be very much simplified and cheapened. Such a rock, however, is not known to exist in amounts large enough to be available. An approach to it is used in the manufacture of the so-called Belgian Portland cements, but owing to variations in the rock in the quarry, cements made even from the best natural mixtures fall below the standard of the Portland cements.

In the Lehigh Valley region, Pennsylvania, as well as in Warren county, N. J.,* the raw materials are an argillaceous or clayey limestone, known technically as "cement rock," and a pure limestone. The constitution of the cement rock is shown by the following manufacturer's analysis of rock from the Alpha Portland Cement Company, near Phillipsburg, N. J. Other specimens will, doubtless, show small variations from this analysis:

Silica.	*Iron and Alumina.*	*Carbon Dioxide.*	*Lime.*	*Magnesia.*
14.44	5.91	33.48	42.1	.37

This rock is deficient in the amount of lime required, according

* In 1898 this area produced 72% of the Portland cement made in the United States. Newberry, U. S. G. S., 20th Annual Report, Part VI, p. 540.

to Newberry's formula, so that it is necessary to grind and mix it with a small amount of pure limestone.

The advantage possessed by these materials is this: The silica, alumina and iron are already intimately associated with almost the required amount of lime in the cement rock, so that the proper union of the silica and the alumina with the lime in burning is readily accomplished. The small amount of additional limestone necessary is readily mixed with the cement rock, and excessively fine grinding is not necessary, since most of the coarse particles remaining in the raw material are of nearly the correct composition. The cost of grinding these hard rocks is, however, greater than in the case of some other raw materials, which are soft or incoherent to begin with.

In some localities a relatively pure limestone is mixed with clay. The following analysis* shows the composition of the materials available at Litchfield, Ky.:

ANALYSIS OF INGREDIENTS OF PORTLAND CEMENT FROM KENTUCKY.

Limestone.	*Per cent.*	*Clay.*	*Per cent.*
Lime,	54.67	Silica,	55.82
Magnesia,	0.31	Iron oxide,	6.19
Carbon dioxide (calculated),	43.30	Alumina,	19.77
Silica,	0.49	Lime,	0.70
Alumina,	Trace	Loss, alkalies, etc.,	19.52
Iron oxide,	0.22		
Sulphuric acid,	0.34		

The use of limestone and clay is, in some respects, not as satisfactory as the cement rock and limestone. Newberry states that in order to ensure the proper combination of the lime with the silica and alumina of the clay, and to prevent the presence of free lime, the rock must be ground so fine as to leave practically no residue on a sieve of 150 meshes per linear inch. The cost of grinding large amounts of hard limestone to this fineness is considerable. Most of the attempts in this country to make Portland cement of these materials have resulted unsatisfactorily in respect to cost of manufacture or quality of product. Within the last year or two, however, a plant at Smith's Landing,

* Newberry, U. S. G. S., 20th Annual Report, Pt. 6, p. 545.

on the Hudson river, has utilized them successfully, as is reported.

At Colton, Cal., Portland cement is made from a mixture of very pure crystallized limestone and clay. The materials have the following composition:*

	Limestone.	*Clay.*	*Clay.*
Lime (CaO),	55.216	2.900	2.300
Magnesia (MgO),	0.000	1.016	1.873
Silica (SiO_2),	0.550	49.300	50.100
Alumina and Ferric oxide (Al_2O_3), (Fe_2O_3),	0.850	20.10	29.700
Carbon dioxide (calculated), (CO_2),	43.384	undet.	3.854
Moisture and organic matter,	.....	undet.	12.300
	100.000		100.127

The resulting cement has the following composition†:

Lime,	60.648
Silica,	22.250
Alumina and Ferric oxide,	12.700
Magnesia,	.378
Sulphate of lime,	2.000
Alkalies,	1.524
	99.500

More successful results have been attained by the use of marl and clay. The composition of the marl may be very similar to that of the limestone, but the marl is soft and unconsolidated, so that it is reduced to the requisite degree of fineness more easily and cheaply than hard limestone. The clay which is used should not contain a large amount of free silica in the shape of quartz sand. The silica, although it is the chief constituent of clay, should exist in the clay combined with the alumina, and not free as sand. Although it is possible to make free silica unite with the lime in burning the cement, provided the mixture has been ground to exceeding fineness, yet in practice this is not fully done. The free silica remains, for the most part, uncom-

*These analyses were kindly furnished by Mr. E. Duryee, of the California Portland Cement Co.

†Analysis furnished by Mr. Duryee.

bined, as so much inert material in the cement, and the lime, which should have united with it, is left uncombined, and causes the cement to swell and crack. The latter difficulty, too much lime, may be guarded against by not including the free silica in the calculations to determine the amount of lime necessary. But even when this is done, a sandy clay yields a cement with a large amount of inert matter, and, consequently, with a lower tensible strength. Generally the best results are obtained with a clay, free from sand, in which the silica is equal to at least three times the iron and alumina together.

The following is an analysis* of a marl used in Indiana:

ANALYSIS OF MARL FROM SYRACUSE. KOSCIUSKO CO., INDIANA.

Lime,	49.55
Magnesia,	1.29
Carbon dioxide (calculated),	40.36
Insoluble,	1.78
Iron oxide and alumina,	1.21
Calcium sulphate,	1.58
Organic matter by difference,	4.23
Total,	100.00

The use of marl and clay is more common in the Central States than in the East. In Michigan, particularly, a number of plants have been recently established to manufacture cement from these materials. But in spite of these developments, by far the larger amount of Portland cement manufactured in this country is made by mixing limestones of varying composition.

The use of chalk and clay as raw materials is very closely allied to the use of marl and clay. Indeed, by many writers no distinction is made between the use of marl and chalk. The chalk is harder than the incoherent marl, but much more readily ground than the hard limestone. Its chemical composition may be nearly the same as the limestone or the marl. A large part of the English Portland cement is made from these materials, as well as other foreign brands, both German and French. Newberry† gives the following analysis of chalk and clay used at White Cliff, Arkansas:

*Newberry U. S. G. S., 19th Annual Report, Part VI, p. 493.
†U. S. G. S., 18th Annual Report, Part V, p. 1174.

ANALYSIS OF MATERIALS AT WHITE CLIFF, ARK.

Chalk.	*Per cent.*	*Clay.*	*Per cent.*
Lime,	50.53	Silica,	73.62
Magnesia,	.54	Alumina and iron oxide,	19.30
Carbon dioxide (calculated),	40.31	Lime,	....
Silica,	5.33	Magnesia,	....
Alumina and iron oxide,	3.03		
Total,	99.74		

Where marls contain a high percentage of silica and some alumina, as is sometimes the case, a good combination results from adding the necessary amount of pure limestone. Thus Portland cement has been made in Denver, Col., from limestone and marl having the following constitution*:

	Limestone.	*Marl.*
Lime,	53.2	35.56
Insoluble siliceous matter,	5.0	32.60
Alkali and magnesia,	undet.	4.5

It is possible to manufacture Portland cement from pure limestone and from shale or slate. Shale and slate are solidified beds of clay, so that their chemical composition may be closely similar to that of clay. But the objections to the use of limestone and clay apply with even greater force to the use of limestone and slate. The quantity of silica is likely to vary greatly owing to the constantly changing amount of sand or grit in the slate, so that there is apt to be difficulty in maintaining a constant product. But the difficulty and cost of grinding these two hard materials to the requisite fineness is even a more serious objection than the presence of free silica in the slate or shale. No factories are known to the writer where these materials are used.

Recently cement has been made in Michigan from caustic soda waste (a very pure form of precipitated calcium carbonate) and clay.†

Various other compounds of lime, silica and alumina may be used, but those already enumerated are the most important.

* Lord, Geology of Ohio, Vol. VI, p. 685.
† Newberry, loc. cit., p. 545.

Growth of the Portland Cement Industry.—The growth of the Portland cement industry in the United States during the last four years has been little short of marvelous.

The increase in production since 1890 is shown by the following table:

1890,	335,500 barrels (400 lbs.)*
1894,	798,757 barrels (400 lbs.)*
1897,	2,677,775 barrels (400 lbs.)*
1898,	3,692,284 barrels (400 lbs.)*
1899,	5,805,620 barrels (400 lbs.)†
1900,	8,503,308 barrels (400 lbs.)†

The same facts are illustrated in the diagram, Fig. 1, in which

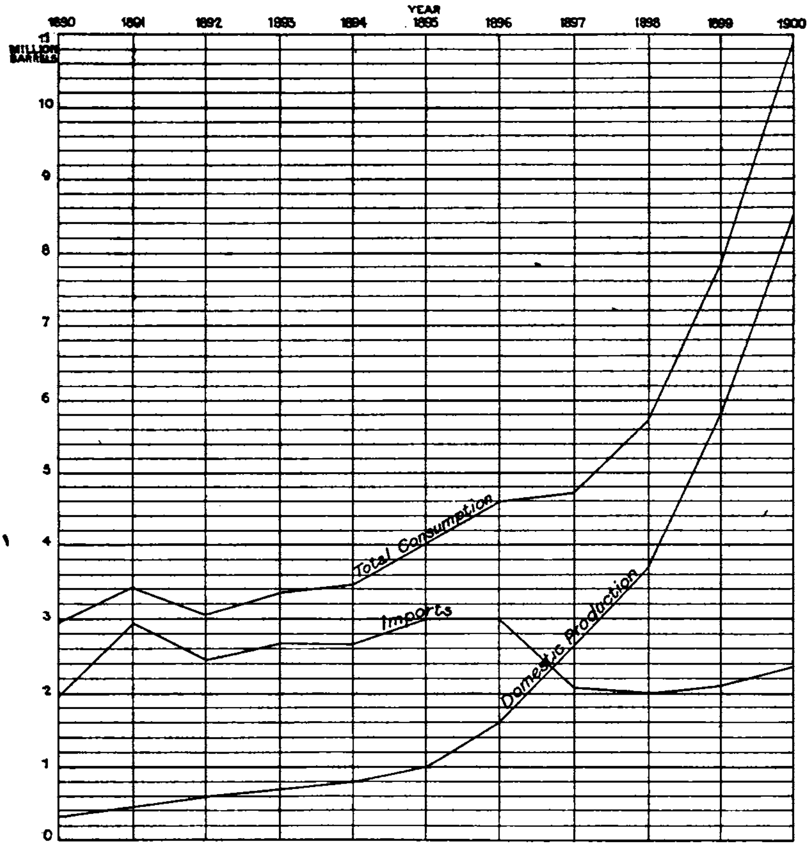


Fig. 1—The Portland Cement Industry, 1890–1900.

* U. S. G. S., 20th Annual Report, Pt. 6, p. 540.
† Engineering and Mining Journal, Jan. 5, 1901. These figures are subject to revision in light of later statistics.

not only the production is graphically shown, but also the imports and the total domestic consumption. With the rapid increase in domestic production, which, although beginning in 1895, did not fairly gain headway until 1896, there was a decided falling-off in the imports, which previous to 1896 had exceeded the home production. The enormous increase thus shown has been almost entirely consumed in the United States, for our exports in this line are insignificant. During 1900 the total consumption in this country was between 10,800,000 and 11,000,000 barrels, as against less than 3,000,000 barrels in 1890.

During the past two years so many new plants have been erected and old ones enlarged that well-informed parties are of the opinion that at present the production is in excess of the demand. It can hardly be doubted, however, but that the industry is as yet in its infancy. Portland cement is constantly being applied to new purposes, and the demand for it will surely increase. It has already begun to crowd out the natural rock cements, the production of which during 1900 showed a decrease of about 13 per cent. from that of 1899. Portland cement, though costing more per pound than the natural cements, is so far superior in setting strength that less of it is necessary for use in concrete, mortar, etc., so that in many cases it is actually cheaper to use.

In 1898 the per capita consumption in Germany* was more than six times that in the United States, and it is still far ahead there, in spite of our marvelous increase in the last two years. All the indications point to the conclusion that whatever over-production may exist at the present time will be overcome in the course of a few years, unless the excessive building of new plants is continued. The business will settle down to a fairly profitable industry in which cheapness of labor, fuel and quality of raw material will be constantly increasing factors of success.

For many years Pennsylvania has led all the other States in this industry, with New Jersey second and New York a close third. In 1898 New Jersey produced about 16 per cent. of the total for the United States. Two plants are in operation, both near Phillipsburg, Warren county, and a third is nearing completion.

* U. S. G. S., 20th Annual Rep., loc. cit.

The Alpha Portland Cement Company is located on the Lehigh Valley Railroad, at Alpha, N. J. (figure 4), with an office at Easton, Pa. This company was formed in April, 1895, and at that time purchased the plant of the Whitaker Cement Company, which had previously run the works at Alpha. The plant was originally built by Thomas D. Whitaker, and cement was first manufactured there in 1891. At present the company owns 140 acres of land underlain by cement rock, which has a depth exceeding 160 feet. At their present plant they have ten kilns, with an output of about 1800 barrels per day. A new plant of ten additional rotary kilns will be completed about April 1st, 1901, which will give them an output of from 3600 to 4000 per day.

Analysis of the Alpha cement is given on page 18, and of their raw material on pages 22 and 43.

The Vulcanite Portland Cement Company has a plant at Vulcanite, on the Central Railroad of New Jersey, close to the Alpha Company. Their office is at Philadelphia. This plant was established in 1894, and now has a daily capacity of 2000 barrels. They own 205 acres underlain by cement rock, and operate eleven rotary kilns. An analysis of the Vulcanite cement is given on page 18. Their raw material is closely similar to that of the Alpha Company.

The Edison Portland Cement Company has been recently organized, and their plant is not yet in operation. The officers are as follows: Wm. H. Shelmerdine, President; W. S. Mallory, Vice-President; W. S. Pilling, Treasurer; T. I. Crane, Secretary; and T. A. Edison, General Manager. The company owns about 600 acres of land near Stewartsville, N. J., a few miles northeast of the Alpha and Vulcanite properties. A mammoth plant, with an ultimate capacity of 10,000 barrels per day, has been designed, and a part of it is being built upon this scale, although other portions are being built for 4,000 barrels at present, and the daily capacity at the start may be not more than 2,500 barrels. Although no date has been set for completion of the works, the manufacture of cement may begin during 1901. Details concerning the rock to be used are given in Chapter III.

CHAPTER II.

The Cambro-Ordovician Rocks of Warren and Sussex Counties.

Raw materials for making Portland cement exist at many localities in Sussex and Warren counties, and to a limited extent in Hunterdon county. The important areas occur in the Kittatinny valley and in some of the inter-Highland valleys. A general description of the rocks in these regions is given in this chapter. The geologic succession is as follows:

Hardiston Quartzite.—At the base of the great limestone formation of the Kittatinny valley a thin bed of sandstone or quartzite is found at many points. It rests upon the crystallines which form the Highlands, and is the earliest of the Paleozoic formations in this region. It varies considerably in composition and in thickness. In many places it is apparently only a coarse sandstone more or less friable, the grains of which are cemented together by lime carbonate. When fresh its color is steel-blue, but the weathered portions are always a rusty brown from the staining of iron. It is usually, but not always, feldspathic. In other localities it is a true quartzite with siliceous cement. Elsewhere it is a conglomerate, usually of pebbles less than an inch in diameter, but sometimes containing well-rounded fragments two to four inches. They are chiefly quartz, feldspar, granite, gneiss, slate and bits of mica. Locally the conglomerate, where it approaches the granite, can be with difficulty distinguished from it by the naked eye. It is simply a decomposed granite, slightly re-assorted and cemented to form an arkose conglomerate.

The thickness varies from a few feet or less to 200 feet or more. In localities where it is great the rock is a conglomerate or a coarse pebbly quartzite. Where thinner it is usually a calcareous sandstone, grading upward into a limestone, and, perhaps, having near its base one or more thin layers of more siliceous sandstone or even quartzite. The crystalline foundation on which the quartzite rests was somewhat irregular, so that the formation varied greatly in thickness and lithological character, and at the time of its deposition the land lay not far to the southeast of the present outcrop of this rock.

In the earlier reports of the Survey* this formation was called the Potsdam sandstone, on the supposition that it was to be correlated with that formation in New York. Its lower Cambrian age is now well established.† Wolff and Brooks applied the term Hardistonville, for which the shorter name Hardiston is now proposed.

Kittatinny or Magnesian Limestone.—The quartzite grades upward into a magnesian or dolomitic limestone of great thickness. This is commonly called the "blue" limestone to distinguish it from the white, coarsely crystalline limestone found near Franklin Furnace and other localities in Sussex and northern Warren. Its color, however, is not always blue. It is frequently grey, sometimes almost white, also drab or even black. It is fine and even-grained. Many of the beds are minutely crystalline, so that the freshly broken surface has a close resemblance to fine-grained lump sugar. But it is never coarsely crystalline.

Various names have been applied to this formation. In the earlier reports of the Survey it is called the Magnesian limestone. It is probably better known as "blue" limestone. In a recent report‡ upon the formation in the vicinity of Franklin Furnace and Hamburg, Wolff and Brooks have used the term Wallkill limestone for that part of this formation included in their studies. The term Kittatinny is, however, preferable, as the limestone is, on the whole, not well exposed along the Wallkill river, and it is pre-eminently the great limestone formation of the Kittatinny valley. In Pennsylvania these beds, together with the overlying limestone formation, are known as the Siluro-Cambrian limestones, Formation II. Further southwest, in Maryland and Virginia, the term Shenandoah limestone has been applied by the United States Geological Survey to limestones of the Great Valley which in New Jersey can be separated into two forma-

* Cook, Geology of New Jersey 1868, p. 71 et seq.
† Weller, pp. 3-4 of this report.
‡ U. S. G. S., 18th Annual Report of the Director. Part II, p. 443.

tions, the Kittatinny limestone and an upper formation, which will be described below.

This formation occurs in beds which vary greatly in thickness and regularity. In part it is made up of thin leaf-like layers of limestone alternating with thin sheets of greenish shale. In other beds the layers of limestone are an inch or more in thickness, and are separated by thinner partings of shale or sandstone. Locally the limestone layers are apparently discontinuous, and the shale or sandy layers not only separate but enclose the more limy masses. In great part, however, this formation is composed of regular beds one, two, three or even more feet in thickness. Locally they are so massive and the formation is so regularly jointed that it is extremely difficult to determine the true position of the beds. Some layers, also, are oolitic, *i. e.,* made up of minute round particles somewhat closely resembling fish-roe. The oolitic layers are apparently confined to the lower portion of the formation.

A marked feature of this formation is the chert, or black flint, which occurs either as seams, sometimes eight or ten inches thick, or as separate masses. The chert layers are usually, but not always, parallel to the bedding planes.

Numerous chemical analyses of the better beds of this limestone have been made by the Survey from time to time with the following results:

	Lime. CaO.	Magnesia. MgO.	Carbonic Acid CO_2.	Alumina and Iron Oxide. Al_2O_3. Fe_2O_3.	Silica and Insoluble Material. SiO_2.*
1, ...	27.6	17.9	41.9	1.7	9.9
2, ...	30.4	19.1	44.9	.8	3.6
3, ...	30.0	19.4	44.9	2.7	2.3
4, ...	29.3	19.5	44.6	2.2	4.0
5, ...	29.1	19.3	43.6	1.2	6.4
6, ...	27.9	17.7	41.4	.9	11.2
7, ...	30.3	16.2	41.6	.6	9.8
8, ...	23.6	16.2	36.04	6.0	15.7
9, ...	26.5	18.4	40.4	5.43	7.0
10, ...	29.4	20.3	45.7	.6	1.8
11, ...	28.6	18.1	34.5	.9	9.3
12, ...	29.0	20.2	44.9	.9	4.8
13, ...	28.5	17.3	41.5	1.7	9.9
14, ...	29.6	20.0	45.4	1.4	2.3
15, ...	29.6	19.2	46.2	1.4	2.9
16, ...	29.2	18.8	43.6	2.4	3.6
17, ...	30.1	20.1	44.4	.8	3.5
18, ...	30.8	19.2	45.4	1.1	3.6
19, ...	29.8	19.9	45.4	1.0	3.4
20, ...	28.2	17.7	41.7	.9	10.8
21, ...	29.4	17.8	42.8	.8	8.8
22, ...	29.9	undet.	undet.	undet.	2.0
23, ...	29.6	"	"	"	2.8
24, ...	25.7	"	"	"	1.9
25, ...	26.6	"	"	"	4.1
26, ...	28.2	20.2	44.3	1.3	5.5
27, ...	27.7	17.4	43.0	1.9	7.2
28, ...	26.4	15.1	45.0	3.7	9.8
29, ...	27.3	14.6	44.8	6.5	4.9
30, ...	32.4	15.5	42.5	8.4	2.0
31, ...	26.3	17.4	41.1	5.3	8.0
32, ...	30.3	18.3	44.1	1.6	4.1
33, ...	31.6	18.3	45.2	3.0	1.6
34, ...	28.22	19.07	....	1.90	8.13
35, ...	28.61	20.52	44.88	1.10	5.90
36, ...	29.62	20.63	....	1.06	4.92
37, ...	30.13	21.71	....	1.40	1.95
38, ...	28.27	15.30	38.88	.98	16.9
39, ...	29.8	19.93	....	0.84	7.23

*Analyses 1-7, 10-21, 27-33 are from the Geology of New Jersey, 1868. Analyses 8 and 9 are from the Annual Report of the State Geologist for 1873; Nos. 22-25 from the Report for 1878; No. 26 from the Report for 1876, and Nos. 34-39 were made by Mr. Myers of Rutgers College for this report.

The samples were collected from the following localities:

1. Chandler's Island, Vernon township, Sussex county.

2. Near Wm. Richey's, Vernon township, Sussex county.

3. Near David Perry's, Wantage township, Sussex county.

4. Near Samuel Vanderhoof's, Wantage township, Sussex county.

5. Near Wm. Dewitt's, Wantage township, Sussex county.

6. On property of Edward Lewis, Wantage township, Sussex county.

7. On property of Edward Lewis, Wantage township, Sussex county.

8, 9. Railroad cut, one quarter mile northwest of Hamburg station, on the N. Y. S. & W. R. R.

10, 11, 12. Moore & Cutler's quarry, Newton, Sussex county.

13. Near Sparta, Sussex county.

14. East of Van Kirk's tavern, Columbia, Warren county.

15. Quarry in the town of Belvidere.

16. Robert Shimer's quarry, Springtown, Warren county.

17. Henry R. Kennedy's quarry, Springtown, Warren county.

18. Charles Twinning's quarry, south of Phillipsburg.

19. James Riddle's quarry, New Hampton, Warren county.

20. Railroad cut, east bank of creek, Changewater, Warren county.

21. Mahlon Fox's quarry, one mile southwest of Asbury, Warren county.

22-25. Quarries at Pennwell (Penville), Musconetcong valley.

26. Quarry at Oxford Furnace.

27. S. H. Leigh's quarry, near Hoffman's Mill, south of Lebanon, Hunterdon county.

28. Near Clinton, Hunterdon county.

29. T. Mulligan & Bro.'s quarry, Clinton.

30. Pottersville, Somerset county.

31. Henry Hilliard's quarry, north of Peapack.

32. Moses Craig's quarry, Peapack.

33. Peapack.

34. O'Donnell & McManniman's quarry, Newton. Middle of a thick, dense, even-textured, blue limestone, three feet from the top.

35. The same. Middle of a massive blue layer three feet thick, seven feet below specimen 34.

36. The same. Layer three inches thick, four feet below specimen 35. Rock a pale blue, with faint streaks of pale yellow.

37. The same. Granular layer, eight feet below No. 36. Rock dark colored and semi-crystalline.

38. Gano's quarry, Annandale.

39. Mulligan Bro.'s quarry, Clinton.

As shown by these analyses, which represent a wide range geographically and many different horizons, the limestone beds of this formation vary but little chemically. It is not a pure limestone, since a large amount of magnesia is present in place of lime, whence the name magnesian limestone, by which it has been commonly known in the Reports of the Survey. The same formation extends into Pennsylvania. Examination by the Pennsylvania Geological Survey of 115 beds in a single quarry near Harrisburg, 371 feet in all, from the lower middle of the formation, showed that layers of nearly pure limestone, with only 2 to 3 per cent. of magnesian carbonate, alternated with beds of dolomitic limestone having 25 to 30 per cent. of magnesian carbonate, or from 12 to 17 per cent. of magnesia. So far as the analyses of the New Jersey Survey go, the great bulk of this formation is a dolomitic limestone. Recent field-work, however, shows that a few thin beds of non-dolomitic limestone alternate with the dolomitic layers near the top of the formation. They are apparently not everywhere present. Owing to the large percentage of magnesia nearly everywhere present in this limestone, it is of no value in the manufacture of Portland cement. In some localities, however, it has been quite extensively burned for lime.

Its thickness is apparently between 2,500 and 3,000 feet, but accurate measurements cannot be obtained. More than 99 per cent. of the limestone of Sussex, Warren and Hunterdon counties belongs to this formation, the extent of which is shown on the geological map of the State.

The Trenton limestone.—Above the magnesian limestone, and resting on it, there is a dark blue, or black, fossiliferous limestone. In the earlier reports it is called the "fossiliferous" limestone, in distinction from the magnesian or Kittatinny limestone, in which fossils had not been found at that time. In age it is to be correlated with the basal portion of the Trenton.*

Nowhere is a continuous section of this formation exposed, but in general the succession of beds is about as follows, beginning from below:

(*a*) Blue-black earthy limestone, rather evenly bedded, weathering to a light blue-gray (32 feet).

(*b*) Probably calcareous shale, usually not exposed (32 feet).

(*c*) A rough, irregularly bedded, dark blue limestone, breaking into knotty slabs (43 feet).

(*d*) Black calcareous shales or earthy limestone, gradually becoming less calcareous and more siliceous or clayey and grading into the overlying slate. Thickness is apparently variable, at least 40 feet, sometimes seemingly much more.

In Sussex county the total thickness is quite uniformly about 135 to 150 feet, except where faults have probably repeated some layers. The formation, however, thickens to the southwest, being probably at least 300 feet at the Delaware, and probably even more than this in the Lehigh valley region, Pennsylvania. The increase in thickness is apparently in the upper calcareous shaly beds.

Relation to the Kittatinny limestone.—The Trenton rests upon the eroded surface of the Kittatinny limestone, so that there is here a break in the geological record. This is shown at the Sarepta quarry near Belvidere. Elsewhere the unconformity is not marked, and does not appear in observations of the dip, and strike where the actual contact is not shown. Further evidence of the time break is found in the fact that at many places the lowest Trenton beds are a conglomerate composed solely of pebbles and bowlders of the underlying magnesian limestone and chert. Elsewhere pebbles of magnesian limestone and chert are included in a matrix of pure limestone, which is sometimes fossiliferous. There are all gradations between the Trenton limestones containing an occasional minute pebble of the Kittatinny limestone or chert, and a coarse basal conglomerate, the fragments of which are but little rounded and have suffered only

* Weller, pp. 4-5 of this report.

slight transportation. Locally the conglomerate appears to grade downward into the Kittatinny limestone, as if it were hardly more than the slightly assorted and reconsolidated detritus of an old land surface. A number of localities have been observed where the conglomerate beds occur somewhat above the base of the formation, apparently intercalated between limestone layers. But even in these localities the pebbles of the conglomerate are either magnesian limestone or chert, and are not from the immediately underlying layers of the Trenton. It cannot be questioned but that the Kittatinny limestone was somewhat eroded before the Trenton beds were deposited.

Many analyses have been made of specimens both of the limestone and of the calcareous shales of this formation. These are given in Chapter III. The more massive beds contain from 85 to 95 per cent. of carbonate of lime and only small amounts of magnesia. Some of the more shaly layers contain 65 to 75 per cent. of carbonate of lime, with sufficient alumina and silica to make a good cement rock. It is this rock which is used with such success in manufacturing Portland cement near Phillipsburg, N. J., and in Lehigh and Northampton counties, Pennsylvania. The purer limestone beds can be used to mix with the "cement rock" in order to raise the per cent. of lime to the necessary figure. Its occurrence in detail will be described in Chapter III.

The Trenton limestone can be readily distinguished from the Magnesian or Kittatinny limestone by the following points: (1) The Trenton is usually fossiliferous. Some surfaces are covered entirely with imprints of shells. Beds otherwise unfossiliferous usually contain crinoid stems, which are best seen on weathered surfaces, as small disks, often with a hole in the center. The fossils of the Kittatinny limestone are so few and so obscure that only an expert can detect them, so for practical purposes the formation can be considered unfossiliferous. (2) The dark blue or black color of the Trenton weathers to a light gray-blue, entirely unlike most of the Kittatinny beds. So, too, the rough, knotty character of the bedding and of the weathered slabs is characteristic of the Trenton limestone. (3) A drop of hydrochloric acid will cause the Trenton limestone to effervesce vigorously, whereas the cold acid on the magnesian limestone acts weakly or not at all. (4) The Trenton may usually be recognized by its position. It lies on top of the Kittatinny limestone and beneath the slate, which is the next higher formation, so that its outcrop forms a narrow strip between the wider belts of these rocks. It is not found, however, in this position where faulting has brought the slate against the magnesian limestone, and it is sometimes faulted into the midst of the magnesian limestone areas, as will be explained below. (5) The magnesian limestone contains frequent masses of black flint or chert. This is never found in the Trenton limestone in New Jersey, except as water-worn pebbles in the basal conglomerate.

The Hudson River Slate.—Overlying the Trenton limestone and shale there is a great thickness of slate, flagstone and sandstone. Its contact with the formation beneath has not been seen. There seems, however, to be no sharp line between the two. The calcareous shales become more clayey and less limy, and gradually pass into a slate, and the intercalated thin layers of limestone are replaced by beds of flagstone or sandstone. This formation has usually been known as the Hudson River. It is commonly black in color, although green and red beds occur. Much of this formation has a marked tendency to split into thin sheets. This cleavage is not along the bedding planes or layers in which the slate was deposited, but cuts across them at various angles. It is in virtue of this tendency to split smoothly and regularly into thin layers that some zones of this formation yield excellent roofing slates.

There is considerable difference in the chemical constitution of various members of this formation, owing to the variations from slate to sandstone. Two analyses were published by Prof. Cook in the Geology of New Jersey, 1868, p. 136:

	No. 1.	*No. 2.*		*No. 1.*	*No. 2.*
Silica,	56.60	68.00	Soda,	0.50	0.11
Alumina,	21.00	14.40	Carbonic acid,	2.20	2.30
Protoxide of iron,	5.65	5.40	Sulphur,	.57	....
Lime,	3.42	2.68	Water,	3.00	2.70
Magnesia,	2.30	1.51	Carbon,	2.69	....
				99.03	99.1

No. 1 is the ordinary bluish-black roofing slate from the quarry at the Delaware Water Gap. No. 2 is a sandy thick-bedded slate from the Port Jervis turnpike, one mile northwest of Coleville. So far as the proportions of silica, alumina, iron and lime are concerned, these slates are not unlike some clays which are used in manufacturing Portland cement. Other analyses are given on pages 52, 74, 77 and 78. The geographical age of this formation is indicated in Mr. Weller's report.

The Geological Structure.—The general relations of these formations, *i. e.*, the Hardiston quartzite, the Kittatinny limestone, the Trenton limestone, and the Hudson River slate, are usually quite simple and easily understood. They have been bent into great folds, which originally formed a succession of arches and troughs. But during the enormously long period which has elapsed since the folding occurred, hundreds, perhaps thousands, of feet of strata have been worn off from the arches, so that beds which were once deep below the surface are now exposed to view. The axes of these folds extend in a northeast-southwest direction, so that the formations form long and comparatively narrow belts extending in the same direction. Along the central line of an upfold of the strata or *anticline* the older rock is exposed. The beds slant or *dip* away from the axis, and younger and higher beds are found towards the flanks. The Kittatinny limestone, being older than the Trenton and Hudson River, occurs along the central line of the anticlines.

The reverse relations are true where the strata are downfolded, *i. e.*, at the *synclines*. Here the younger beds are found along the medial line, towards which the strata dip and the older beds are found on the flanks. The accompanying section, figure 2, illustrates these relationships. As shown there, the

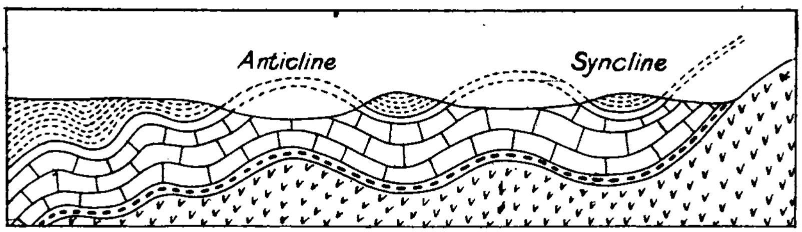


Fig. 2—Anticlinal and Synclinal Folds.

Trenton limestone, including the beds of "cement rock," occurs between the Kittatinny limestone and the Hudson River slate. It is found on the flanks of the folds, not along their axes, and it dips beneath the slate.

The simple structure of anticlinal and synclinal folds is often complicated by faults or fractures, along which the strata have moved past one another. The fault planes may be inclined at various angles, and the motion may have been in any direction along them. As a result of faulting a given bed may not appear at the surface, as is illustrated at B, figure 3, or it may be

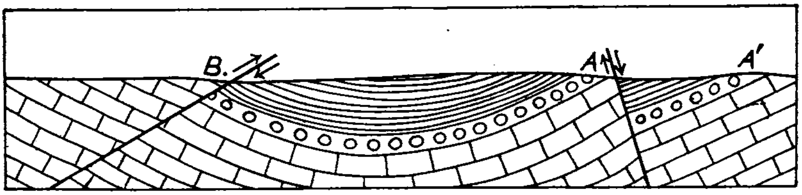
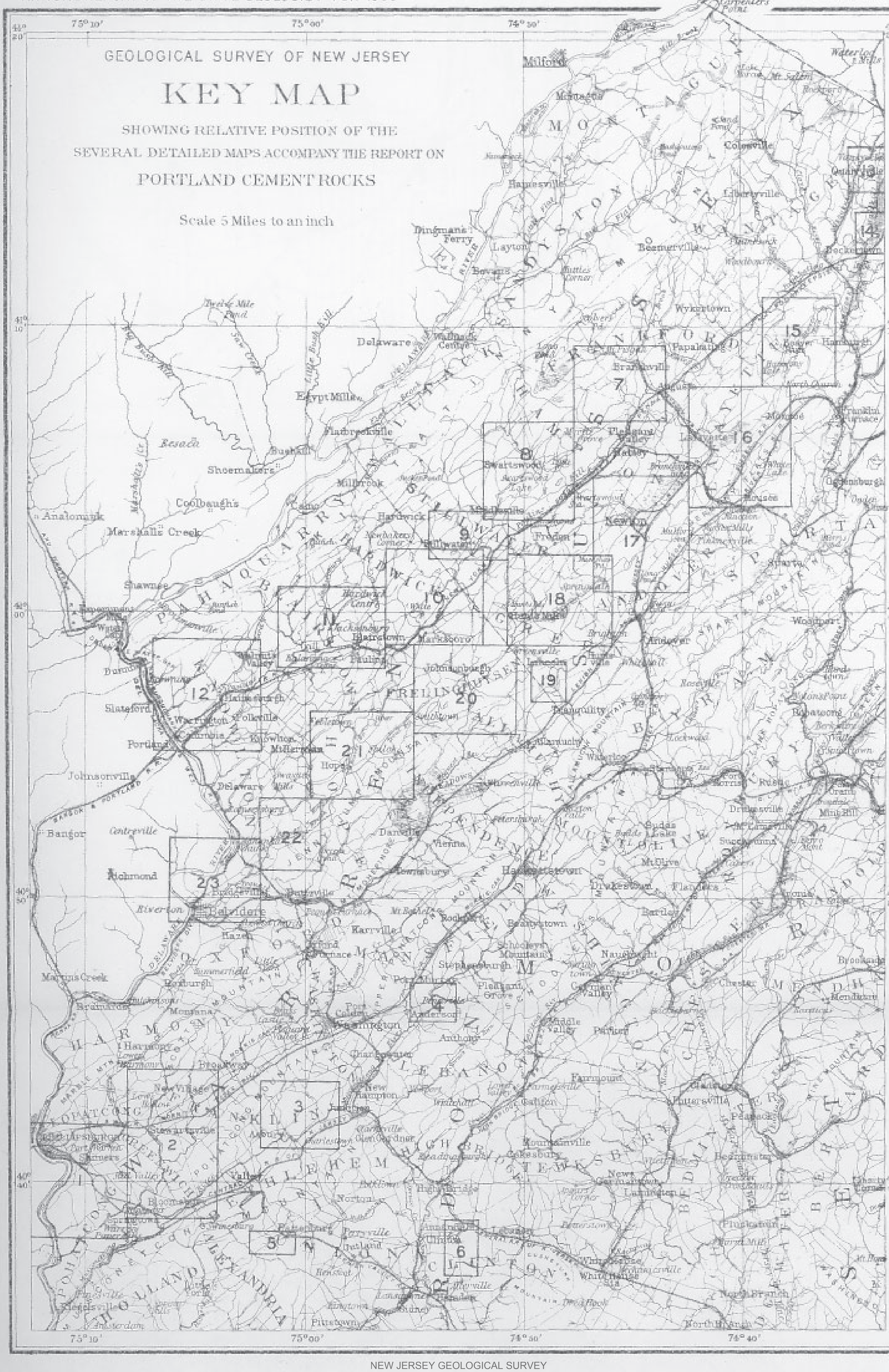


Fig 3—Section showing how faults may repeat an outcrop A and A', or may cut it out entirely, B.

repeated and form a double line of outcrops, A and A' in figure 3. Consequently, the Trenton limestone does not occur everywhere between the outcrops of slate and Kittatinny limestone where it is expected, and it sometimes does occur apparently in the midst of the older limestone formation where it is not expected. Again for long intervals the rock may be buried beneath thick accumulations of glacial drift, which conceal its outcrop, but in these cases it can always be found by digging. Numerous examples of these exceptions will be given below in Chapter III. The general boundaries of the slate and of the Kittatinny limestone are shown on the Geological Map, sheet 20 of the Atlas of New Jersey, and from it the extent of the Trenton limestone can be inferred. The actual exposures are shown on the large scale sketch maps accompanying the detailed descriptions in the next chapter. The location of these maps in reference to each other and to the area as a whole are shown on Plate I.


GEOLOGICAL SURVEY OF NEW JERSEY
KEY MAP
SHOWING RELATIVE POSITION OF THE
SEVERAL DETAILED MAPS ACCOMPANY THE REPORT ON
PORTLAND CEMENT ROCKS
Scale 5 Miles to an inch
Port Jervis
Milford
Hainesville
Dingman's Ferry
Layton
Beemerville
Colesville
Libertyville
Wykertown
Delaware
Egypt Mills
Flatbrookville
Bushkill
Shoemakers
Coolbaugh's
Marshalls Creek
Shawnee
Swartswood
Newton
Branchville
Augusta
Lafayette
Hamburg
Franklin Furnace
Ogdensburg
Sparta
Andover
Blairstown
Hope
Columbia
Portland
Slateford
Johnsonville
Bangor
Richmond
Belvidere
Riverton
Hackettstown
Washington
Oxford Furnace
Stewartsville
New Hampton
Asbury
Bloomsbury
Clinton
Lebanon
Whitehouse
Califon
Pittstown
Frenchtown
Milford
Stanhope
Dover
Chester
Mendham
Port Morris
Budd's Lake
Mt. Olive
Schooley's Mountain
German Valley
Peapack
Bedminster
North Branch
Flemington
75° 10'
75° 00'
74° 50'
74° 40'
41° 20'
41° 10'
41° 00'
40° 50'
40° 40'

CHAPTER III.

Detailed Description of Trenton Limestone and Cement Rock Areas.

The most important area of Trenton limestone and cement rock is found southeast of Phillipsburg. It extends from Carpentersville northeast, through Still Valley and Stewartsville, almost to New Village. Its limits are shown on the accompanying maps, figures 4 and 5. Its width varies from hardly two

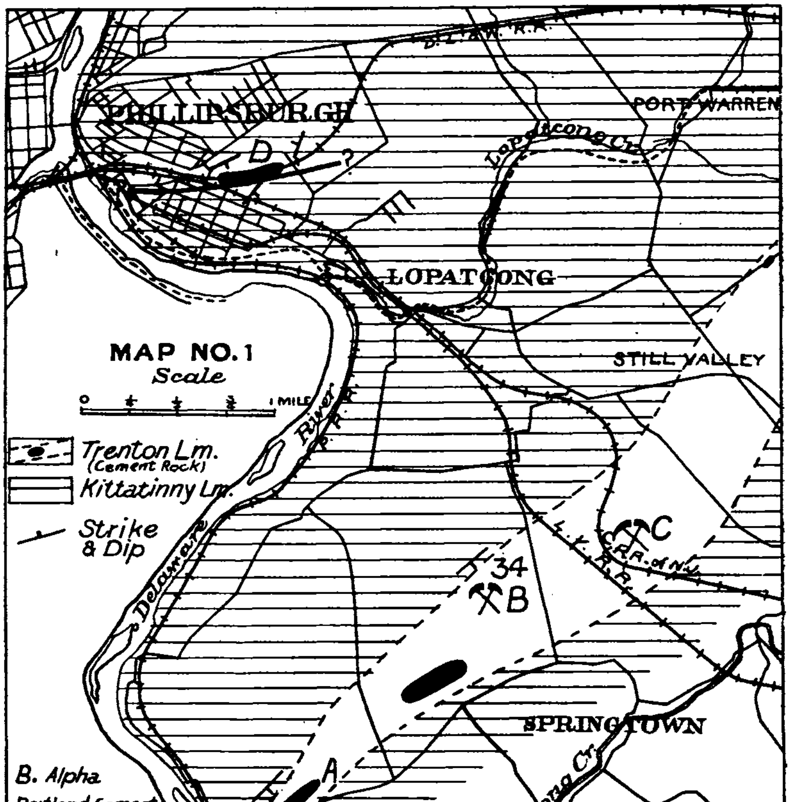


Fig. 4—The Trenton Limestone, near Phillipsburg.

hundred yards to about half a mile, although in most places its limits cannot be determined accurately owing to drift deposits. Near Carpentersville the belt is narrowest. Outcrops are found along the crest and southern slope of a narrow ridge north of the Carpentersville schoolhouse (A, figure 4). Much of the rock is a pale pinkish color when weathered, although black on a fresh surface. Along the northern slope of the ridge the magnesian limestone outcrops. Only the cement rock is found here. The limestone layers are apparently deeply buried along the bottom of the hollow followed by the road. Analyses of the rock in this vicinity* have been obtained from Mr. Clarence L. Murphy, Plainfield, N. J., and are here given.

ANALYSES OF CEMENT ROCK, MURPHY FARM, CARPENTERSVILLE.

Silica.	*Iron and Alumina.*	*Lime.*	*Magnesia.*	*Calculated CO.*
17.707	7.915	41.794	.380	33.248
14.595	6.861	40.296	.671	32.500
10.712	5.982	39.999	.654	32.148
10.262	7.186	44.722	1.401	36.682
20.578	5.441	39.839	.629	31.997

Northeast of these outcrops the rock is deeply covered with drift until in the vicinity of the Alpha and Vulcanite Portland Cement Companies' works (B and C, figure 4). The cement rock is well exposed in the quarries of these companies as well as in the railroad cuts along the Central Railroad of New Jersey and the Lehigh Valley. In the railroad cuts the rock is seen to be frequently faulted by overthrusts, and much sheared. Near the middle line of the belt the beds are closely folded and crushed, being locally doubled over upon themselves in closely compressed synclines and anticlines. Towards the margins the dips are more regular. Along the northern flank the dip averages about 25°-30° southward. The beds are greatly sheared, but the shearing follows for the most part the bedding planes.

Nearly all traces of fossils have been destroyed by the shearing, but a few crinoid stems are distinguishable, and many of the light streaks of crystallized calcite marking certain layers are long-

*These samples were taken from different openings separated from each other within an area of one-half mile.

drawn-out crinoid stems. The typical knotty blue-black limestone of the Trenton is not exposed in these cuts nor in the quarries. It is apparently deeply buried along the margins of the formation. From the dips shown in the railroad cuts, these beds probably form a complicated synclinal fold underlain by the Kittatinny or magnesian limestone. The greater width of the belt here as compared with that at Carpentersville is probably due to the greater complexity of the folding. A part of the belt may be faulted off at Carpentersville, although no positive evidence of this was obtained.

The constitution of the cement rock is given on page 22. Another analysis of a specimen taken at random from the Alpha quarry shows a slight excess of lime necessary for Portland cement, even according to the maximum of Newberry's formula.

ANALYSIS OF CEMENT ROCK FROM THE ALPHA PORTLAND CEMENT CO.
LOCALITY NO. 34.

1. Silica,	9.68
2. Alumina and iron oxide,	7.29
3. Lime,	45.94
4. Magnesia,	1.29

In the vicinity of Still Valley the rock is covered with drift, and no outcrops were observed. But along the road one mile southwest of Stewartsville (figure 5) typical knotty fossiliferous Trenton limestone was found at the base of the formation in close proximity to the magnesian limestone. Southwest of Stewartsville the belt is much narrower than at Vulcanite, and the explorations made by the Edison Company appear to show that the cement rock and the magnesian limestone are intimately associated, as if the rocks were here greatly crushed and faulted. The boundaries shown on the sketch map are probably only approximately correct.

Northeast of Stewartsville all rock outcrops are covered by a mantle of drift until the quarry of the Edison Portland Cement Company is reached (A, figure 5). Here both the limestone and the cement rock are found, the former being exposed in contact with the Kittatinny or magnesian limestone. The contact seems to be along a fault plane, but the disturbance is probably slight, as the two formations agree somewhat closely in dip and occasional magnesian limestone pebbles occur in the lower beds of the Trenton. The heavy limestone layers are about 45 feet thick, and

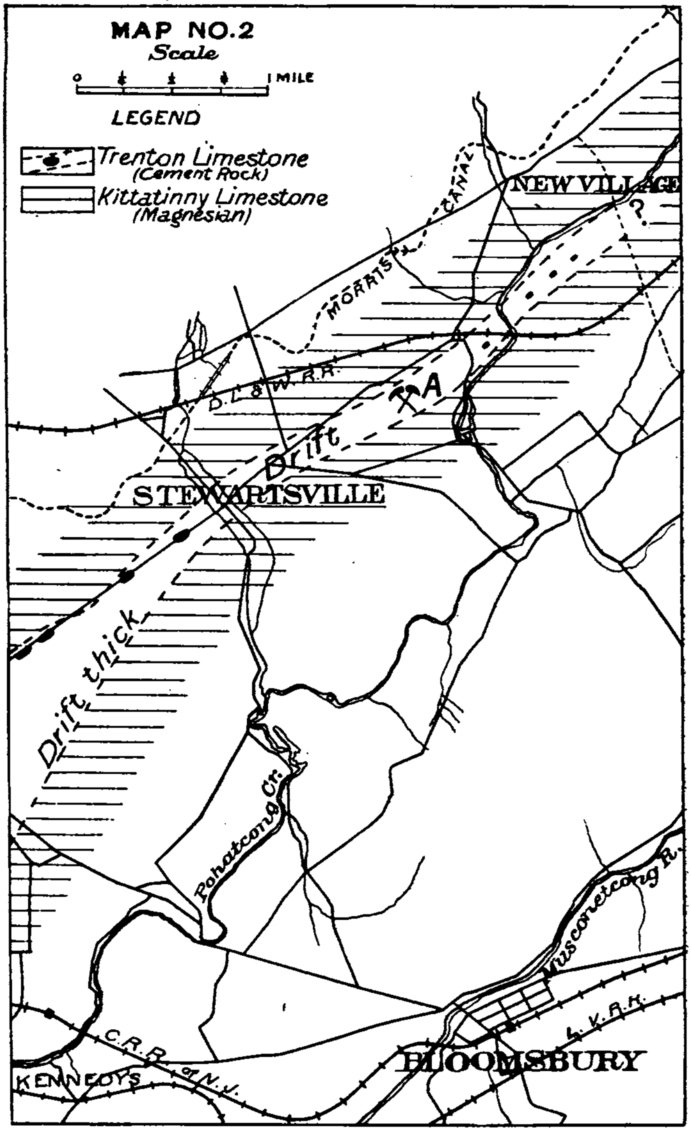


Fig. 5—Outcrops of Trenton Limestone, near Stewartsville.

dip steeply 75°-80° to the southeast, the beds being slightly overturned. The adjoining Kittatinny limestones are vertical.

Above the limestone layers come the more earthy beds, the so-called "cement rock," which were exposed, at the time of our visit, in a row of prospect holes. This belt is between 700 and 800 feet wide, the layers, so far as could be determined, forming a compressed and slightly overturned syncline, both limbs dipping to the southeast. Very considerable shearing has accompanied the folding.

The Edison company has tested the rock very thoroughly by means of drill holes and chemical analyses. Their analyses show (1) at the base of the formation about sixty feet of limestone, which is almost a pure lime-carbonate. Above this comes (2) about 100 feet of rock less pure, but still high in lime, then (3) about 130 feet of cement rock of almost exactly the proper proportions, and (4) in the central part of the syncline still higher beds, which are too low in lime for Portland cement as they stand, but which can be readily brought to the correct proportions by adding material from either 1 or 2.

A number of analyses obtained from Mr. Edison of samples from this locality are given below. No. 1-16, inclusive, are from drill-hole No. 2, the others from drill-hole No. 3. These drill-holes traversed the beds at right angles, so that the analyses show the variations from layer to layer.

ANALYSES OF CEMENT ROCK, EDISON PORTLAND CEMENT COMPANY.

	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	CO_2 (*Calculated.*)
1, ...	23.04	8.15	2.41	33.70	.83	27.40
2, ...	19.32	7.00	1.99	36.86	1.06	30.14
3, ...	19.51	7.05	2.03	36.80	1.18	30.20
4, ...	23.68	8.12	2.57	33.30	1.41	27.57
5, ...	20.29	6.85	2.11	36.84	1.34	30.29
6, ...	19.98	7.23	1.99	36.78	.58	29.54
7, ...	21.10	7.68	1.92	35.45	.48	28.38
8, ...	18.15	6.08	1.78	38.00	1.63	31.65
9, ...	21.32	8.16	2.22	35.19	undet.	27.56
10, ...	21.72	8.27	2.34	35.30	"	27.73
11, ...	33.90	11.94		27.00	"	21.21
12, ...	35.95	11.28		25.71	"	20.20
13, ...	31.39	10.48		38.84	"	22.66
14, ...	17.97	8.27		37.87	"	29.76
15, ...	24.91	8.40		34.44	"	27.02
16, ...	35.07	11.60		25.64	"	20.14

	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	CO_2. (Calculated.)
17, ...	19.17	6.23	2.57	37.51	undet.	29.47
18, ...	20.20	5.92	2.53	37.51	"	29.47
19, ...	16.97	6.08	2.26	38.29	"	30.09
20, ...	19.87	7.83	3.95	35.61	"	27.94
21, ...	16.81	9.76		38.81	"	38.81
22, ...	17.96	7.11	2.53	37.95	"	29.82

The cement rock is found again at various points further northeast on the south side of the Pohatcong creek, south of New Village, where it has been exposed in prospecting holes. Its extension still further northeast is uncertain owing to the thick deposits of drift. If present at all, it is probably to be found along the center of the valley on the southeast side of the creek.

Phillipsburg.—The rock underlying Phillipsburg is almost entirely the Kittatiny or magnesian limestone. A small mass of the Trenton cement rock, however, was found in a cut along the Delaware, Lackawanna and Western Railroad, one-quarter of a mile east of their round-house (D, figure 4). At the west end of the cut massive beds of Kittatinny limestone occur, with an average dip of 45° S., 27° E. A little further east the Trenton limestone and shale are found resting upon the unevenly eroded surface of the older limestone. Small water-worn pebbles of magnesian limestone occur in the basal beds of the Trenton, but the typical basal conglomerate is not developed. The rock is chiefly a thin-bedded calcareous shale, which dips in general 20° to 30° S. 10 E., and in which crinoid stems and bryozoans were found by Mr. Weller. Near the eastern end of the cut the Trenton beds on the south wall are overlain by the older magnesian limestone, but the contact is not shown. These beds have undoubtedly been overthrust upon the Trenton shales in the manner indicated in figure 6. The area is too small to be of any importance commercially.

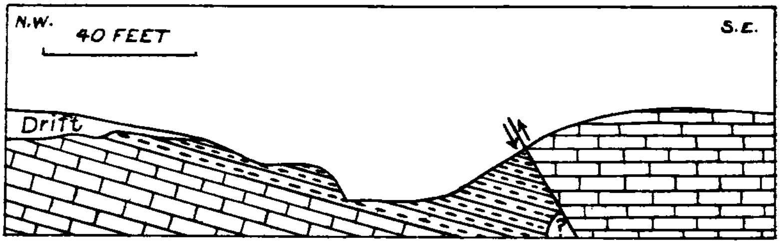


Fig. 6—Section showing the probable relations of the Trenton and Kittatinny Limestones in the D. L. & W. railroad cut, at Phillipsburg.

Asbury.—Northwest of Asbury there is a narrow belt of Hudson River slate inclosed in a compressed overturned syncline of the magnesian limestone. The Trenton limestone ought to occur along the boundary of the slate area, between that and the older limestone. Traces of it have been found at the two localities northwest of Asbury, shown in figure 7. At A small obscure

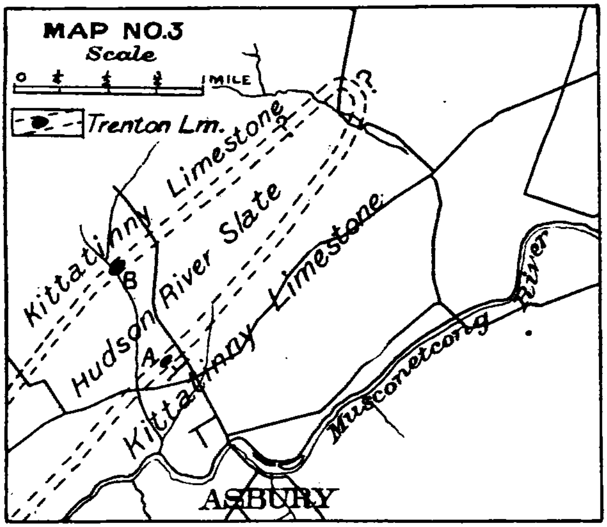


Fig. 7—Outcrops of Trenton Limestone, near Asbury.

exposures of a limestone conglomerate were found in a peach orchard, between the slate and the magnesian limestone, and detached fragments of the conglomerate were noted at a number of localities in the neighborhood. No exposures of the fossiliferous limestone nor of the cement rock, however, were found, although they are undoubtedly present, but perhaps at a considerable depth. At B, one mile northwest of Asbury, the typical fossiliferous limestone, with some pebble-bearing layers, was found in a small exposure on the side of a deep ravine. It occurs on the northwestern limb of the syncline, and dips steeply southeast, so that the width of outcrop of the entire formation would probably not be more than 200 feet. There are no exposures of the cement rock, but trenching would probably expose them.

Pennwell (Penville).—A much larger area of Hudson River slate extends from Hackettstown almost to Port Colden. This, also, is a compressed syncline in structure, but the limestone on the northwestern flank has been cut out by a fault, which brings the slate against the gneiss of Pohatcong mountain. No Trenton limestone is known to occur along this boundary of the slate, and it is hardly possible that any exists there. It ought to be present, however, along the southeastern border from Hackettstown to Anderson and beyond. It was found at one locality only, at the quarries near Pennwell (A, figure 8). Elsewhere the border of

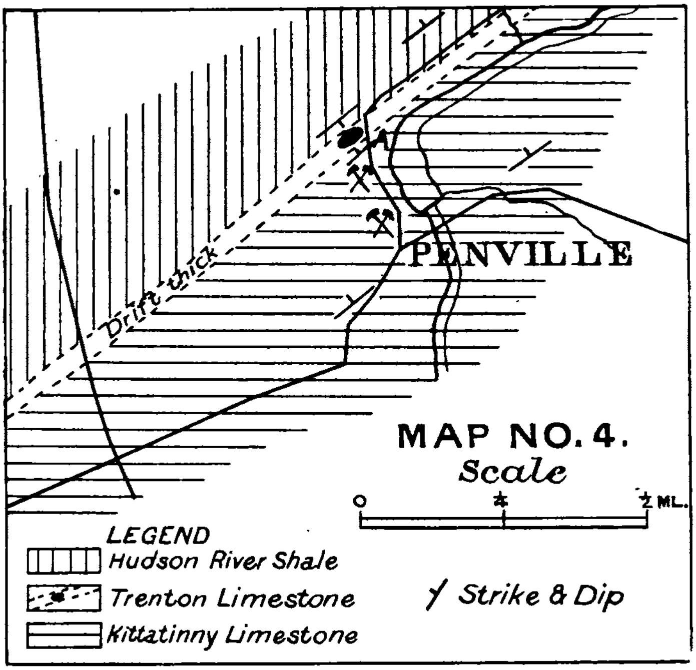


Fig. 8—Outcrop of Trenton Limestone, near Penville.

the slate is usually marked by a drift-filled depression, which is undoubtedly underlain by the Trenton limestone. The greater solubility of the Trenton rocks, as compared either with the slate or the magnesian limestone, aided in the formation of this depression, which is filled with early glacial drift and wash from the neighboring slopes.

At the westernmost of the Pennwell limestone quarries, the fossiliferous Trenton limestone, with a few feet of the basal conglomerate, was found resting against the vertical beds of the magnesian limestone, and parallel with them. The conglomerate layers are found at the west side of the quarry, just back of the lime-kiln. A few feet away the knotty, semi-crystalline blue-black fossiliferous limestone is found. A few rods further west in a deep ravine, weathered beds of calcareous shale occur. Still further west is the slate. The thickness is probably 140 or 150 feet, the beds being nearly vertical.

Pattenburg.—A mile southwest of Pattenburg outcrops of Trenton "cement rock" were found along a brook (figure 9).

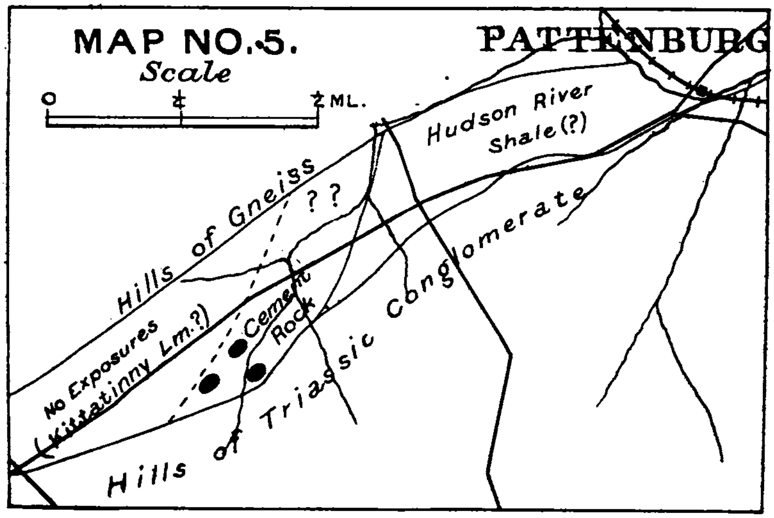


Fig. 9—Outcrops of Trenton Limestone, near Pattenburg.

The rock is so crushed and slickensided that nearly all fossils have been destroyed, but a few obscure forms were found by Mr. Weller. Owing to deposits of glacial drift and of wash from the surrounding slopes, and the consequent absence of exposures, the limits of the formation are somewhat doubtful. It is reported to cover at least 150 acres, and to exceed sixty feet in depth. A company has been formed and preliminary steps towards utilizing this rock for cement have been taken. The following analyses of two average lots of the rock were obtained from Mr. Chester Tomson, of Clinton:

ANALYSES OF CEMENT ROCK NEAR PATTENBURG.

Silica (SiO_2),	8.42	18.60
Alumina (Al_2O_3),	2.30	5.80
Lime (CaO),	44.64	38.76
Magnesia (MgO),	.36	.66
Calculated carbon dioxide (CO_2),	34.47	31.20

A sample lot of cement was made from this rock, mixed with the proper amount of pure limestone. The cement analyzed as follows:

ANALYSIS OF SAMPLE LOT OF PORTLAND CEMENT.

Silica (SiO_2),	21.52
Alumina (Al_2O_3),	11.00
Lime (CaO),	60.87
Magnesia (MgO),	3.30

The cement was reported to have stood the standard tests well, and to have shown a high tensile strength after setting.

Annandale.—The Kittatinny limestone and the Hudson River shale are found in the vicinity of Clinton and Annandale, but the Trenton beds were found along their boundary at only one point. Elsewhere the two formations seem to have been faulted against each other. That the rocks have been greatly disturbed is shown by the fact that in a railroad cut near Jutland eighteen faults were noted in the Hudson River shale within one hundred yards.

A small outcrop of the Trenton limestone occurs on the bank of the brook west of the farm buildings of Thos. Connolly, a mile and a half south of Annandale (A, figure 10). The rock is slightly conglomeratic, magnesian limestone pebbles up to one inch in diameter being abundant in some layers. The thickness of the beds exposed is not more than eight feet. Thirty feet to the west are outcrops of the Hudson River slate, and eight feet to the east are ledges of the magnesian limestone, so that the maximum possible thickness here, fifty feet, is much less than the normal thickness. Elsewhere along the contact line the formation is apparently entirely cut out by the fault.

Just south of Gano's quarry (B, figure 10), at Annandale, a black shale outcrops in the brook. It resembles slightly the

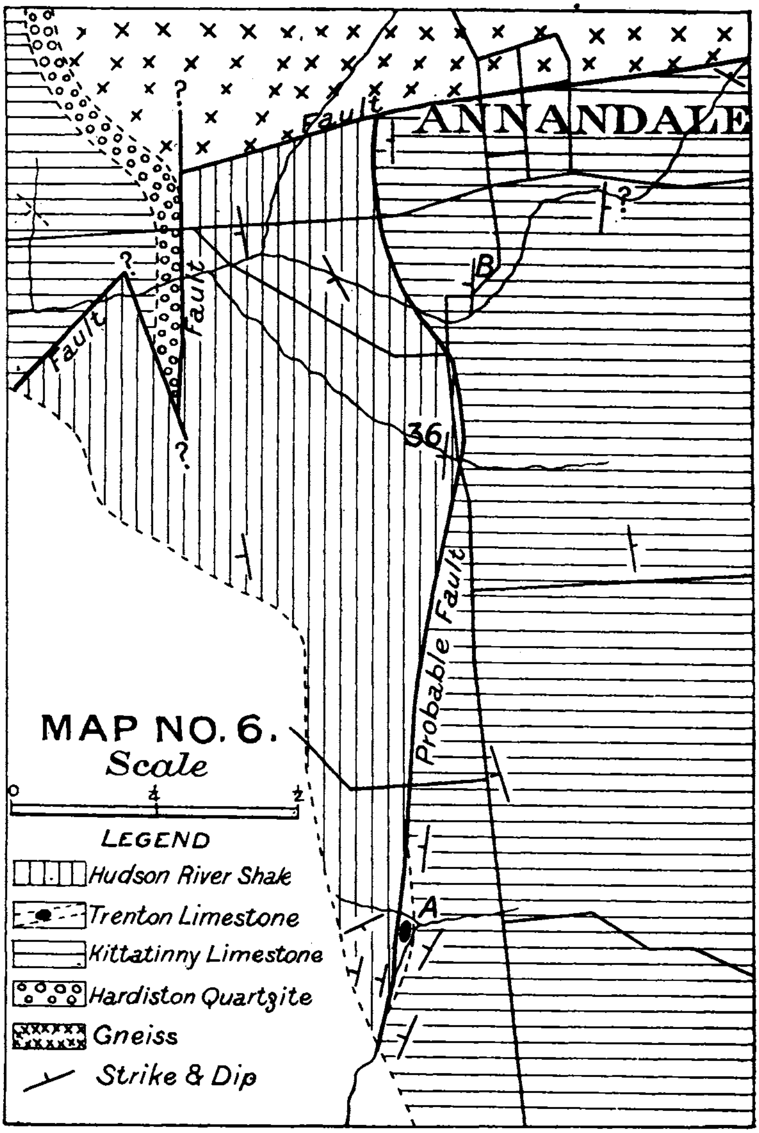


Fig. 10—Outcrop of Trenton Limestone near Annandale.

"cement rock," but upon analysis it was found to have the following composition:

ANALYSIS OF SHALE. LOCALITY NO. 36.

Insoluble, including silica,	77.53
(Silica),	(58.76)
Oxide of iron and alumina,	10.10
Lime,	3.56
Magnesia,	4.28

Branchville.—An anticline of Kittatinny limestone, two to three miles wide, extends from Branchville to the Delaware river. Normally the Trenton limestone would form a narrow belt along its flanks next to the slate. The southeastern flank, however, has apparently been faulted, for the Trenton has been found there at only four localities, and at many points the slate and magnesian limestone outcrop so close to each other as to render it certain that only a fraction of the Trenton formation,

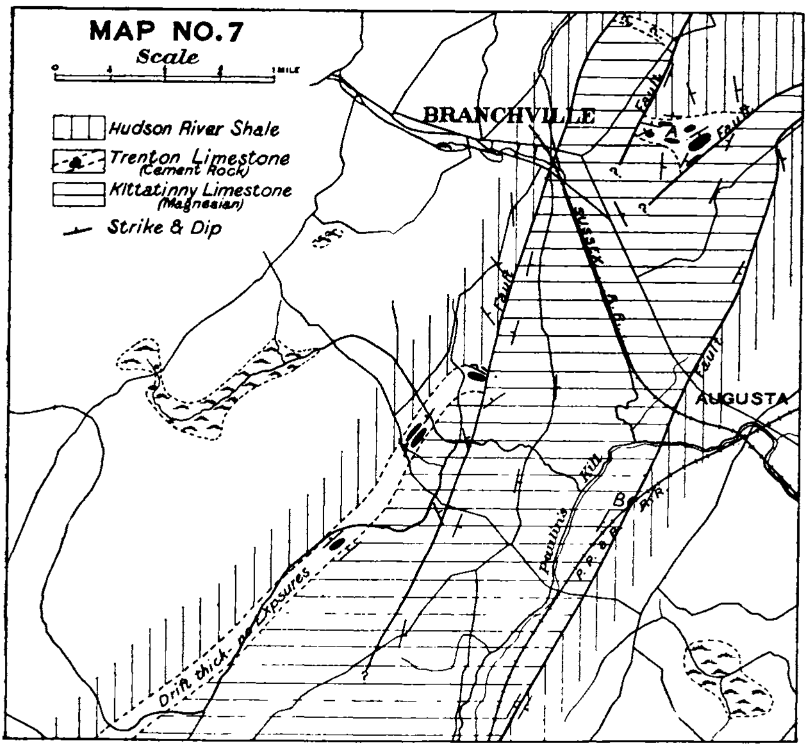


Fig. 11—Outcrops of Trenton Limestone, near Branchville.

if any, can occur in the interval. Elsewhere heavy glacial deposits along this line may conceal the formation. It outcrops more commonly, however, along the northwestern border, but at few points has been cut out by faulting.

Half a mile east of Branchville, on the lands of Jesse G. Roe (A, figure 11) beds of Trenton occur on the southern brow of a high hill, the summit of which is slate, and the lower slope the Kittatinny limestone. They are nearly horizontal, dipping gently northward so as to pass beneath the slate. The rock is here a dark blue, fossiliferous limestone, some layers of which contain small pebbles of magnesian limestone. An analysis by Dr. Cook* showed nearly ten per cent. of carbonate of magnesia. Descending the hill to the east, the pebbly beds grade into a heavy basal conglomerate, in which the fragments of older limestone and chert range up to one foot in diameter. The cement rock is not exposed, but perhaps can be found near the slate. This area is a somewhat extensive one, but the presence of the magnesian limestone pebbles in much of the formation is detrimental to its use for Portland cement.

South of Branchville and northwest of the Warren county poor-house good exposures of the Trenton beds are found (1, figure 11). The beds dip 17° northwestward, and the following section occurs, beginning at the base:

1. Limestone beds,	24 ft.
2. Mostly calcareous shales (cement rock?),	38 "
3. Limestones with some shaly layers,	12 "
4. Calcareous shale (cement rock?) with some heavy limestone layers,	30 "
5. Unexposed—in part at least probably cement rock,	130 "
Total,	234 "

An analysis of a sample of limestone from the lower beds gave the following result:

ANALYSIS OF TRENTON LIMESTONE. LOCALITY NO. 1.

Insoluble, including silica,	2.27
Oxide of iron and alumina,	0.46
Lime,	54.98
Magnesia,	0.84

* Geology of New Jersey, 1868, p. 133.

This is a remarkably pure limestone, since the maximum amount of lime in any limestone is 56 per cent. It is not a cement rock itself, but mixed in the proper proportions with rock from the more shaly layers it ought to make good cement, or burned by itself furnish a fine quality of quick-lime. Similar beds are exposed one-fourth of a mile northeast and also about one-half mile southwest. Elsewhere in this vicinity the formation is thickly covered by glacial deposits.

Augusta.—Half a mile southwest of Augusta (B, fig. 11) a small exposure of Trenton limestone is found in a railroad cut. The maximum thickness possible between the adjoining outcrops of Kittatinny limestone and Hudson River slate is 25 to 30 feet. This is the only exposure of Trenton found along this side of the Kittatinny limestone anticline from Augusta to near Blairstown. Owing to faulting, only a small part of the normal thickness is here present.

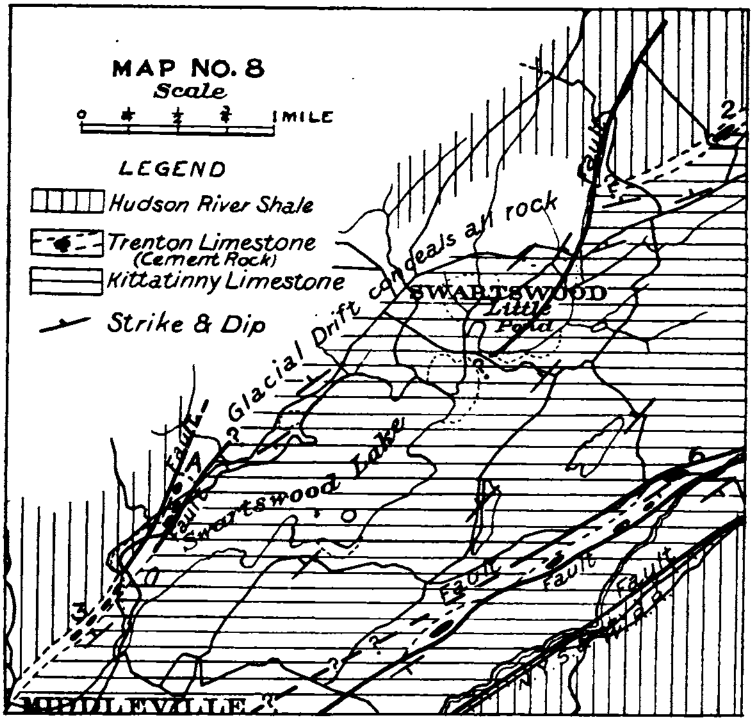


Fig. 12—Outcrops of Trenton Limestone, near Swartswood.

Myrtle Grove.—Three-quarters of a mile southwest of Myrtle Grove (2, fig. 12) ledges of the Trenton limestone occur on the hillside above the road from Swartswood lake to Branchville. The lower beds of hard, knotty, blue limestone outcrop here, and fragments of the more shaly layers, resembling the cement beds, occur on the surface, but the beds themselves are not exposed. The rocks dip gently to the northwest at a comparatively low angle, and the belt has a width from 125 to 150 yards.

A slightly weathered sample of limestone on the surface gave the following upon analysis:

ANALYSIS OF EARTHY LIMESTONE. LOCALITY NO. 2.

Insoluble (including silica),	11.86
Oxide of iron and alumina,	1.09
Lime,	48.36
Magnesia,	0.56

Owing to the weathering the per cent. of lime is lower, and that of the other elements, particularly silica, slightly higher relatively than in a perfectly fresh specimen. It is highly probable that a good Portland cement can be made by the proper combination of rocks from this vicinity.

Swartswood Station.—Trenton shaly beds occur on the road from Swartswood to Swartswood station, just west of the Paulinskill (6, fig. 12). The belt is 150 yards in width, and lies between hills of the older magnesian limestone. The beds dip 27° southeastward, and are fossiliferous, but the fossils are much distorted by shearing. To the northeast the outcrops soon disappear beneath the flood plain and terraces of the Paulinskill. To the southeast outcrops both of the limestone and of the shaly layers occur at frequent intervals for about a mile. Near the house on the Joseph Snyder farm the basal conglomerate, containing bowlders one and a half to two feet in diameter, occurs, as well as beds of pure limestone and of calcareous shale. Near William Stickle's the magnesian limestone apparently closes in and pinches out the Trenton beds. But an isolated knoll with some of the conglomerate layers was found in the woods along this same line one-third of a mile southwest of Stickle's. The probable structural relations of these Trenton beds in the midst of the Kittatinny limestone are shown in figure 13. The anti-

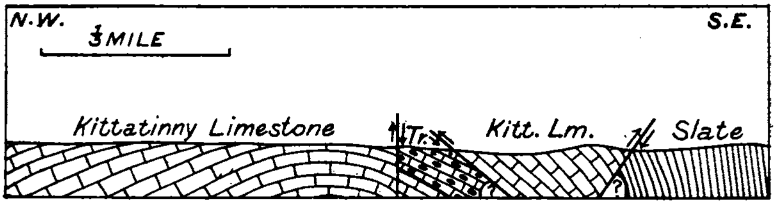


Fig. 13—Probable relationships of the Limestones and Slate northwest of Swartswood Station.

cline is profoundly faulted along its axis, and the southeastern half depressed, thus bringing down the Trenton. On the southeast the Kittatinny limestone seems to have been overthrust to the northwest upon the Trenton beds.

The proximity of this deposit to the railroad, one-third of a mile distant, makes it a valuable locality. It was impossible without digging to secure a perfectly fresh specimen, but a sample of the somewhat weathered shale gave the following result upon analysis:

ANALYSES OF EARTHY TRENTON LIMESTONE. LOCALITY NO. 6.

Insoluble (including silica),	43.38
(Silica),	(33.48)
Oxide of iron and alumina,	4.37
Lime,	24.89
Magnesia,	3.74

According to this analysis the rock is rather high in silica and low in lime, and also approaches the danger limit in magnesia. A considerable proportion of the insoluble residue, less the silica, is probably iron and alumina. Analysis of a fresh unweathered specimen from a depth of several feet would probably show a rock with more lime and relatively less silica, a rock which might be used. The above analysis hardly does justice to these beds.

Swartswood.—In the vicinity of Swartswood village the drift accumulations are so heavy that it is impossible to determine with certainty the underlying formation. The structure is apparently complicated by numerous faults, and no Trenton beds were found, but near the southwest end of the lake there are several well-marked areas. The first of these is near Bellview cottage (fig. 12, A). The Trenton beds are well exposed (1) along the highway, (2) in an abandoned railroad cut, and on the hillside above the cottage. At the water's edge, just south of the cut and north of a swamp, the horizontal beds of Trenton and Kittatinny limestone are faulted against each other, the fault line being visible at low water. On the hillside above the cottage the bed dips 15° to 20° to the southeast, so that the lowest beds, a basal conglomerate of Kittatinny limestone pebbles four or five inches in diameter, in a matrix containing Trenton fossils, occur higher on the slope. Adjoining them, and still higher, are ledges of Hudson River slate. The structure is shown on the accompanying section (fig. 14). The beds exposed here are

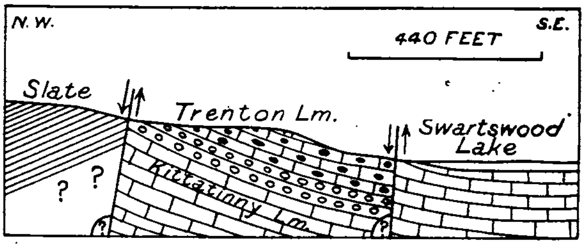


Fig. 14—Probable Structure near the south end of Swartswood Lake.

chiefly limestone, but doubtless some of the shaly layers are also present.

At the extreme southeast end of the lake the Trenton beds are shown along the highway, and can be traced, without difficulty, southwest across the hill almost to Middletown (3, fig. 12). The belt is about ninety yards wide, and the outcrop of the harder limestone layers is almost continuous, while the more earthy layers make shallow depressions between them. The line of outcrops can be readily recognized by a belt of cedars, which stand in marked contrast to the cleared fields on the slate and to the deciduous woods on the magnesian limestones. A sample from a bed of dense black limestone was analyzed with the following result:

ANALYSIS OF TRENTON LIMESTONE. LOCALITY NO. 3.

Insoluble (including silica),	10.49
Oxide iron and alumina,	.75
Lime,	49.10
Magnesia,	1.13

The accompanying shaly layers would probably show a higher content of silica and alumina and a lower per cent. of lime, so that the proper combination of lime, silica and alumina can, perhaps, be obtained here. The locality is, however, some distance from a railroad.

Stillwater.—A mile northeast of Stillwater station ledges of coarse conglomerate occur at the bend of the road in front of Mr. William Roy's (A, fig. 15). The basal portion of the con-

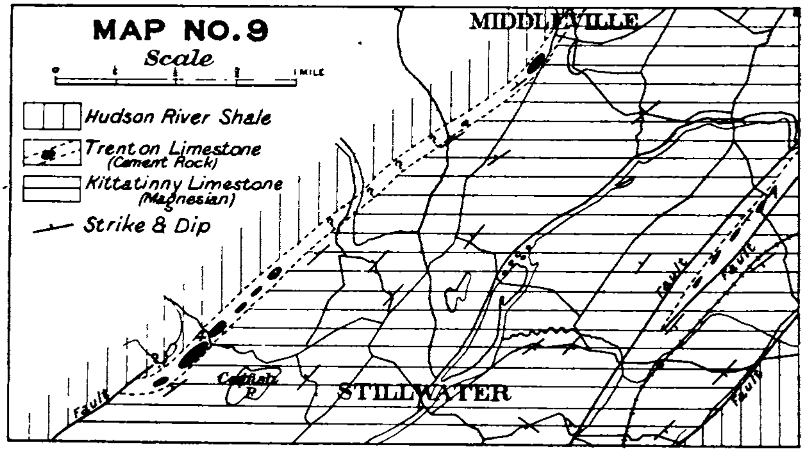


Fig. 15—Outcrops of Trenton Limestone, near Stillwater.

glomerate, which has a thickness of thirty or forty feet, can be distinguished with difficulty from the underlying limestone, but the pebbles in the higher beds are better rounded, and its aqueous origin can hardly be questioned. A few rods to the south beds of calcareous shale were noted by the roadside, which aid in correlating this horizon with the Trenton. Ledges of the conglomerate occur in the fields to the southwest for half a mile, but owing to the heavy drift deposits the fossiliferous limestone and shale beds are not shown. These outcrops are in line with those northwest of Swartswood station, and are probably due to the same system of faults along the axis of the anticline. Although near the railroad, it is doubtful whether this area is valuable commercially.

For nearly two miles southwest of Middleville only traces of the Trenton beds can be found, owing to the heavy drift deposits. But northwest of Stillwater, on the farm of Edward Mains (4, fig. 15), the limestone is quarried and burned for lime. The rock forms a prominent hill between the higher hills of slate and the rough-wooded ledges of the Kittatinny limestone. On the adjoining property to the northeast is another small quarry. The quarries are in the limestone layers rather than the shaly beds, which do not outcrop prominently, although doubtless present. Specimens from both these quarries were analyzed by Dr. Cook,* with the following results. The first represents an average from Wesley A. Mains' quarry, the second was from A. T. Mains' quarry:

ANALYSES FROM NEAR STILLWATER. LOCALITY NO. 4.

	I.	II.
Silicic acid and quartz,	1.8	15.8
Alumina and iron oxide,	.2	1.6
Lime,	54.7	43.2
Magnesia,	....	2.2
Carbonic acid,	43.0	31.4
Alkalies,	.4	....
	100.1	94.2

The first of these two shows a remarkably pure limestone, nearly 98 per cent. carbonate of lime. This rock can be used to good advantage to mix with a cement rock which is deficient in lime, such a rock as can probably be found between the slate and these quarries. The distance from a railroad is, however, a serious drawback to the utilization of these beds. The limestone is also valuable for making quick-lime, to which use it is sparingly put.

* Geology of New Jersey, 1868, p. 398.

Half a mile southwest of Mains' quarry the Trenton is apparently cut out by faulting, and the Kittatinny limestone adjoins the slate for a short distance. But it soon reappears in a series of small knolls below the steep hillside of the slate, both north and west of Mud pond (A and B, fig. 16). Thence the belt can be traced by somewhat frequent exposures to a small quarry

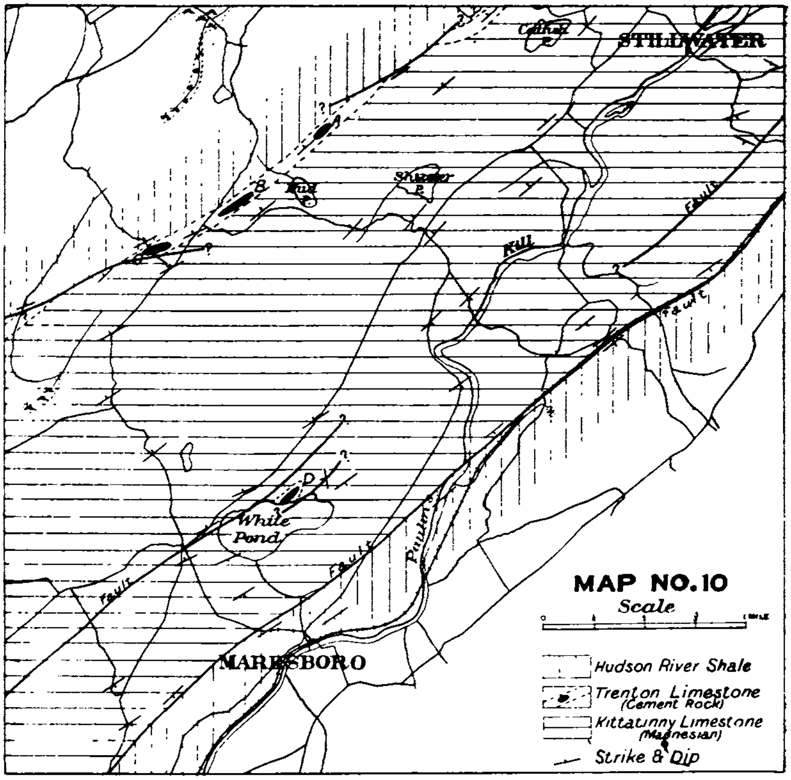


Fig. 16—Outcrops of Trenton Limestone, north of Marksboro.

near the house of Clark Hill (C, fig. 16). Here the beds have a thickness of 140 feet, dipping 25° to the northwest. The exposures are chiefly the same pure limestone layers as are exposed in Mains' quarry, and also north of Mud pond. The slate is well exposed along the highway just above and west of the Trenton beds. An abundance of pure limestone can be obtained at many points along this belt, and the cement rock layers, although not exposed conspicuously on the surface, are doubtless present, interbedded with the limestones and between them and the slate.

White Pond.—Several knolls of Trenton limestone and cement rock, surrounded by ledges of magnesian limestone, occur in the woods on the north side of White Pond, near Marksboro (D, fig. 16). The rock is much sheared, owing to the faulting by which it was brought to this position near the axis of the anticline, a position similar to that of the beds northeast of Stillwater station, and also northwest of Swartswood station. Its exact limits cannot be readily determined, nor can the sequence of beds be made out, but the rock, so far as shown, is apparently an earthy limestone of chemical composition suitable for cement. No analysis of it, however, was made.

In this connection the shell-marl deposits of White Pond may be mentioned. The shores and bottom of the pond are covered with a thick deposit of shell marl which exceeds fourteen feet in thickness at many places. A partial analysis of this marl is here given:*

ANALYSIS OF MARL FROM WHITE POND.

Carbonate of lime,	92.25	(Lime, 51.66)
Carbonate of Magnesia,	2.98	(Magnesia, 1.42)
Sand and clay,	1.56	
Water, vegetable matter, etc.,	3.21	
	100.00	

This marl, in its high content of lime and low content of magnesia, can be used with clay for Portland cement. Similar marls are successfully used in Michigan and Indiana. The fact that no expensive grinding is necessary, as in the case of a hard limestone, is an important point in favor of the marl.

During the early part of the year (1900) negotiations were begun by capitalists for control of the surrounding property with the intention of erecting a Portland cement plant here. We were informed that the necessary rights had been purchased, but at time of writing matters seem to be at a stand-still. The marl

* Annual Report of the State Geologist for 1877, p. 24.

is present in practically unlimited amounts, and analysis shows that it is of good quality. The clay necessary can, perhaps, be found beneath the marl, or can be readily imported, or the slate which occurs in great abundance near at hand can be used after fine grinding. The locality is not far from a railroad. From the standpoint of the raw materials there is apparently no reason why the enterprise should not be successful.

Jacksonburg.—Southwest of Clark Hill's (C, fig. 16), the Trenton beds are either cut out by faulting or covered by thick glacial accumulations, so that no outcrops are found for two miles or more, save a small exposure in the bank of Blair's Creek,

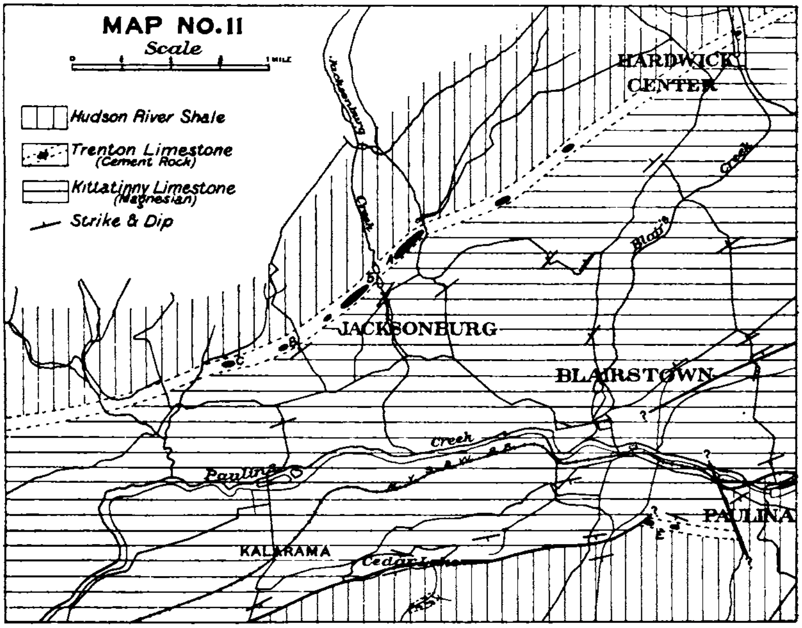


Fig. 17—Outcrops of Trenton Limestone, near Jacksonburg and Blairstown.

near the north end of the mill-dam, at Hardwick Center (fig. 17). For the next two miles, also, the drift is thick, and only occasional small exposures are found, but in the vicinity of Jacksonburg, one mile northwest of Blairstown, the formation is well developed and finely exposed. The rock occurs along the brow of the hill just back of the grist-mill (5, fig. 17). The Kittatinny limestone forms the precipitous slope below, and the slate outcrops along the summit and in a series of ridges to the northwest. Fossils are extremely abundant here, some layers being made up almost entirely of them, and this locality affords the best collecting ground of this formation. The Trenton belt is about ninety yards wide, the beds dipping 25° to the northwest. Two samples from this locality have the following composition:

ANALYSES OF SPECIMENS. LOCALITY 5.

	(5.)	(5a.)
Insoluble (including silica),	87.20	0.97
Oxide of iron and alumina,	3.57	0.86
Lime,	2.41	55.70
Magnesia,	1.46	0.45

No. 5, a somewhat weathered sandy limestone, is of no value for cement. No. 5a is a remarkably pure limestone, the specimen being taken from a layer composed almost entirely of fossils. Neither analysis can be considered as fairly representative of these beds, but the average is probably nearer to 5a than 5. If there is any considerable amount of rock as good as that of the sample 5a, this locality may be an important one, even though it is not on the railroad. A shallow trench would doubtless show a complete section of the bed here, and confirm the probable presence of the cement rock.

East of Jacksonburg creek outcrops are common (A, figure 17) for a quarter of a mile or more. To the southwest, one-half mile west of Jacksonburg, two small outcrops, B and C, were noted rising as low knolls above the gravel plain. A small ledge of basal conglomerate occurs one-half mile north by east of Walnut Valley, just at the edge of a line of woods. Elsewhere the rock is apparently deeply drift-covered.

From this point southwest to the Delaware river the border of the slate is marked by a thrust fault, along which the slate has been pushed over upon the Kittatinny limestone for a short distance. A crushed and brecciated zone of slate twenty to thirty feet wide, marking the fault-line, can be seen in the bed of Yard's creek, about 200 yards above the stone bridge, near the forks of the road, two miles northeast of Hainesburg (A, fig. 18). The Kittatinny limestone is exposed within five feet of the

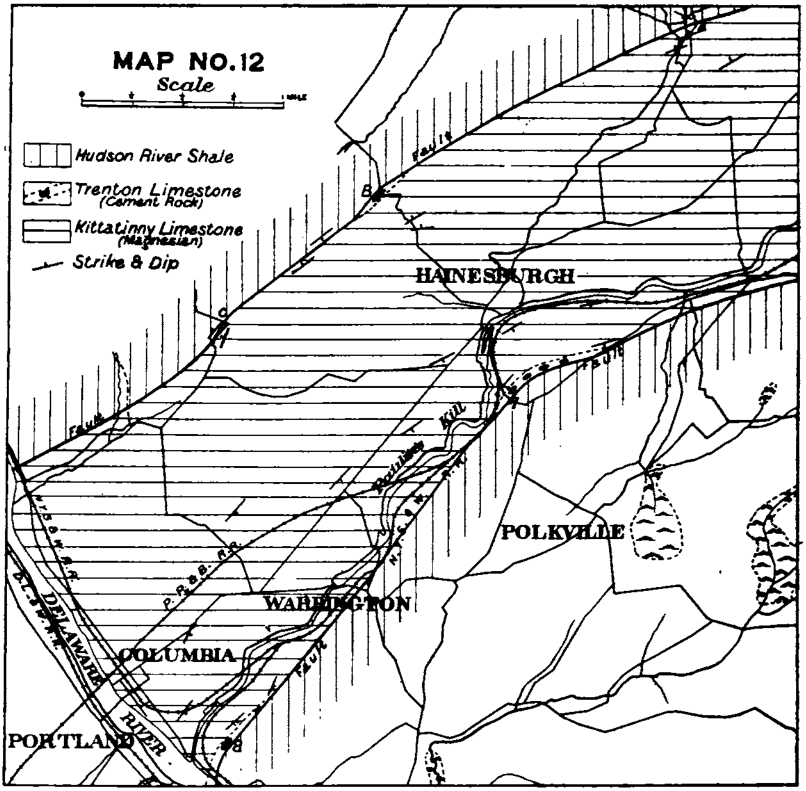


Fig. 18—Outcrops of Trenton Limestone between Hainsburgh and the Delaware River.

slate. Some one, deceived by the lustre of the brecciated slate, started to open a "coal" mine here, but it is needless to say without success.

In only one locality along the fracture is the Trenton known to outcrop. A small exposure of very fossiliferous limestone only a few feet in extent occurs along the road leading northwest from Hainesburg, at a sharp turn, high up on the hillside (B, fig. 18). As the slate and magnesian limestone outcrop close at hand, its maximum width cannot exceed twenty-five yards, equivalent to a thickness of thirty to forty feet. In the fields, a few rods to the southwest, there are somewhat larger exposures, showing, also, a few feet of the basal conglomerate next to the older limestone. Elsewhere along this border the Trenton is entirely absent, or, if present, is covered by drift so that no outcrops were found. A mile and a quarter west of Hainesburg (C, fig. 18), near a small slate quarry, the magnesian limestone outcrops within a few yards of sheared and crushed beds of slate, but the Trenton beds are not present.

Blairstown.—South of Blairstown and west of Paulina a few small exposures of the fossiliferous limestone occur along the depression between the older limestone and the slate (E, fig. 17). Owing to faulting the area is a very limited one, and not likely to prove profitable commercially, although it is only a short distance from the railroad. Near the east end of Cedar lake a small mass of Hudson River slate was found resting directly upon the Kittatinny limestone, against which it had been faulted. A hundred yards further west along the contact line a thin layer of the Trenton conglomerate was found resting upon the older limestone. Here, apparently, only the basal portion of the Trenton is preserved along the fault line.

Hainesburg.—At Hainesburg (fig. 18) the upper beds of the Kittatinny limestone are shown opposite the railroad station. A few yards distant along the wagon-road a coarse basal limestone conglomerate is found, containing bowlders one to two feet in diameter. Ascending the hill, the conglomerate becomes finer, and is then succeeded by the typical blue-black fossiliferous limestone. Along the crest of the hill is the slate. The belt of Trenton does not exceed fifty yards in width, including the conglomerate. The dip is variable, with a maximum of 56° to the southeast. The upper beds, however, are probably not present, as the thickness is hardly more than 110 feet. Analysis of a sample from a dense black unfossiliferous layer shows the following composition:

ANALYSIS OF LIMESTONE, HAINESBURG. LOCALITY NO. 7.

Insoluble (including silica),	8.10
(Silica),	(2.62)
Oxide of iron and alumina,	2.38
Lime,	48.04
Magnesia,	2.84

The rock as it stands has too much lime, almost too much magnesia, and too little silica and alumina for Portland cement, but by the addition of a small amount of clay this can be corrected. With a clay of the composition given on page 24 about 20 per cent. should be added to the limestone, according to Newberry's formula, but in actual practice a slightly larger amount would be necessary. The proper proportions might also be obtained by mixing with this rock some of the more earthy layers. The location of these beds close to the railroad renders the deposit worthy of further investigation by interested parties.

Columbia.—Half a mile southeast of Columbia and east of the Paulinskill a narrow line of the Trenton limestone occurs near (south of) an old lime-kiln (8, fig. 18). Only the lower part of the formation is present, the upper being cut out by a fault. The lowest beds contain small water-worn grains of the magnesian limestone. A specimen taken from a fossiliferous layer has the following composition:

ANALYSIS OF LIMESTONE, COLUMBIA. LOCALITY NO. 8.

Insoluble (including silica),	4.30
Oxides, iron and alumina,	1.23
Lime,	52.58
Magnesia,	0.65

The high per cent. of lime in this sample and the nearness of the area to the railroad may render it available commercially. Persons in search of a high-grade limestone should examine this locality further. Exploration by trenching may show that some of the cement beds are also present.

In the foregoing pages all the Trenton rock areas along the belt from Branchville to Columbia have been described. Those along a belt from the Wallkill river at the State line to Belvidere will now be considered. Within this area the Trenton occurs in several lines of outcrop, the most regular of which is that on the northwestern side bordering the slate belt from Belvidere nearly to Deckertown. With a few exceptions to be noted below, the Trenton beds, *i. e.*, the pure limestone or the calcareous shales, or both, can be readily found at short intervals all along this line. There is more irregularity due to faulting along the borders of the other slate areas.

Quarryville.—East of Quarryville a mass of the Kittatinny limestone lies within the slate (fig. 19). Its structural relations

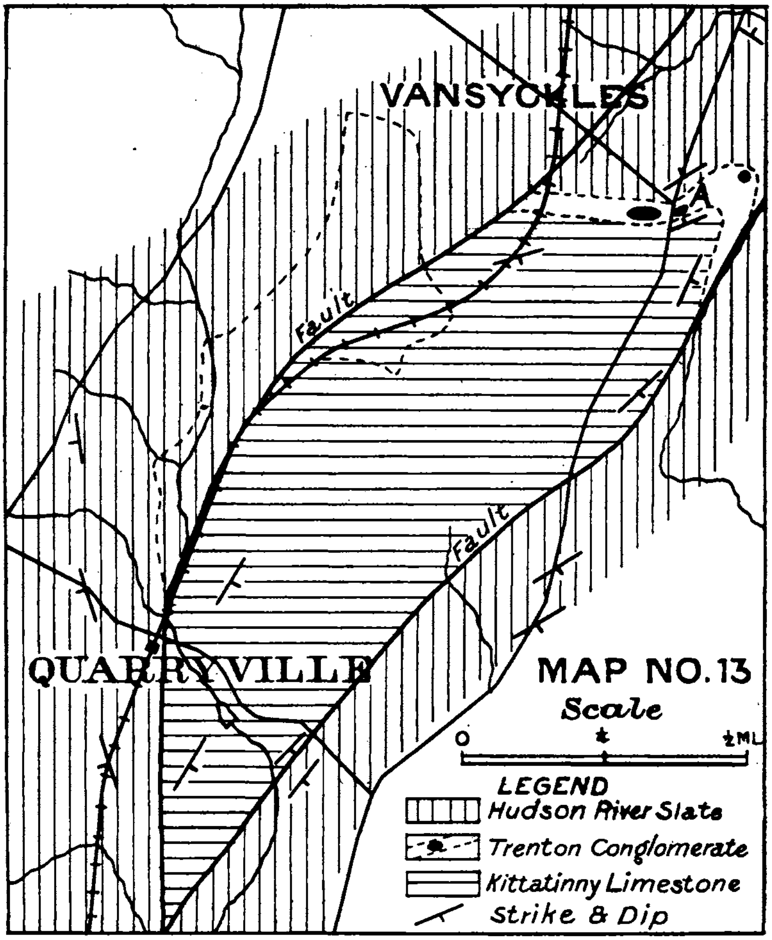


Fig. 19—Outcrops of Trenton Conglomerate, near Quarryville.

are such as to indicate that faults separate the slate from the limestone save at the northern end near the Dunn Vale schoolhouse, where ledges of the basal lime conglomerate (A) occur both west and south of the schoolhouse. Drift accumulations conceal much of the adjoining rock, and the structure is somewhat doubtful. Digging may reveal some of the limestone or shaly cement beds, but the locality is not a promising one.

Deckertown.—Two miles northeast of Deckertown traces of the Trenton limestone are found (A, fig. 20). A small knoll of

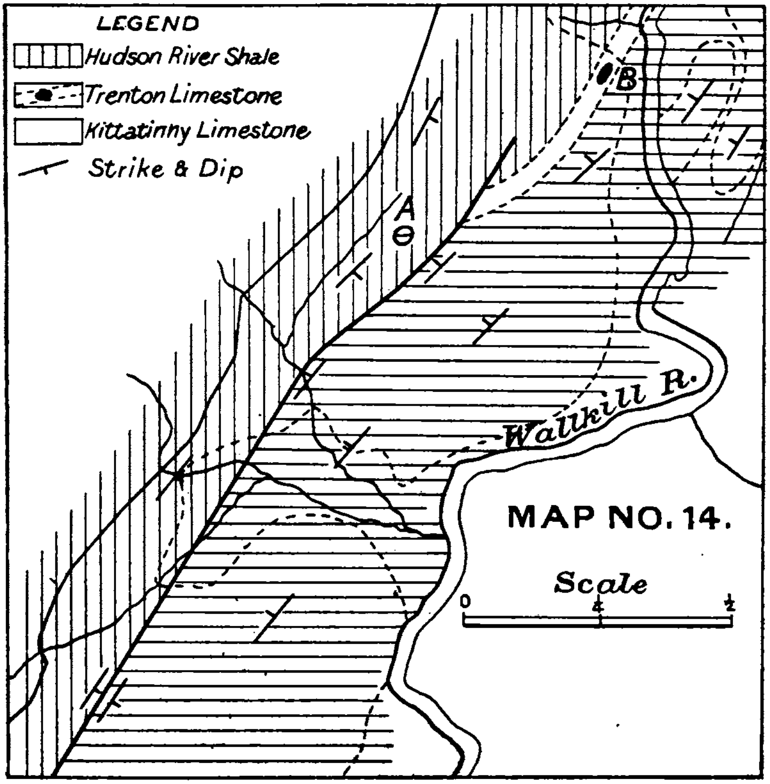


Fig. 20—Outcrop of Trenton Limestone, northeast of Deckertown.

the Kittatinny limestone apparently rests upon the slate along an overthrust fault. Sheared masses of Trenton limestone occur on the northern slope of the knoll. The exposure is a small and unimportant one. Half a mile north by east, near the Wallkill river (B, fig. 20) is another small knoll of the same limestone between nearly vertical beds of slate and the older limestone. Perhaps it has the extension indicated on the map. Northeast of this point the alluvial deposits along the Wallkill bury whatever beds of Trenton may occur.

Beaver Run.—South of Deckertown the slate and magnesian limestone are faulted together, and the Trenton is not found until in the vicinity of the Pond schoolhouse, two miles north of Beaver Run. Near the summit of the hill, immediately north of the schoolhouse (A, fig. 21), small exposures of fossiliferous

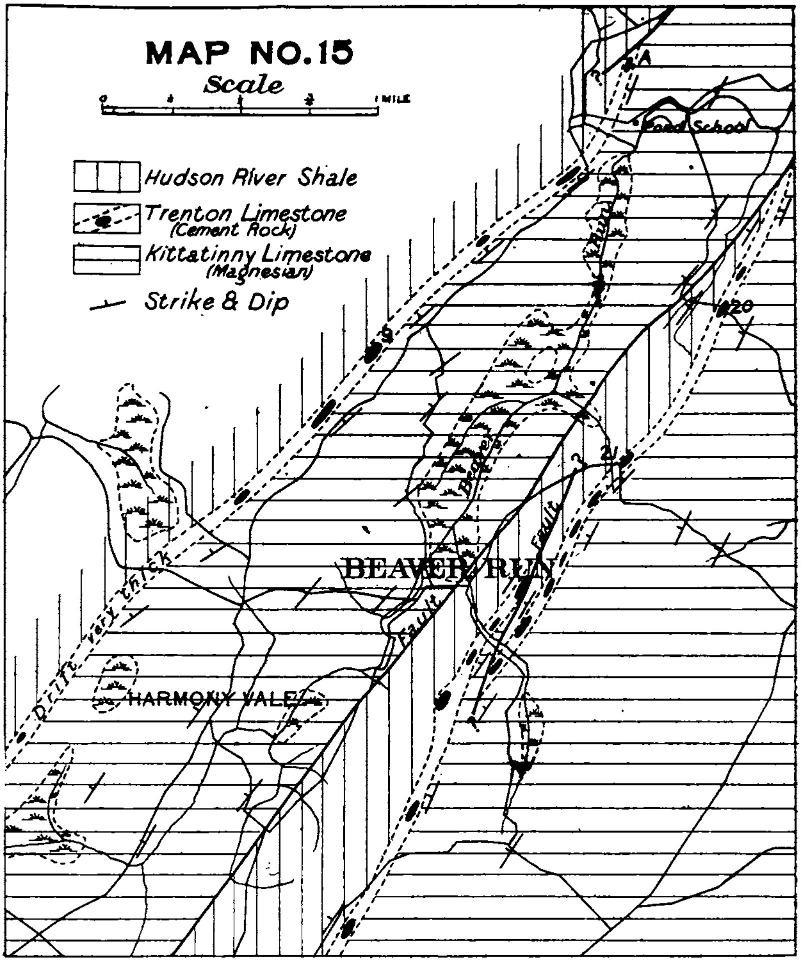


Fig. 21—Outcrops of Trenton Limestone, near Beaver Run

The formation can be readily traced along the edge of the woods southward to J. B. Harden's (21, fig. 21), where it outcrops at the bend of the road. A specimen of the limestone layers from a knoll behind his house had the following composition:

ANAYSIS OF TRENTON LIMESTONE. LOCALITY NO. 21.

Insoluble (including silica),	2.54
Oxides, iron and alumina,	1.14
Lime,	53.64
Magnesia,	.81
Calculated, CO_2,	42.72

There are also other good exposures along the summit of the hill south of his house. As shown in figure 21, the formation here outcrops in two lines, separated by a narrow strip of slate and magnesian limestone. The structure along a section for a mile and a half from northwest to southeast through Beaver Run is shown in figure 22. Along the belts shown in figure 21 there

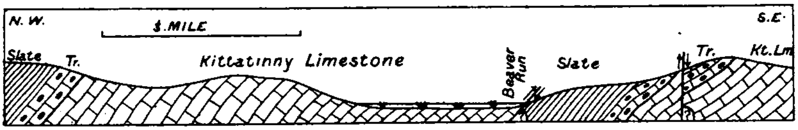


Fig. 22—Section at Beaver Run, showing probable relations of the Trenton Limestone to the Kittatinny Limestone and the Hudson River Slate.

is no doubt but what there is an abundance of rock high in carbonate of lime, with probably a large amount of earthy limestone, suitable for cement, although the latter is not so conspicuously exposed. Here again, however, the distance from a railroad is considerable.

Monroe Corners.—One-third of a mile north by west of Monroe Corners the Trenton beds outcrop along the crest of a prominent knoll, the Kittatinny limestone forming the eastern slope, and the slate being found on the west (A, fig. 23). The knotty fossiliferous beds are exposed, while the softer, more earthy layers are probably buried by soil. The width is here something over fifty yards, and the ledge is 300 yards in length.

A few chert and Kittatinny limestone pebbles occur in the lower layers, but the typical basal conglomerate was not found. The same beds are again exposed one-fourth of a mile northward,

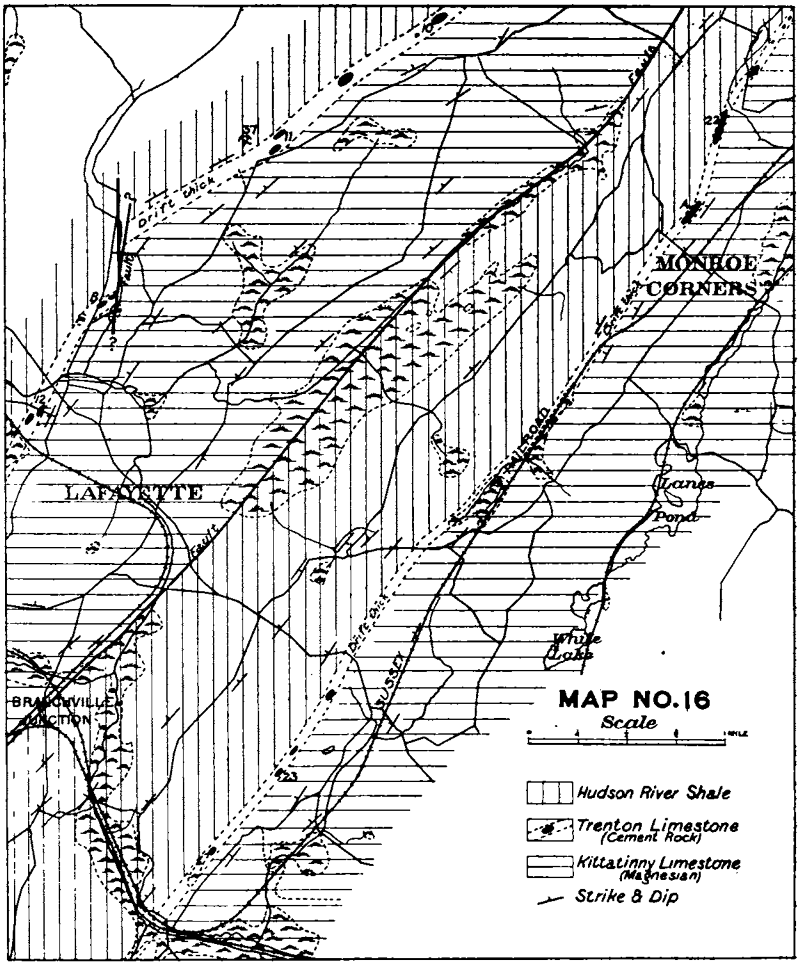


Fig. 23—Outcrops of Trenton Limestone, near Monroe Corners.

just southwest of the house of Mrs. Fuller (22, fig. 23). An analysis of a sample of the limestone from this locality showed that its constitution is as follows:

ANALYSIS OF TRENTON LIMESTONE. LOCALITY NO. 22. MONROE CORNERS.

Insoluble (including silica),	10.67
Oxide of iron and alumina,	1.49
Lime,	49.03
Magnesia,	0.70

Still further north the bottom beds were found to the right of the road on the westward slope of a wooded ridge. Thence northward for a mile there are occasional small exposures. All three of these localities are readily accessible and near the Sussex railroad. The analysis shows that the rock is very low in magnesia and comparatively high in lime. Mixed with a small amount of clay, rather rich in alumina, it could be readily utilized for cement. The typical "cement beds" were not seen, but a little stripping would probably expose them. These localities are worthy of consideration by parties interested in cement rocks.

For three miles southwest of Monroe Corners the Trenton outcrop lies along a line of swamps and heavy glacial deposits, so that no exposures were found. Then for a mile or more there are several localities where it appears on the surface, and doubtless many other places where a little trenching would uncover it. The largest outcrop of these (23, fig. 23) is on the property of Leonard McCloud. A specimen of the limestone from this locality had the following composition:

ANALYSIS OF TRENTON LIMESTONE. LOCALITY NO. 23.

Insoluble (including silica),	26.51
Oxides, iron and alumina,	1.63
Lime,	43.09
Magnesia,	0.78

Owing to the steep dip of the beds the width of the formation is here hardly more than fifty or sixty yards, and only the harder limestone layers in the lower part are exposed. The more shaly layers, although probably present, are buried by drift. The ledges observed, as well as the probable extent of the formation, are shown in figure 23.

Lafayette.—On the farm of Zachariah Simmons, between Lafayette and Harmony Vale, and also on the adjoining properties, both northeast and southwest, there are conspicuous knolls of the Trenton beds, which here form a belt from seventy-five to one hundred yards wide. Analysis of a limestone from the Simmons property (10, fig. 23) gave the following:

ANALYSIS OF TRENTON LIMESTONE. LOCALITY NO. 10.

Insoluble (including silica),	9.53
Oxide of iron and alumina,	1.81
Lime,	49.11
Magnesia,	0.65

This specimen contains a considerable excess of lime over what is demanded by Newberry's formula. If, however, it be mixed with a clay or with a more clayey limestone, a good combination can be made. The excess of silica over alumina and iron is not as great as is the case in some of the specimens.

At J. C. Demorest's (11, fig. 23), near the slate quarries, the outcrop is 150 yards wide, and the shaly limestone beds are shown, as well as more massive, purer layers. The following analysis was made of a specimen of this limestone:

ANALYSIS OF TRENTON LIMESTONE. LOCALITY NO. 11.

Insoluble (including silica),		13.41
(Silica),	(10.72)	
Oxides, iron and alumina,		1.46
Lime,		49.13
Magnesia,		.34

A sample of the slate from the adjoining quarry had the following composition:

ANALYSIS OF HUDSON RIVER SLATE. LOCALITY NO. 37.

Insoluble (including silica),	76.22
Oxides, iron and alumina,	13.05
Lime,	2.67
Magnesia,	0.93

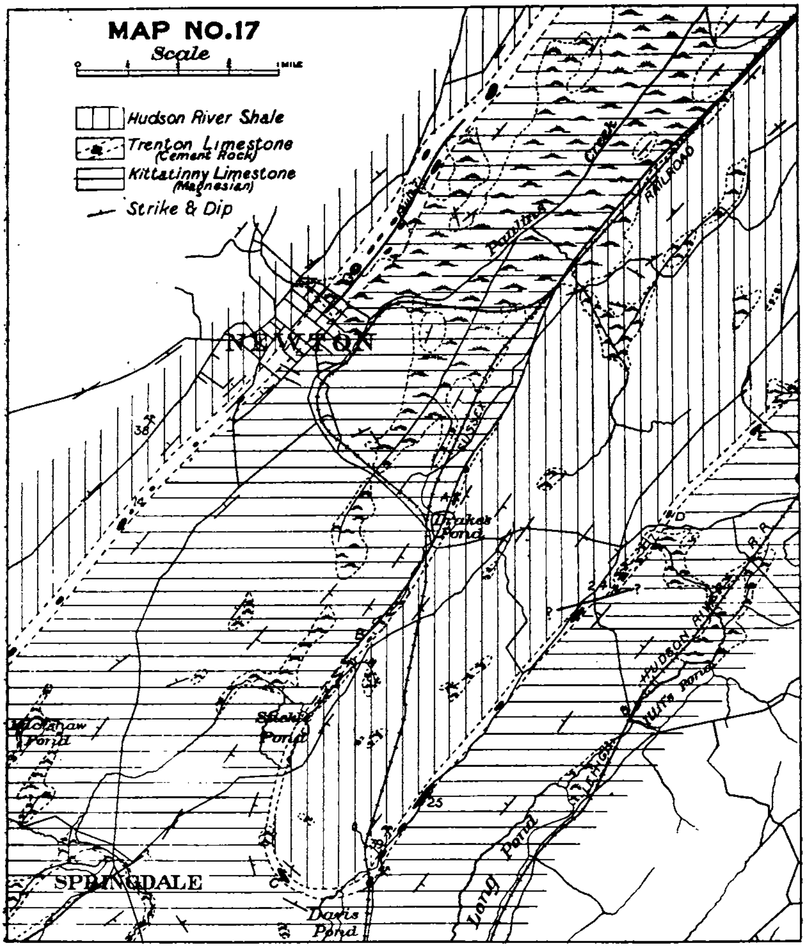
Some exposures of the Trenton beds occur near the highway, a mile northwest of Lafayette (B, fig. 23), and again between the railroad and the highway, half a mile west by north of the village (12, fig. 23). The latter locality adjoins the railroad, but the constitution of the rock, as shown by a sample selected somewhat at random, is not such as to warrant it exploitation.

ANALYSIS OF TRENTON LIMESTONE. LOCALITY NO. 12.

Insoluble (including silica),	13.52
Oxides, iron and alumina,	0.61
Lime,	39.12
Magnesia,	8.21

The high content of magnesia may be due to minute water-worn grains of the Kittatinny limestone, although the rock as exposed is not conglomeratic, and no fragments of the older rock were noted in the specimen taken.

Newton.—Both northeast and southwest of Newton the Trenton beds are well developed at a number of localities, the most important of which are shown in figure 24. The hill, just north



No. 24—Outcrops of Trenton Limestone, near Newton.

of the ball-park (13), is underlain by it. Good exposures of the shaly beds, the limestone and the conglomerate beds occur at its southern end. The belt has a width of over 300 yards, probably due to faulting as the basal conglomerate layers are apparently repeated. The formation can be traced by frequent outcrops for a mile northeast gradually decreasing in width and, at length, ending. The conglomerate beds, composed of pebbles usually under one-half an inch in diameter, are a conspicuous feature. A specimen of the conglomerate from this locality is shown in plate II. Analysis of three specimens from the ledges near the ball-park are as follows:

ANALYSES OF LIMESTONE. LOCALITY NO. 13. NEWTON.

	13.	*13a.*	*13b.*
Insoluble (including silica),	17.23	8.48	24.91
(Silica),	(13.88)	....	(20.24)
Oxides, iron and alumina,	2.44	1.04	2.37
Lime,	41.12	37.95	30.46
Magnesia,	3.78	11.68	9.82

The unusual amount of magnesia in two of these specimens is probably due to minute particles of the dolomitic limestone imbedded in it. The specimens were taken from horizons somewhat widely separated. Whether or not the magnesia is so widely disseminated in this vicinity as to preclude the use of any of this rock for cement can only be determined by more systematic exploration and analysis than the Survey has been able to undertake.

Southwest of Newton the same rock, but not conglomeratic, is found at a number of localties along the lower slope of the slate hills. Only the harder, lower limestone layers are exposed, and the softer earthy cement beds are to be looked for in general between the limestone and the slate. The analysis of a specimen from the Babbitt property by Dr. Cook* is given below, together with that of a specimen from the same locality, analyzed by Mr. Myers.

* Geology of New Jersey, 1868, p. 398.

TRENTON CONGLOMERATE. (*Three-fifths natural size.*)

ANALYSES OF TRENTON LIMESTONE FROM THE BABBITT PROPERTY. LOCALITY NO. 14.

	1868.	*No. 14.*
Insoluble (including silica),	....	4.33
Silicic acid and quartz,	5.8	undet.
Oxides, iron and alumina,	4.7	1.1
Lime,	49.0	52.76
Magnesia,	0.9	.84

Both these analyses show the specimens to be a high-grade limestone, with very little magnesia. It was impossible, without trenching, to determine whether the cement beds are present.

Near here is the New Jersey Slate Company's quarry. A fragment of fine, dense black slate from their dump-pile had the following chemical composition:

ANALYSIS OF SLATE—NEWTON QUARRY. LOCALITY NO. 38.

Insoluble (including silica),		79.36
(Silica),	(58.76)	
Oxides, iron and alumina,		10.73
Lime,		2.07
Magnesia,		2.57

The above partial analysis was made with a view of obtaining some idea of the availability of this slate for mixing with the limestone. By mixing limestone of the composition of No. 14 and the slate in the proportions of about four to one, a cement having approximately the following composition may be made:

Silica,	22%
Iron and alumina,	4½%
Lime,	64%
Magnesia,	1.7%

Such a cement would be much lower in iron and alumina than the commercial cements (see p. 18), and would probably contain a larger amount of inert material, although in his laboratory experiments Newberry obtained good results with a cement having even less alumina than this. The actual value of cement, however, must be determined by mechanical tests in addition to chemical analysis.

Drake's Pond.—Ledges of the purer limestone are found just north of Drake's pond (A, fig. 24). The outcrop is a narrow one, the maximum width being only thirty yards and apparently the whole formation is not present. It is near the railroad, however, and so may be readily worked, if analysis should show it to be of the proper composition. A still smaller exposure was noted northeast of Stickle pond, near a bend in the road (B, fig. 24).

There are also exposures of the Trenton west of Davis' pond, along an old wood-road at the foot of a high southward facing bluff of slate (C, fig. 24). Owing to the wooded surface, its extent is not readily determined. It is not far removed from the railroad, however, and may prove valuable on that account.

Just east of Davis' pond ledges of the Trenton are exposed in a small railroad cut. A few rods to the east is a quarry of magnesian limestone, between which and the Trenton there is a fault of unknown extent.

A series of knolls and ridges of Trenton limestone extends from the old slate quarry (39, fig. 24) northward to John Ayers' house. The beds stand nearly vertically, and the width of outcrop is about fifty yards. Only the lower, harder limestone beds outcrop, but the calcareous shales are probably to be found along a narrow depression next to the slate. Analysis of rock from this locality gave the following result:

ANALYSIS OF TRENTON LIMESTONE. LOCALITY NO. 25. JOHN AYRES.

Insoluble (including silica),	3.19
Oxides, iron and alumina,	1.27
Lime,	52.85
Magnesia,	.76

The specimen shows a high-grade limestone, which will make good quick-lime, or, if there is much of it of as high a grade as the sample, it may pay to quarry it for shipment, as it is not far from the railroad.

PARTIAL ANALYSIS OF SLATE. LOCALITY NO. 39. JOHN AYRES.

Insoluble (including silica),	81.17
Oxides, alumina and iron,	9.80
Lime,	1.13
Magnesia,	2.48

A combination similar to that suggested for the Newton slate is possible, with approximately the same results. It is very questionable, however, whether the use of the slate and the limestone would be commercially profitable, owing to the cost of the necessary fine grinding of both constituents (pp. 23, 26).

The same beds are again prominently exposed about a mile northeast of Ayres', near the road to Iliff's pond (24, fig. 24). Analyses of two specimens from horizons fifty feet or more apart gave the following results:

ANALYSIS OF TRENTON LIMESTONE. LOCALITY NO. 24.

	A.	*B.*
Insoluble (including silica),	2.87	13.05 (9.50 silica)
Oxides, iron and alumina,	1.82	1.42
Lime,	54.04	47.95
Magnesia,	0.81	0.57

Specimen A is almost a pure lime carbonate; the other is less pure, but still high in lime. Both can be used for cement if mixed with clay or with a clayey limestone. The locality is only a short distance from the Lehigh and Hudson railroad at Iliff's pond.

Small exposures are also found west and northwest of Mulford station on the Lehigh and Hudson railroad, at the localities indicated on the map (D and E, fig. 24). It is doubtful whether they have any commercial importance.

Whittingham Estate, Southwest of Newton.—Good exposures of both the limestone and the cement rock are found near the house of Mr. W. C. Whittingham, three miles southwest of Newton (15, fig. 25). The best exposures occur along a small stream where both the basal limestone beds and the upper shaly layers are exposed. A well* drilled in the bed of the stream penetrated the cement rock for a depth of fifty-seven feet. The underlying magnesian limestone was not reached. The transition of the limy beds into the overlying slates is shown in the banks of the ravine below the waterfall. A specimen of the rock found in the

* Data obtained from Stotthoff Bros., Flemington, who drilled the well.

road just above Mr. Whittingham's house has the following composition:

ANALYSIS OF LIMESTONE. LOCALITY NO. 15. WHITTINGHAM ESTATE.

Insoluble (including silica),	11.96
Oxides, iron and alumina,	1.60
Lime,	46.88
Magnesia,	0.40

Still purer limestones, as well as more clayey layers, occur here. These are the same beds as seen on the Babbitt farm, near Newton and at the ball-park, but the conglomerate phase does not occur or, at least, is not shown.

Outcrops of the same belt are also more or less frequent to the southwest, as shown on the map (A, B, C, fig. 25). The rock is

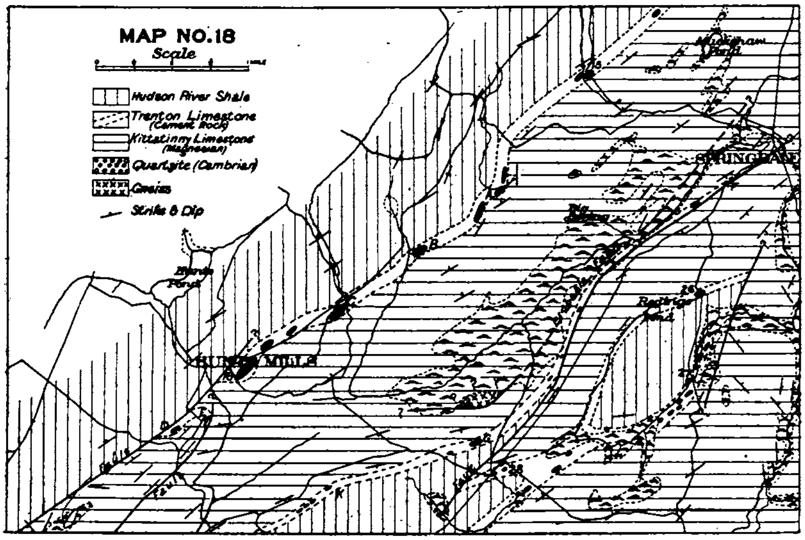


Fig. 25—Outcrops of Trenton Limestone, between Springdale and Hunt's Mills.

often highly fossiliferous, and can readily be distinguished by this means from the underlying magnesian limestone. The width of outcrop is usually about 150 yards.

Just east of the house of Mr. David Warbasse the limestone is found. The house probably stands upon the cement rock. A large wooded knoll of magnesian limestone lies to the south, and the slate hills are just north of the house.

Huntsburg.—The high hill, just north of the Huntsburg (Hunt's Mills) school-house, is mainly of Trenton limestone, although the older formation outcrops on the east and south sides. Owing to a slight roll in the strata the outcrop is here wider than usual. The limestone beds are well exposed, but the calcareous shales are mostly hidden by drift. Some of the lower beds contain small pebbles of magnesian limestone and chert. So far as exposed, they are mostly a dull, more or less earthy appearing, bluish rock, with some semi-crystalline beds. Analyses of specimens of these two varieties gave the following results. The first is the semi-crystalline rock:

ANALYSIS OF TRENTON LIMESTONE. LOCALITY NO. 16. HUNTSBURG.

Insoluble (including silica),	5.50	14.85
(Silica),	(5.02)	....
Oxides, iron and alumina,	1.94	1.41
Lime,	50.16	47.55
Magnesia,	1.67	0.65

The second specimen represented a fair average of the beds exposed on the surface. In choosing the first specimen care was taken not to take a fragment in which magnesian limestone pebbles were visible.

The same beds are found at several points near the road for a mile northeastward, the most important exposure being near the corner (C, fig. 25). Southwest of Huntsburg glacial deposits mostly conceal this formation, although a small exposure was found half a mile distant on the southwestern slope of a knoll of the magnesian rock (D, fig. 25), and another ledge (E) a few rods east by north of D.

Springdale.—South of Springdale the rock structure is complicated by faults, as well as by folds. As a result, the Trenton limestone is found in a number of localities where its presence was not expected. A few hundred yards southwest of the Springdale school-house there is an isolated knoll of a heavy basal conglomerate, the poorly rounded fragments of which range up to two feet in diameter. It is surrounded by ledges of the Kittatinny limestone, and at first sight its occurrence here is a mystery, but a few hundred yards southwest fossiliferous calcareous shales are found along the roadside, and in the adjoining field ledges of the typical Trenton limestone occur (F, fig. 25). Its occurrence here in the midst of the Kittatinny limestone is due to faulting. The knoll of conglomerate lies along the fault line, which passes close to the school-house.

Occasional outcrops of Trenton are found along this fault line, just east of the swamp, as far as John Wolf's (G), where there are good exposures. The cement shales outcrop on the hillside west of his house. The Hudson River slate underlies the meadow along the brook, and the Trenton is found again along the public road, and in the adjoining field. The structure is shown in figure 26, a cross-section from the knoll G, southeast for three-quarters

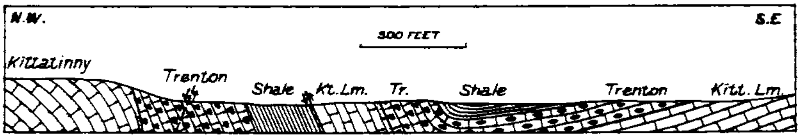


Fig. 26—Section showing probable structure near John Wolf's, southwest of Sprindale.

of a mile. On the hillside (G)* the outcrop is 176 yards wide, and the apparent thickness, perhaps increased by faults or small compressed folds, is much in excess of that observed elsewhere. Owing to the weathering of the surface layers, fresh specimens of the cement shales could not readily be obtained for analysis. A sample of the hard limestone layer from the exposure near the road had the following composition:

ANALYSIS OF TRENTON LIMESTONE. LOCALITY NO. 28. JOHN WOLF.

Insoluble (including silica),	1.70
Oxides, iron and alumina,	0.81
Lime,	54.26
Magnesia,	1.09

This is one of the purest limestones found, only two specimens, Nos. 1 and 5a, showing a higher content of lime. There is no

* Near the left of the diagram, Fig. 26.

question but what there is a large deposit of high-grade limestone, and probably of cement rock at this locality, but its distance from the railroad is a serious obstacle to its exploitation.

A series of outcrops (K, fig. 25) can be traced along a narrow belt west by south of Wolf's, as far as the road leading northwest from Greensville. The magnesian or Kittatinny limestone lies on the northwestern side and the slate on the southeast. The dip is steep and the outcrop narrow. Its southwestern extension is lost beneath the gravel deposits northeast of Johnsonburg.

A mile south by west of Springdale there is a syncline of slate, shaped like the bowl of a spoon. A narrow strip of the Trenton limestone probably surrounds it, although owing to the drift exposures were found at only a few localities. Two of these are worthy of mention. The first is on the farm of John Farrell (26, fig. 25), where the rock is exposed in the road and along the edge of the woods back of the house. The following section, in descending order, is exposed along the road:

7. Hudson River slate.	
6. Unexposed—probably calcareous shale—(cement rock?), ...	105 feet.
5. Calcareous shale, ...	6 "
4. Hard black semi-crystalline limestone, ...	1 foot.
3. Shaly limestone and shale, ...	5½ feet.
2. Thin-bedded blue-black earthy limestone, ...	27 "
1. Magnesian or Kittatinny limestone.	

Dr. Cook published an analysis of rock from this vicinity, which is here given along with one made by the present survey of a specimen taken from layer No. 2.

ANALYSES OF TRENTON LIMESTONE. LOCALITY NO. 26

	*	*Layer No. 2.*
Insoluble (including silica), ...	...	7.83
Silicic acid and quartz, ...	6.6	undet.
Oxides, iron and alumina, ...	.8	1.19
Lime, ...	49.4	50.65
Magnesia, ...	1.0	0.55
Carbon dioxide, ...	40.1	40.41

South of Farrell's and east of the road (H, fig. 25) is a narrow wooded ridge, the crest of which is composed of lower Trenton

* Dr. Cook, Geology of New Jersey, 1868, p.

beds, with the underlying magnesian limestone on the eastern slope. The higher shaly layers are probably to be found beneath the meadow along the brook.

Another good exposure is found at Mr. Wm. Phillips', near an

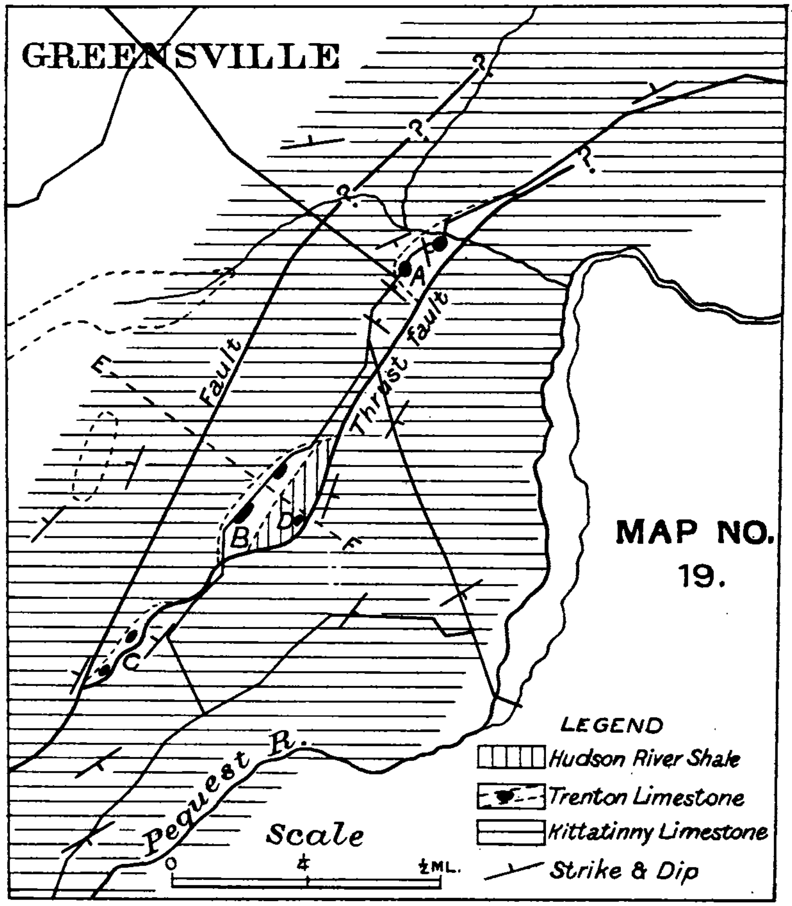


Fig. 27—Outcrops of Trenton Limestone, southeast of Greensville.

old saw-mill (27, fig. 25). Here the upper, black calcareous shale is found on both sides of the brook, with outcrops of the lower limestone beds on the hill to the south. Analysis of the shales show the following composition:

ANALYSES OF TRENTON SHALE. LOCALITY NO. 27. SOUTH OF SPRINGDALE.

Silica,	29.78
Oxides, iron and alumina,	8.29
Lime,	30.10
Magnesia,	2.13

Southwest from Phillips', as far as John Wolf's, occasional outcrops are found as indicated on the sketch map (fig. 25), but much of the area underlain by this formation is covered by drift or swamp deposits.

Greensville.—A mile southeast of Greensville the fossiliferous Trenton shale is exposed near the barn of Mr. G. A. Williams (A, fig. 27), and ledges of the limestone outcrop along the roadside. Masses of the basal conglomerate are also found in the vicinity. The occurrence of the Trenton here in the midst of the magnesian limestone is due to faulting. It is found again along the road to the southwest (B), and also near the house of Mr. John Hibler (C). At one point a small mass of the Hudson River slate (D) occurs above the Trenton shale. Figure 28 shows

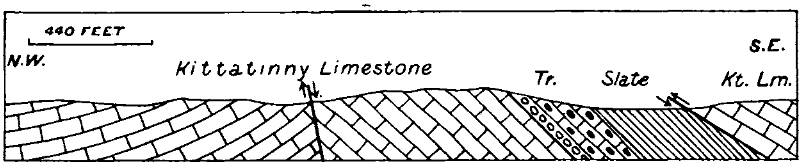


Fig. 28—Section along line E-F., Fig. 27.

the probable structure along the line E-F. So far as can be determined the Trenton beds are only small masses along the fault lines, and are probably not of sufficient extent to be commercially important.

Johnsonburg.—In the vicinity of Johnsonburg the slate and magnesian limestone are for the most part separated by faults and the Trenton beds are absent. Three small areas (A, B, C, fig. 29), however, are known where the Trenton is found along the fault lines. At A it outcrops on the southern slope of a slate knoll. Its vertical and linear distribution is irregular, and the slate has apparently been overthrust upon the Trenton beds so as to nearly conceal them. At B there is a prominent knoll of the calcareous shale, east of which the limestone layers are exposed. This locality is just west of a small cave in the magnesian limestone, due north of Johnsonburg. At C, west of Johnsonburg, a small mass of the Trenton shale was found on the side slope of a hill of slate, along a N-S fault line. The areas are too small to be of importance, commercially.

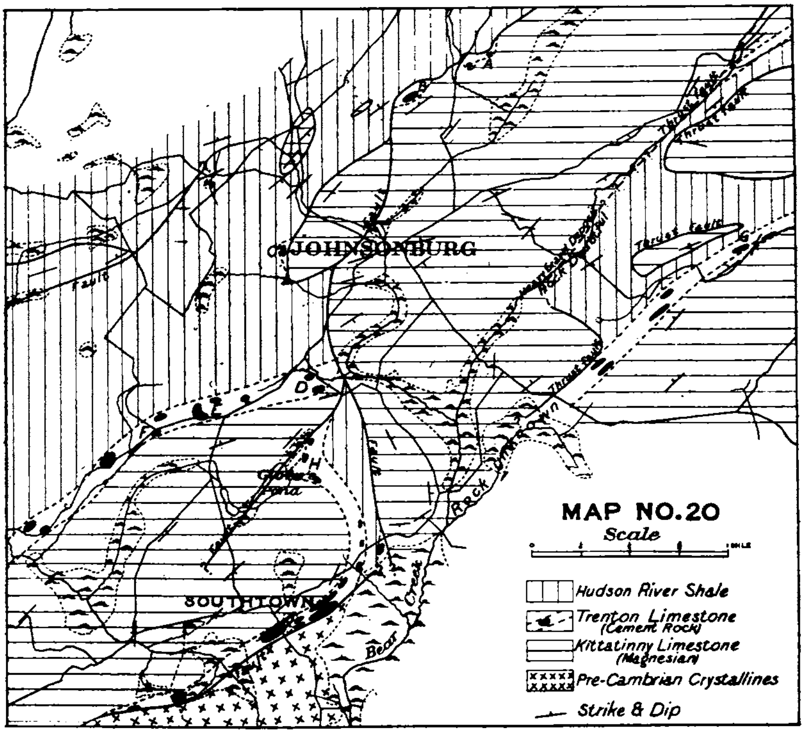


Fig. 29—Outcrops of Trenton Limestone, near Johnsonburg.

Three-fourths of a mile southwest of Johnsonburg the Trenton beds are exposed along a farm lane, just southeast of the road to Hope (D, fig. 29). From this point to Hope, a distance of five miles, the road lies nearly all the way upon the Trenton formation, the outcrop of which has a width varying from 100 to 500 yards. The calcareous shales form a high knoll just east of W. H. Ackerson's (E, fig. 29), where the weathered material has been taken for use on the roads. Good exposures are also found near Mr. Henry's house (F). The position of other exposures is indicated on the map.

Beds of the conglomerate are found at a number of localities along this belt towards Hope, notably at A, B, C, figure 30. The

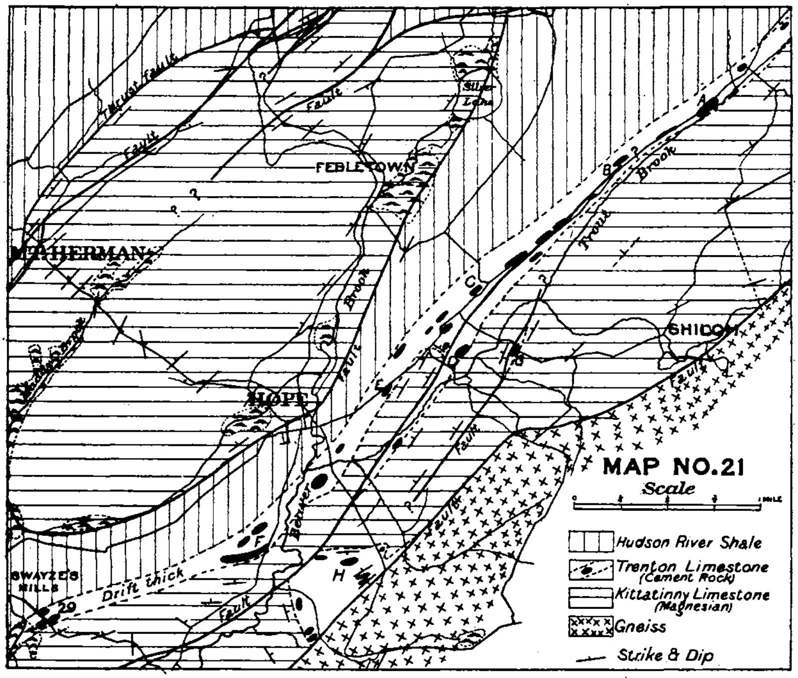


Fig. 30—Outcrops of Trenton Limestone and Conglomerate, near Hope.

fragments of magnesian limestone and chert range up to one foot in diameter, although the bulk of the material is only three or four inches in diameter. The fragments are well rounded and have suffered considerable transportation. At C the conglomerate bed is at least 40 feet thick. These conglomerate layers are apparently not at the base, but are interbedded in the Trenton limestone, the base not being shown. Exposures, however, are not sufficiently numerous to settle beyond doubt whether these beds are actually interbedded in the limestone, or whether they are really basal layers faulted into this position. The abrupt change in width of the formation, a mile northeast of Hope, is probably due to a fault, as indicated on the map, a fact which may account for the exceptional position of the conglomerate.

Hope.—For four miles northeast of Hope the calcareous shale beds are more frequently exposed than usual. The rock has been greatly sheared, so that only obscure traces of fossils can be found. The cleavage planes dip northwest less steeply than the bedding planes, and the movement along them has been such that the outcrop has been widened. Observations of a few fossils show that they have been stretched in the direction of the shearing planes. This, together with the fault just mentioned, may account in part for the abnormal width of the outcrop, but there is no doubt but that the formation increases in thickness towards the southwest. An abundance of rock, suitable for Portland cement, can probably be found at many points along this line, care being taken, of course, to avoid those beds containing pebbles of the Kittatinny limestone.

The outcrop is the widest north of John Dill's house (D, fig. 30), and near Isaac Wildrick's (E), at Hope, calcareous shales, similar in appearance to those used for cement at Vulcanite and Alpha, have been quarried for road material. Cement rock is believed to underlie the meadow south of Dill's, but only traces of the basal conglomerate were found along the eastern side. Just south of Hope it forms a knoll above the alluvial deposits, and at Daniel Vliet's (F, fig. 30), it forms a high hill back of the house. Here the conglomerate is exposed apparently at the base of the formation, although the actual contact is not seen. The dip is low and the outcrop is consequently wide.

Good exposures occur along the road just southeast of Swayze's mills (29, fig. 30), where the base is well defined, and the transition of the calcareous shales into the slate is exposed along a small washout on the hillside. The thickness here is apparently more than 300 feet—a figure considerably more than the estimates in areas further north. The actual thickness, however, may be somewhat increased by shearing or by small, close folds, a number of which are exposed in the upper Trenton beds in a small opening a quarter of a mile southwest of here. There is no doubt, however, but what the formation thickens towards the Delaware, the increase apparently being in the upper shaly limestone, beneath the slate. A few magnesian pebbles occur here in the lower beds, but no marked conglomerate was found. The belt is terminated by faulting a mile south of Swayze's mills, a small outcrop being found near the fault line at the end of a ridge of Kittatinny limestone.

ANALYSIS OF TRENTON LIMESTONE. LOCALITY NO. 29. SWAYZE'S MILLS.

Insoluble (including silica),	2.64
Oxides, iron and alumina,	0.82
Lime,	53.88
Magnesia,	0.72

A belt of the Trenton limestone and shale is found a mile and a half east of Johnsonburg. It is doubtless the same, structurally, as the outcrops found at Phillips' (see p. 84), but the most of the intervening area is thickly drift-covered. Ledges of conglomerate occur along the road a few rods east of B. C. Morris' house, and near them are outcrops of the purer limestone layers (G, fig. 29). Exposures are more or less frequent as far southwest as the road from Johnsonburg to Allamuchy, beyond which all rock outcrops are buried by the gravel deposits bordering the Pequest meadows. The layers exposed are similar to those found elsewhere and already frequently described.

Glover's Pond.—South of Johnsonburg a belt of Trenton is found near Glover's pond, the best exposures occurring at the northern end of the pond. Owing to the drift the upper limit of the formation is indefinite. It is succeeded eastward, however, by a narrow belt of the slate, which, in turn, is bounded on the east by a fault, which brings up the Kittatinny or magnesian limestone. From Glover's pond the Trenton outcrop describes a curve towards the northeastern end of Jenny Jump mountain. Near Southtown, on the road to Danville (J, fig. 29), there are remarkable exposures of the basal conglomerate. The beds dip about 25 degrees towards the crystalline rocks of Jenny Jump mountain, the nearest outcrop of which is 28 yards from the conglomerate. The well-rounded pebbles are very strikingly shown upon the smooth glaciated ledges. Their average size is two to four inches, but a few one foot in diameter occur. All are magnesian limestone or chert. Although the gneiss and pre-cambrian crystalline limestone are close at hand, no pebbles derived from them occur in the conglomerate, which is confirmatory evidence of the fact conclusively shown by the structure that a fault of great throw bounds the mountain on the northwest side. Interbedded with the conglomerate are layers of "sandstone," likewise derived from the magnesian limestone, and some beds of purer limestone resembling the typical Trenton. The finer layers are all considerably sheared. No fossils, save the ever-present segments of crinoid stems, were found. Neither limit of the conglomerate is shown, but its thickness is apparently from 90 to 100 feet.

It can be traced southwest as far as Thomas Robinson's, where the fault brings the underlying Kittatinny limestone against the gneiss. Northeastward it grades laterally into the limestone and calcareous shales, so that within a mile the character of the formation is apparently completely changed.

Hope.—In the vicinity of Hope there are several other areas of Trenton, in addition to the important belt already described (p. 88). A mile west of Shiloh (G, fig. 30) a narrow outcrop is found on the road along a fault line just east of Trout brook. Both the limestone and shale occur, greatly sheared owing to the faulting. Northward the belt passes beneath the alluvium along the brook, and southward apparently pinches out, some beds of conglomerate being found near its southern termination.

A mile south of Hope there is a prominent knoll (H) 125 feet high, adjoining the gneiss of Jenny Jump mountain. On the southeastern slope, next to the mountain, there are ledges of the coarse basal conglomerate. Along the summit of the hill the fossiliferous limestone beds are found, and at the base of the northwestern slope the conglomerate beds are shown again. The general structure from Mt. Herman to Jenny Jump mountain is

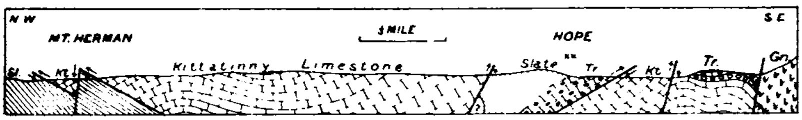


Fig. 31—Section through Hope, from Mt. Herman to Jenny Jump Mountain.

shown in figure 31. The conglomerate has a very considerable thickness, 50 to 70 feet.

Southwest of Hope, between Swayze's mills and Sarepta, there are only a few small unimportant exposures of the Trenton, the formation being for the most part covered by glacial drift. The location of these is indicated in figure 32, A, B, C, D, E.

At A, near Marshall Gibbs', sheared beds of conglomerate

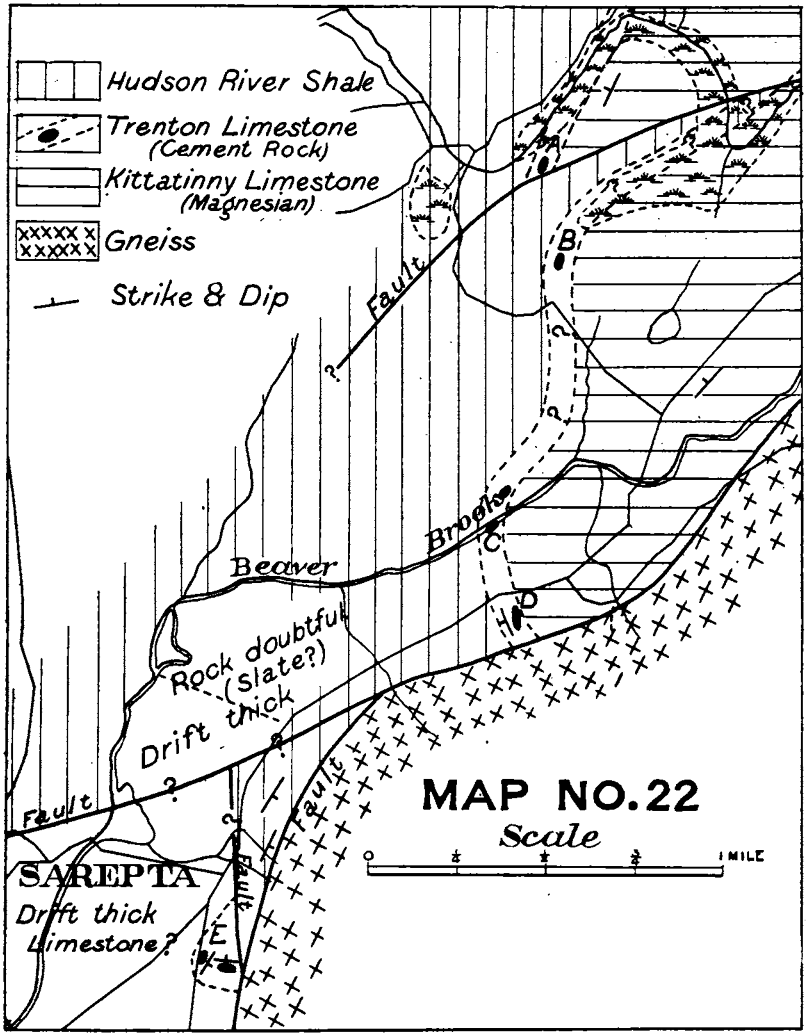


Fig. 32—Outcrops of Trenton Limestone, north of Sarepta.

of chert pebbles, with a siliceous matrix and beds of the fossiliferous limestone, are found at the southern end of a tongue of the Kittatinny limestone, inclosed between two areas of slate. At B, one-quarter of a mile south, are small exposures of the calcareous shale. The same rock is again seen in the bed of Beaver Brook at C, and along the base of the slate hill north of the stream. There are other exposures, with a nearly vertical dip, at D. Owing to the scarcity of outcrops the actual limits of the Trenton are not readily determinable, and the boundaries as shown in figure 32 may be only approximately correct.

At E, two-thirds of a mile north of Bridgeville station, the Trenton outcrops in the road and in a number of small quarries near by. The dips are variable and the structure is complicated. A fault certainly separates it from the gneiss of Jenny Jump mountain on the east. It may pass beneath the slate to the north, or be separated from it by a fault. Owing to the glacial drift its extent and structural relations are largely hypothetical. The rock was formerly burned for lime to a small extent. Its nearness to the railroad may make this a valuable source of nearly pure limestone, as a narrow-guage tramway could readily be constructed to the railroad.

The following analysis by Mr. R. K. Meade, Easton, of a cement rock found on the Iliff property in this vicinity was kindly furnished by Mr. Thomas Marshall, of Trenton:

ANALYSIS OF CEMENT ROCK. ILIFF PROPERTY.

Silica,	27.08
Oxides, iron and alumina,	8.76
Carbonate of lime,	55.37
(Lime, 31.00).	
Carbonate of Magnesia,	3.83
(Magnesia, 1.83).	
Water,	2.60
Undetermined,	2.36

Sarepta.—The Trenton limestone and conglomerate are well shown in the western half of the large limestone quarry (31, fig. 33) near the Delaware, Lackawanna and Western railroad at Sarepta, northeast of Belvidere. The beds dip gently to the northwest and rest uncomfortably upon the older Kittatinny limestone, to which the bulk of the rock exposed belongs. The Trenton appears in the north wall of the quarry, a little west of the center. Here it is a coarse conglomerate at its base, with fragments two feet in diameter, but it becomes finer above. In the matrix of the finer layers fossils, chiefly segments of crinoid stems occur. Here as elsewhere all the fragments of the conglomerate are derived from the underlying formation. There is

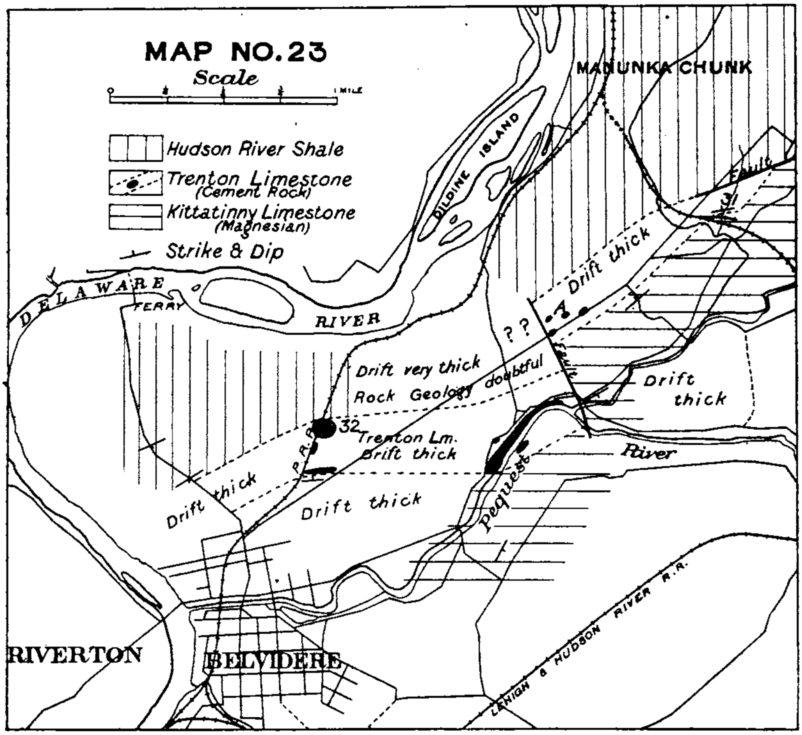


Fig. 33—Outcrops of Trenton Limestone, near Belvidere.

no sharp line of demarkation between them, but the conglomerate beds clearly cross the layers of the magnesian limestone at a low angle. The fragments in the basal layers of conglomerate were evidently not transported far, the beds being probably the reconsolidated fragments which accumulated at the old Ordovician shore line, only slightly reworked and assorted. Overlying the conglomerate there is a black, knotty, heavy-bedded limestone, not abundantly fossiliferous. Occasional small pebbles of the older limestone are found in some layers. These beds are exposed to a thickness of 40 to 45 feet. Further quarrying to the northwestward will show a much greater thickness. A specimen containing nó conspicuous Kittatinny limestone pebbles had the following composition:

ANALYSIS OF TRENTON LIMESTONE. LOCALITY NO. 31. SAREPTA.

	A*	B*
Insoluble,	11.72	...
Silica,	(8.80)	5.46
Alumina,	..... } 1.00	.81
Iron,	..... }	1.02
Lime,	47.37	49.38
Magnesia,	2.06	2.26

Belvidere.—There are large deposits of non-magnesian limestone and cement rock in the vicinity of Belvidere. A mile north of the Pennsylvania depot there are extensive exposures of the black calcareous shale along the railroad. A few rods south of the cuts and east of the railroad are a series of small quarries in the basal beds, where a fossiliferous limestone 25 feet thick, containing pebbles of magnesian limestone, is found. Between these exposures there are heavy gravel deposits. The width of the belt is 330 yards, and as the dip is steep, from 20 degrees to 50 degrees to the northwest, the thickness is apparently much greater than that found further northeast. But a part of this apparent thickness may be due to folds concealed beneath the glacial deposits. The shale in the railroad cut has the following composition:

ANALYSIS OF CEMENT ROCK. BELVIDERE. LOCALITY NO. 32.

Silica,	22.72
Oxides, iron and alumina,	8.15
Lime,	35.78
Magnesia,	1.86

Owing to the glacial gravels the formation cannot be traced in either direction from the railroad more than a few rods. A mile east, however, the same beds outcrop for several hundred yards

*Analysis A was made by Mr. Myers; Analysis B was obtained from Mr. Edison.

along the Pequest river, near Dr. A. F. Morris'. The rock is chiefly the calcareous shale, with some limestone layers. The conglomerate beds were not observed. The outcrop is terminated at the corner near the Springdale farm by a northwest-southeast fault, which causes an offset to the northwest of a third of a mile. But the same beds are found along the straight road to Sarepta, due north of the Springdale farm (A). Owing to drift deposits the limits of the formation are difficult to determine accurately and those indicated in figure 33 are approximate only.

Through the kindness of Mr. Thomas A. Edison the following analyses of specimens from various localities in this vicinity are given. The samples were chiefly from the Morris and Earye farms, but their order of arrangement below has no geographical or geological significance. Mr. Edison's explorations were very extensive and these are but a few of the analyses made by him.

ANALYSES OF TRENTON LIMESTONE AND CEMENT ROCK, VICINITY OF BELVIDERE.

T. A. EDISON.

	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	CO_2 calculated.
1, ...	1.86	.60	.51	53.64	.81	43.03
2, ...	2.52	.44	.47	53.24	1.08	42.62
3, ...	2.03	.57	.51	53.02	.91	42.69
4, ...	5.03	2.06	1.23	49.73	1.02	40.19
5, ...	5.37	3.45	.98	49.50	.85	39.84
6, ...	5.76	3.25	1.36	49.30	.64	39.44
7, ...	5.00	2.84	1.28	48.72	.96	39.33
8, ...	8.38	4.03	1.32	45.45	1.34	37.18
9, ...	11.90	4.42	1.70	44.18	1.18	36.01
10, ...	11.71	4.36	1.62	43.47	1.82	36.15
11, ...	12.46	4.82	1.62	43.44	1.15	35.41
12, ...	12.80	5.39	1.70	42.85	1.35	35.16
13, ...	11.11	4.40	1.91	42.51	2.89	36.57
14, ...	13.82	5.03	1.70	42.30	1.49	34.86
15, ...	14.54	5.59	1.83	41.19	1.46	34.08
16, ...	20.59	5.33	1.87	38.38	1.39	31.67
17, ...	14.90	7.42	1.87	38.20	1.09	31.20
18, ...	17.04	6.90	2.13	37.53	2.17	32.88
19, ...	22.71	5.84	2.13	36.50	1.69	30.52
20, ...	22.39	6.90	1.74	36.41	1.53	30.30
21, ...	16.20	6.71	1.91	36.37	3.21	32.10
22, ...	19.53	6.03	1.70	35.71	3.33	32.73
23, ...	22.77	6.53	2.52	35.05	1.52	29.20
24, ...	22.96	7.35	2.04	35.03	1.59	29.28
25, ...	24.45	5.68	1.57	35.00	2.21	29.89
26, ...	27.90	7.89	1.70	32.10	1.40	26.78

THE UPPER DELAWARE VALLEY.

Limestones and calcareous shales of various kinds are found along Wallpack ridge, from Tri-states to Wallpack bend, on the Delaware river. With the exception of that part of the ridge near Tri-states all this area is so far removed from any railroad that for lack of transportation facilities whatever deposits of cement rock and limestone there may be, must remain undeveloped for many years. For this reason these limestones were not studies with the same care as those of the Kittatinny valley.

Dr. Cook* published, in 1868, analyses of specimens from various horizons, which indicate that many of the beds have a high per cent. of carbonate of lime and are practically free from magnesia. Finely ground and mixed with clay in the right proportion, they would make good Portland cement, or the rock could be used to raise the per cent. of lime in a cement rock deficient in it. These formations were described by Mr. Weller in the annual report for 1899, pp. 1-46.

A specimen of the Bossardville limestone (Cook's ribbon limestone) from Richard Stoll's† farm near Wallpack Center had the following composition:

BOSSARDVILLE LIMESTONE NEAR WALLPACK CENTER.

1. Silica,	12.80
2. Oxides, alumina and iron,	2.10
3. Lime,	44.85
4. Magnesia,	2.18
5. Carbonic acid,	37.68

Outcrops of the Bossardville limestone are frequent from Flatbrookville to Peter's Valley, along the eastern foot of the ridge. At the Nearpass quarry, near Tri-states, the beds are exposed just above the base of the section there shown. It has a thickness of 12 feet four inches.

Specimens from Sanford Nearpass' quarry, near Tri-states, were analyzed by Cook with the following results:

* Geology of New Jersey, p. 395.

† This and following names are those of the owners of the property at the time of Dr. Cook's report, 1868.

	1.	2.	3.	4.
1. Silica,	8.50	4.00	22.80	4.10
2. Alumina,	16.90	1.10	8.94	.90
3. Oxide of Iron,			2.57	
4. Lime,	39.87	52.52	20.44	52.92
5. Magnesia,	1.42	.33	12.08	....
6. Carbonic acid,	33.31	41.80	31.06	41.58

No. 1 is Cook's "fire-stone," a part of the Decker Ferry formation. No. 2 is Cook's "old-quarry stone," the identification of which is somewhat indefinite, but it is probably the top of the Rondout water-lime formation. No. 3, the so-called "pethstone," is No. 7 of the Water-lime formation (p. 20, Annual Report for 1899). No. 4, the "quarry-stone," is the Tentaculite limestone, described in last year's report. Another specimen of the Tentaculite limestone had 51.5 per cent. of lime and 5.5 per cent. of silica and quartz.

The Nearpass quarry is not so far removed from the railroad at Port Jervis but that some of these beds may be profitably utilized. From analyses 2 and 4 above the "old-quarry stone" and the "quarry-stone" are seen to be high-grade limestones. Analysis of the shaly layers in the quarry may show a rock with the right proportions of alumina and silica. In Mr. Weller's paper, in the report for 1899, some of the important exposures of these formations are noted.

Dr. Cook also gives the following analyses of specimens, the exact geological horizon of which cannot be determined from the record:

ANALYSES OF LOWER HELDERBERG LIMESTONES.

	1.	2.	3.
1. Silica,	9.80	8.70	10.80
2. Oxides, alumina and iron,	2.10	1.50	2.60
3. Lime,	48.88	49.67	45.19
4. Magnesia,	.35	.69	.80
5. Carbonic acid,	38.90	40.00	36.75

In this table No. 1 is limestone from John Schooley's farm, near Peter's Valley; No. 2, from that of Joshua Cole, Montague; No. 3, from that of Calvin Decker, Wallpack Ridge.

WHITE MARL DEPOSITS.

In addition to the limestones described in the previous part of this report, there are in Sussex and Warren counties shell-marl deposits, often of considerable extent, some of which may be sufficiently pure to be used for Portland cement in combination with clay. No recent study of these deposits has been made, but the following data from the earlier reports of the Survey, particularly from the Annual Report of 1877, may be of value in this connection. These partial analyses were published in 1877:

	Carbonate of Lime.	Carbonate of Magnesia.	Sand and Clay.	Water, Vegetable Material, &c.	Description.	Owner and Location.*
1	98.33	. . .	0.90	0.67	White, pulverulent. No vegetable matter, ...	Job J. Decker, Andover, Sussex Co.
2	88.86	. . .	9.96	2.16	Precipitate from water,.	Benj. Van Sickle, Peter's Valley, Sussex Co.
3	97.73	. . .	0.60	1.59	White, dense, fine, ...	Abm. M. Cooke, Shiloh, Warren Co.
4	95.34	2.18	.98	1.50	Surface marl, white, solid, fine, ...	Abm. M. Cooke, Shiloh, Warren Co.
5	96.32	1.57	1.16	.96	Drab-white, fine and with shells, ...	Daniel M. Howell, Hunt's Mill, Sussex Co.
6	92.25	2.98	1.56	3.21	White, pure, some grass roots, ...	White Pond, Marksboro, Warren Co.
7	89.87	2.29	.97	6.87	Ash-colored, many shells, light, ...	Henry S. Cook, Hope, Warren Co.
8	96.54	1.47	2.05	0.00	White, very fine, medium density, ...	Martin Drake, Newton, Sussex Co.
9	84.52	1.76	8.46	5.26	Surface marl, ...	Martin Drake, Newton, Sussex Co.
10	90.18	0.00	9.75	. . .	White, very dense, thick shells, ...	Sink pond near Lincoln, Warren Co.
11	99.04	0.00	.55	0.41	White, very light, pure,	Jacob Voss, near Lincoln, Warren Co.
12	68.73	0.00	23.99	7.28	Dark-colored shells and vegetable matter, ...	Isaac Bonnell, Montague, Sussex Co.
13	94.75	0.00	.71	4.54	White, very light, pure,.	White pond, Monroe Corners, Sussex Co.
14	64.20	0.00	16.21	16.59	White shells and clay,..	Francis Layton, Centerville, Sussex Co.

* These names are of property owners in 1877.

Dr. Cook reported the shell marls from the following localities in Warren and Sussex counties:

1. *Roe pond*, Vernon township. The pond has an area of about 15 acres. The marl is found on all the shore-line, and is covered by a layer of black muck, one to two feet deep.

2. *Williams farm*, four miles south of Vernon. The marl was shown in ditching the meadow, but its extent was not learned.

3. *Black Creek meadows*, Vernon township.

4. *Meadows east of North Church*, Hardiston township.

5. *Fowler estate farm and Mud pond*, Hardiston township.

6. *Lane's pond*, Sparta township. The shells may be seen about the shores of this pond, but no marl of any extent is shown. It may be found deeper.

7. *White pond*, Germany flats, Sparta township. Marl occurs on the shores and under the southern end of the pond. The area of the pond and marly shore is about 40 acres.

8. *Drake's pond*, near Newton. The pond has an area of seven or eight acres, and a maximum depth of 36 feet. Ledges of the Trenton limestone outcrop on the north shore. The thickness of the marl is not known. The Sussex railroad is only a few rods distant.

9. *White or Davis' pond*. Shell marl occurs in White pond and the adjoining meadows, two miles north of Andover. It has an area of several acres. Depth of the marl is unknown.

10. *Decker's pond*, one mile southwest of Andover. The marl occurs in the pond and in a 10-acre meadow to the south, where borings showed a thickness of 20 feet of muck and marl. The deposit is a large one.

11. *William Wolf's farm, Trout brook*, Green township, locality unexplored.

12. *J. Collins Drake's farm, south of Reding's pond*, Green township. Extent of the marl is unknown, owing to a thick covering of muck. It may underlie several areas of a wet basin.

13. *John A. Ayres' meadows*, near Lincoln, Green township. The marl lies beneath one to two feet of muck in a meadow several acres in extent—the site of an old pond.

14. *Jacob Vass' farm, Long pond,* three-eighths of a mile south-southeast of Lincoln and near the county line. There may be three acres of marl here, beneath one or two feet of muck. The pond dries up in hot weather.

15. *Sink pond,* near the county line, southeast of Lincoln, Green township. It has no outlet and dries up in summer. Its area is between seven and eight acres. The marl lies beneath one to two feet of black loam and muck.

16. *Hazen's pond,* Frelinghuysen township. Marl is reported to occur in and about the shore, but deep beneath muck and water.

17. *Cook's pond,* one mile northeast of Johnsonburg. The marl deposit is in a narrow valley, nearly a mile in length, but only an eighth of a mile wide. It lies beneath the meadow and also in the pond. Its thickness is not known.

18. *Glover's pond,* one mile south of Johnsonburg. The area of the pond is about 50 acres, the marl being visible about its shores and in the shallow water. Its depth is not known. The Trenton limestone outcrops at the northern end of the pond.

19. *Long pond,* of L. J. Howell and A. M. Cooke, northeast of Hope. This little pond, three acres in extent, has no outlet and frequently dries up. The marl deposit is thick, but somewhat covered by muck.

20. *George H. Beatty's meadows,* west of Hope. This is a large area near Hope, said to be underlain by marl.

21. *Rice or Reid pond,* two and one-half miles north of Hope, between the slate and limestone. Its area is three of four acres. Depth of marl is unknown.

22. *George Carter's farm,* south of Blairstown. Here marl is cut in ditching. There are several acres of meadow, but the extent of the marl is unknown.

23. *White pond,* near Marksboro. The marl deposits here have already been described (p. 61).

24. *Catfish pond,* near Stillwater. Its area is about five acres. The extent of the marl is unknown.

25. *Grass pond,* Green township, one mile south of Hunt's mills. Its area is said to be 30 to 40 acres, and the marl is covered

by muck, save in the center. The marl is at least five feet thick in places.

26. *Isaac Bonnell's farm,* Montague township. The marl occurs in a meadow along Chambers' mill brook, covering an area of 75 to 100 acres. Borings made years ago found it to be 15 feet thick. It is covered by two feet or so of soil and muck.

27. *Isaac Cole's farm,* southeast of Brick House, Montague township. The marl occurs in a meadow near the Milford and Hainesville road, and is said to have an area of 50 acres.

28. *James Bevans' farm,* north of Hainesville, Sandyston township. The marl occurs in a meadow, but its extent is unknown.

29. *Francis Layton's farm,* west of Centerville, Sandyston township. The deposit lies in a wet meadow, 10 or 12 acres in extent, and covered by one or two feet of black muck. The marl is estimated to be 10 feet thick in places.

30. *James C. Bevans' meadows,* near Dingman's Ferry. The deposit has an area of seven to eight acres. The muck is said to be one or two feet thick, and the marl may be three or four feet in depth.

The above list shows that shell marls are widely distributed in these two counties, and it is not improbable that there are other localities where beneath the muck of swamps and wet meadows this deposit can be found. As stated in chapter I, the use of marl and clay for Portland cement has been successful in the central west, notably in Michigan and Indiana. The analyses of the New Jersey marls show that they have the proper composition for such use. Beds of clay are frequently found in the same meadows with the marl, so that both raw materials are at hand. It will certainly be desirable if some use may be made of the New Jersey shell-marl deposits.

PART III.

Artesian Wells

By LEWIS WOOLMAN.

Artesian Wells.

OUTLINE.

INTRODUCTION.

I. Wells in Southern New Jersey.

At Parkdale.
At Minotola.
At Bridgeton.
At East Bridgeton.
At Cedarville.
At Greenwich.
At Vineland.
At South Vineland.
At South Millville. Twelve wells.
At Millville. Four wells.
At Atlantic City:
  At Atlantic Brewing Co.
  At the Shelburne.
  At the Chelsea.
  At Ice Co.'s Plant, Tennessee avenue.
  At the Chalfonte.
At Tuckahoe.
At Holly Beach.
At Cape May:
  Stratigraphy and water-horizons.
  Early artesians.
  Columbia House.
  Water department wells.
  N. J. S. R. R.
  Sewell's Point.
  Cape May Point.
At Cape May Court House.
At Fort Mott, near Salem.
At Fort Dupont, Del., opposite Fort Mott.
At Pitman.
At National Park.
At Gloucester. Four wells.
At Philadelphia U. S. Navy Yard.
At Camden, foot of Penn street.
At Hedding.
At Moorestown. Edw. Harmer's.
At Mount Holly.
At Runyon.
At Lakewood.
At Maurer.
At Lawrence Harbor.
At Keasby's Landing.
At Perth Amboy.
At East Oceanic.
At Chapel Hill.
At Red Bank, Monmouth county.

II. Wells in Northern New Jersey, &c.

Sec. 1.—Bored Wells reported by P. H. & J. Conlan.

At Fort Greble, N. Y.
At New York City, N. Y.
At Green Point, Brooklyn, N. Y.
At Port Chester, N. Y.
At White Plains, N. Y.
At South Amboy.
At Rahway.
At Paterson.
At South Plainfield.
At Ridgewood.
At Hohokus.
At Short Hills.
At Milburn.
At East Newark and Garfield, N. J., and at Irvington, N. Y.
At Fort Mott.
At Fort Dupont, Del.

Sec. 2.—Bored Wells reported by W. R. Osborne.

At Sewaren.
At Fresh Ponds.
At Perth Junction, near Metuchen.
At Plainville, east of.
At Two Bridges.
At Mount Pleasant.
At New Brunswick, three miles from.
At New Brunswick, one mile from.
At New Durham.
At Iselin.

Sec. 3.—Bored Wells reported by Stotthoff Bros.

At Swartswood.
At Newton, Sussex county.
At Sparta. Two wells.
At Lake Hopatcong.
At Bernardsville. Two locations.
At Passaic.
At Aldene.
At Elizabeth.
At Carteret.
At Perth Amboy.
At Flemington.
At Plainfield.
At Neshanic.
At Stanton.
At Skillman.
At Ewing.
At Trenton.
At Easton, Pa.
At Siegfried, Pa.
At Nazareth, Pa.
At Roxborough, Pa.
At Bristol, Pa.
At Hinman, N. Y.

Sec. 4.—Bored Well reported by J. P. Cooper.

At East Rutherford.

Sec. 5.—Bored Wells reported by Owen Lynch.

At Springfield and Springfield Mountain. Four wells.
At Milburn.
At Irvington.
At Newark. Three locations.

Note by the State Geologist—The records of wells in the northern part of the State, and in New York and Pennsylvania, as given in part II of Mr. Woolman's report, have many references to "sandstone," "trap," "gray rock," "granite" and other rocks passed through in these well-borings, but no specimens of these rocks have been received at the Survey office, and there has not been any opportunity of verifying these statements as to the nature of these rocks.

ARTESIAN WELLS.

INTRODUCTION.

We have this year again prepared records and data respecting artesian and other bored wells in New Jersey, together with similar information respecting a few wells in the adjacent States of New York, Pennsylvania and Delaware. We present, firstly, those wells bored in the unconsolidated beds of the southern or coastal plain portion of the State, and, secondly, those in the northern or more rocky section. In previous annual reports the wells in the southern portion of the State, drawing respectively from Cretaceous, Miocene and later beds, were each grouped in separate sections. This year, however, it seems desirable to group together wells at certain localities, but which draw from strata of different ages. For this reason we shall arrange all records in geographical order, presenting, first, those along the belt of country nearest the ocean, and then those within the belt bordering the Delaware river and a line joining Trenton and Amboy. This arrangement, however, practically places first the wells drawing from Miocene strata, and from their overlying post-Miocene beds, and second the wells drawing from Cretaceous strata, and also from their overlying post-Miocene beds.

A special feature of this year's report is the summarizing of data obtained from well-borings at Cape May and vicinity that have been made since 1879. Some of them have had notice in former annual reports, while others are now for the first time recorded herein.

ARTESIAN WELL NEAR PARKDALE.

Elevation, 60 feet; depth, 90 feet.
Water rises within 7 feet of the surface.

This well is located in Ryder's cranberry bog, about one and a quarter miles east of Parkdale station, on the N. J. Southern railroad and about one and three-quarter miles northwest of a well in Rockwood's cranberry bog, of which records were published in the annual reports for 1885, page 138, and for 1892, page 297. This boring was made by W. C. Barr, who has kindly furnished the following record:

	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 with small gravel,	4 " =	86 " " 90 "

Beneath the last-named stratum there was a *chocolate-colored clay,* on which the boring stopped.

We regard the beds, at least from the depth of 68 feet to the base at 90 feet, as possibly belonging to the Beacon Hill formation, and of Miocene age.

ARTESIAN WELL AT MINOTOLA.

Elevation, 120 feet; diameter, 3 inches; depth, 100 feet.

An artesian well has been put down by J. H. Lewis, of Vineland, at Minotola, a station on the Pennsylvania Railroad Company's Newfield branch to Atlantic City. This station is at the crossing of this road and the New Jersey Southern railroad, and is about five miles northeast of Vineland.

The elevation of the surface is about 120 feet, and the depth of the well 100 feet. We are informed that the material penetrated consisted almost entirely of yellowish sands and gravels, and that no heavy, dark clays, such as are characteristic of the Miocene beds, were encountered, although these probably lie not many feet below the bottom of this well.

The strata passed through probably belong almost entirely to the sands of the Beacon Hill formation, which contain, both here and at Bridgeton, Millville and Vineland, as noted in reports of wells at these places (see pages 109, 110, 112, 113, 114 and 115), a great deal of water in their lower portions, the water being retained therein by the impervious Miocene clays beneath them.

ARTESIAN WELL AT BRIDGETON.

Elevation, 80 feet; diameter, 4 inches; depth, 114 feet.
Water rises within about 18 feet of the surface.

Jos. W. Pratt has bored a well at Bridgeton for J. H. Sharp & Son, of which he has furnished a full series of the borings from which we make the record below. The location is west of the Cohansey creek, and one or two blocks west of Cumberland county court-house. The elevation we judge from the topographical map of the survey to be about 80 feet.

RECORD.

No. 1.	Reddish gravelly clay at the	Surface.	Beacon Hill.
" 2.	Yellowish clay at	10 feet.	
" 3.	Yellow sand at	25 "	
" 4.	Yellowish white clay at	27 "	
" 5.	Yellow fine gravel,	32 "	
" 6.	Light yellow sand as No. 3,	33 "	
" 7.	Dark brown iron stone crust at	35 "	
" 8.	Orange yellow sand at	41 "	
" 9.	Moderately coarse gravel at	49 "	
" 10.	Dull yellow, slightly clayey sand, at	51 "	
" 11.	Whitish sand at	69 "	
" 12.	Light yellow sand at	76 "	
" 13.	Orange-colored sand at	79 "	
" 14.	Gray sand with water at	104 to 114 "	
" 15.	"Solid black clay" on which the boring stopped at	114 "	

The dark clay at the base of this well, at the depth of 114 feet, probably represents the Miocene, while nearly all the strata above probably belong to the Beacon Hill formation.

The water-horizon at 104 to 114 feet, the location having an elevation of 80 feet, is about the equivalent of the 65-foot horizon at East Bridgeton, where the elevation is only 25 feet. This horizon is in the basal portion of the Beacon Hill formation, which, as is noted in this and in a number of preceding annual reports, is now used for water-supply at Glassboro, Clayton, Vineland, Millville, Parkdale, Minotola, etc. At all these places, except Vineland, where probably the borings were not continued sufficiently deep, Miocene clays have been found to occur beneath these water-bearing Beacon Hill sands. The clays being impervious, cause the water to be retained in the sands overlying them. Its thickness at Millville, beneath the lower flood plain of the tidal portion of Maurice river, approximating 100 feet.

THREE ARTESIAN WELLS AT EAST BRIDGETON.

Elevation, 25 feet; depth of two of these wells, each, 65 feet; depth of the third well (test well), 175 feet.

These wells are at an ice manufacturing establishment on the east side of and near the head of East lake on the easterly margin of Bridgeton.

Two of the wells have a depth of 60 feet, and are finished in the basal portion of the sands and gravels of the Beacon Hill formation.

The other well, the deepest of the three, proved to be only an experimental one, since impervious clays of very considerable thickness were encountered in the lower two-thirds of the boring, and those interested becoming discouraged, the boring was discontinued. Probably the 200-foot water-horizon, afterward developed at Millville,* could have been found here had the boring been continued sufficiently deep. This we regard as the equivalent of the well-known excellent and copious 800-foot Atlantic City horizon, which at that place has a thickness of some 60 or 80 feet, though at Millville it is not nearly so thick. It nevertheless furnishes at the last named point a large supply of water, as has been learned by a test boring recently made there, and which will be reported next year.

The strata revealed by these borings are as follows:

Light yellowish sands	50 feet	= 50 feet.	Beacon Hill and Miocene.
Coarse gravel with water furnishing the two shallow wells	15 "	= 65 "	
Black clay or mud	110 "	= 175 "	

The identity of the water horizon between the depths of 50 and 65 feet with that between the depths of 104 and 114 feet in West Bridgeton is noted in the last paragraph on page 109.

* A record of this Millville boring will probably appear in next year's annual report.

TWO ARTESIAN WELLS AT CEDARVILLE.

Elevation, 15 feet; diameter of each, 4 inches.
No. 1. Depth, 50 feet. Water rises within 7½ feet of the surface.
No. 2. Depth, 53 feet. Water rises within 5 feet of the surface.

Joseph W. Pratt reports having drilled two four-inch wells, 60 feet apart, for W. L. Stevens & Bro., at Cedarville, about eight miles south of Bridgeton, and states that either well will produce 100 gallons per minute. The depths of these wells and the rise of the water therein are as noted above.

From a series of borings, furnished by the contractor, we make the following record:

Soil,	0	feet	to	4	feet.	
Whitish clay,	4	"	"	8	"	Beacon Hill.
Large heavy gravel,	8	"	"	10	"	
Orange-colored sand with heavy gravel mixed,	10	"	"	13	"	
Heavy yellow gravel and fine sand mixed,	13	"	"	16	"	
Dull yellow sand,	16	"	"	25	"	
Orange yellow sand, medium quality,	25	"	"	35	"	
Orange yellow sand, slightly coarser, and *water bearing,*	35	"	"	53	"	

Judging from the specimens of the borings these wells draw from the gravels that overlie the Miocene clays, which, as noted in the record of a former well at his place, published in last year's Annual Report (page 103), probably occur at the depth of about 93 feet, where there was then noted a black clay on which that boring stopped.

SHALLOW ARTESIAN WELL AT GREENWICH, N. J., AT VANEMAN & TURNER'S CANNERY.

Elevation, 15 feet; diameter, 3 inches; depth, 31 feet.

From Joseph W. Pratt we have received the following record of a well put down by him at the location noted above. It obtains water from a four-foot bed of coarse sand or fine gravel, of which a specimen has been received and which represents either the Beacon Hill or a still later gravel deposit.

A mixture, described by the driller as black sand and mud, occurs next below the water-bearing sand. This may possibly be of Miocene age, since Miocene fossils occur in loose blocks of stone on the margin of the upland where it joins the meadows west of the town.

RECORD.	*Thickness.*	*Total. depths.*
Clay,	7 feet =	7 feet.
Gravel,	3 " =	10 "
Light brown sand,	4 " =	14 "
White sand,	7 " =	21 "
Light brown sand,	4 " =	25 "
Orange-yellow coarse sand, with water,	4 " =	29 "
Black sand and mud,	2 " =	31 "

The supply of water probably comes from the same horizon as that furnishing two wells at Bridgeton, of which a record appears in this report (pages 109 and 110).

This well is upon the same property* as that on which many years since an unsuccessful boring was made to the depth of 690 feet, the facts respecting which have appeared in the Annual Reports for 1885, page 131, and 1894, page 190.

In the latter report a composite section of the beds of this region was made from the data then in hand respecting this deep (690-foot) well, and a more shallow one, 190 feet deep, on the meadows at Bayside near by. This composite record notes at Bayside 33 feet of recent alluvial marsh mud, which evidently replaces in part at least the 29 feet of Beacon Hill sands, noted in the present record, and which had probably been carried away by erosion at Bayside before the deposition of the more recent alluvial deposit.

SIX BORED WELLS AT VINELAND, FOR THE WATER DEPARTMENT.

Elevation, 80 feet; diameter of each, 6 inches; depths, 124 to 150 feet.

Vineland has been heretofore furnished with water-supply from one or more wells of no very great depth, put down at Keighley's shoe factory a few blocks east of the West Jersey railroad station.

* The property was then under the control or ownership of Job Bacon.

The borough authorities have recently laid extensive lines of water-pipe beneath the streets and have had drilled a series of six six-inch wells on a plot of ground at the corner of West street and the New Jersey Southern railroad, the location being west of West Jersey Railroad Co.'s station. The elevation of this plot is 80 feet above tide, and the depth of the wells is as follows:

No. 1,	124 feet.	No. 4,	150 feet.
No. 2,	128 "	No. 5,	144 "
No. 3,	132 "	No. 6,	136 "

The material penetrated by all of these wells is a light yellowish sand nearly to the base of each, where a water-bearing coarse sand or fine gravel was reached, within which the various wells were finished. The water stands naturally within four and one-half feet of the surface. Tests were made by pumping two of the wells together at one time, and again by pumping two other of the wells together at another time, and we are informed sufficient water was obtained from either of these two pairs of wells to supply the wants of the city for 24 hours without difficulty.

The sands and gravels from the surface all the way down belong to the Beacon Hill formation, and the water-horizon developed is approximately the same as that developed by the wells at Millville (see pages 114 and 115) and at Bridgeton (see pages 109 and 110). At these two localities test-borings were made which showed a stiff black or dark blue clay underlying these sands. This clay which we regard as of Miocene age probably also underlies the water-bearing stratum at Vineland, but, if so, none of the borings went deep enough to reveal it. It would be interesting to know whether or not it does so occur, and if it does, to obtain specimens of the same. The knowledge either of the existence or non-existence of this Miocene clay at this point would greatly assist in revealing the exact stratigraphical relations existing at Vineland.

ARTESIAN WELL AT SOUTH VINELAND.

Elevation, 70 feet; diameter, 3 inches; depth, 105 feet.

Golder & Lewis have put down a well at a glass-sand pit on the east side of the West Jersey railroad, about three-fourths of a mile south of South Vineland station, and a short distance north of Clayville station, at a point which we estimate has an elevation of about 70 feet. This well was commenced in the bottom of a sand-pit, but the measurements of depths given on the record below are from the natural surface. This well draws water from toward *the base* of the Beacon Hill sands from practically the same horizon as that supplying the wells of the water department at Vineland (see page 112), and also the wells at the two glass factories at Millville (see the two next records). The Vineland water department's wells seem, however, to be stratigraphically deeper in these Beacon Hill gravels than this one (see page 113). The record of this well, as furnished by the contractors, is as follows:

White glass sand,	5	feet to	40	feet.
Light yellow sand of same texture as the white above,	40	" "	85	"
Coarse yellow gritty sand = fine gravel the size of wheat grains. *Water-bearing,*	85	" "	105	"

This well was finished at the base with a strainer ten feet long.

TWELVE ARTESIAN WELLS AT SOUTH MILLVILLE, AT WHITALL, TATUM & CO.'S LOWER GLASSWORKS.

Elevation, 5 feet; diameter of each well, 3 inches; depth of each, 80 feet. Water rises just to the surface.

These wells, twelve in number, were drilled by Golder & Lewis. They are situated in the southern part of Millville, at the lower of the two glassworks of Whitall, Tatum & Co., at this place, this one being formerly known as the Schetterville glass-works, and are on the flats or lower flood plain of the Maurice river, the elevation of which we estimate at about five feet above tide.

These wells were all drilled to a nearly uniform depth of about 80 feet. The water flowed over the surface from some two or three of the wells which were on ground slightly lower than the others, while from all of the other wells the water rose to the surface.

Each well was finished at the bottom with a strainer four feet long, below which was a five-foot length of unperforated casing.

These wells, from near the surface all the way down, penetrated only the light yellowish and whitish sands of the Beacon Hill formation, and ended in a coarse yellowish gravel at the base of the same. This basal bed rests upon a thick, impervious stratum of Miocene clay that occurs but a foot below the bottom of these wells at, say, not over 100 feet below tide, as has been learned from a deep test boring recently put down by the Millville Water Company, which it is intended to report next year.

FOUR ARTESIAN WELLS AT MILLVILLE, AT WHITALL, TATUM & CO.'S UPPER GLASSWORKS.

Elevation, 3 feet above high tide; diameter of each well, 3 inches.
Depths of wells Nos. 1 and 2—80 and 82 feet.
Depths of wells Nos. 3 and 4—92 and 93 feet.
The water rises within *one* foot of the surface.

Besides the twelve wells previously reported at Whitall, Tatum & Co.'s lower glassworks at Millville, Golder & Lewis have also put down for the same firm at their upper glassworks four three-inch wells, the location being upon the east bank of the Maurice river, about two blocks north of the point where Main street, or the Bridgeton turnpike, crosses that river. The depths of the first two wells were 80 and 82 feet respectively, and the depths of the last two 92 and 93 feet. The wells were separately tested by pumping, and each yielded 100 gallons or over per minute. As at the company's lower works, the water-horizon is at the base of the Beacon Hill sands, the borings being in these sands from very near the surface all the way down. The water rises to within one foot of the surface, the elevation being about three feet above high water.

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

1. At the Atlantic Brewing Co.

Elevation, 10 feet; diameter, 6 inches; depth, 850 feet.

2. At the Shelburne.

Elevation, 8 feet; diameter, 6 inches; depth, 830 feet.

3. At the Chelsea House.

Elevation, 10 feet; diameter, 6 inches; depth, 840 feet.

4. At Ice Company's Plant, at the foot of Tennessee avenue.

Elevation, 8 feet; diameter, 6 inches; depth, 838 feet.

5. At the Chalfonte.

Elevation, 8 feet; diameter, 6 inches; depth, 844 feet.

Water rises in all the above wells either to or very near the surface.

During the year five wells, as noted above, have been drilled at Atlantic City to the great Miocene water-yielding sand bed, which has heretofore been called in these annual reports the 800-foot Atlantic City horizon, that being about its average or mean depth. All of these wells were put down by Uriah White. We will now separately notice each well.

Well at the Brewery.—This well is at the northwest corner of Arctic avenue and the Reading railway tracks. The top of the water-yielding sand was found at 770 feet. The well was finished with a strainer 50 feet long, having an additional length of 10 feet of blank pipe at the bottom, so that the well draws from between the depths of 790 and 840 feet. The water rises within one foot of the surface. Rock 8 inches thick was found at 690 feet.

Well at the Shelburne.—This well is at the foot of Michigan avenue. The top of the great diatomaceous clay bed was met with at 404 feet, and its base at 690 feet. At the latter depth a thin stratum of rock was encountered. The water-bearing sand was found to occupy the interval between the depths of 780 and 830 feet. The water rose within a few feet of the surface. This well was tested by pumping at the rate of 120 gallons a minute, lowering the water in the well to 15 feet from the surface.

Well at the Chelsea.—This well is located in the rear of the recently erected Chelsea House, which is on the ocean front between Brighton, or 29th, avenue and Morris, or 30th, avenue. The well is also about 150 feet east of Pacific avenue. The top of the great diatomaceous clay bed is reported at 411 feet, and the bottom at 670 feet. A stratum of rock about one foot thick was found at 680 feet. The top of the water-bearing sand was at 780 feet. The well was drilled to the depth of 840 feet, and was finished with a strainer at the base 50 feet long. The water rose barely to the surface.

Well at the Ice Factory.—This well is at the foot of Tennessee avenue, a short distance west of the board-walk. A shallow well had previously been put down at the same factory to the depth of 130 feet. This location is also near Young's Ocean Pier, where a very deep boring is being drilled, the depth of which, up to the time of printing this, is 2,285 feet. This latter well will probably be reported next year, illustrated by a section which will present the facts obtained from all of these three adjacent borings. The top of the great diatom clay bed occurs in the well now under consideration at 405 feet. The top of the great Miocene water-yielding sand was found at 790 feet. The total depth of the boring is 838 feet. The well was finished at the bottom with a 50-foot strainer length.

Well at The Chalfonte.—This well is located near the foot of North Carolina avenue, and on the westerly side of the same, and is about opposite to a well at the Haddon House, of which a record appears in the annual report for 1896, page 170. The top of the great diatom bed was found at the depth of 400 feet, and its base at 690 feet, where a thin seam of rock, perhaps one foot thick, occurs. This rock seam at the base of the Miocene diatom clay bed has been found in most, though not in all, of the wells at this place that have been put down deep enough to reach the water-horizon which occurs at the average depth of 800 feet. Next below this rock in this well, and in most of the other wells in the city, occurs a fossiliferous* non-diatomaceous sandy clay about 30 feet thick. A coarse gravel occurs at 720 to 730 feet. This is succeeded by dark brownish clays, with alternations of clayey sand, to the depth of 783 feet, where the great Miocene water-bearing sand stratum was entered, which has a thickness here of about 60 feet. The upper half of this bed consists of a rather dark, coarse brown sand, and the lower half of finer sand considerably lighter in color, the shade of which

* The fossils are Miocene molluscs.

may be described as brownish or brownish gray. The well was finished at the base with a strainer 50 feet in length.

SHALLOW BORED WELLS AT TUCKAHOE, AT THE SOUTHERN NEW JERSEY R. R. CO.'S STATION.

Elevation, 10 feet; depth, 14 feet.
Note of deeper test boring—Depth, 135 feet.

In 1895 we received from M. F. Bónzano, then Assistant Manager of the Southern Railroad of New Jersey, the following notes respecting the company's attempts at that time to obtain water at Tuckahoe:

"At Tuckahoe we put down a test well 135 feet deep last winter and went through various beds of clay and fine sand, without finding any quantity of water sufficient to draw water supply from. About two months ago I found out that several years ago a pipe had been driven immediately adjoining our station at Tuckahoe, and it furnished a good quality of drinking water. This pipe had been withdrawn for some reason several years ago. As we were badly in need of good drinking water for our station and cars, I determined to ascertain whether we could get good water near the site of the old well. At a depth of 14 feet we found a bed of heavy gravel and in it a strong flow of very good water. I therefore determined that in the original test wells, that had been put down, we had overlooked the spring within 14 feet of the surface, and made arrangements to put down a number of wells near where we had put down the test well last winter, which was within 100 feet of the point where we had found such good water. We put down four wells without being able to find water and were compelled to locate the wells north and towards the station before we could find the water. In going down we went through a *yellowish, white, fine sand about 11 feet, and below that the bed of heavy gravel stones*, in which we found water.

"It appears to me that there is some fault in the clay beds at that point and that they dam off the water beneath the surface so as to make it impossible to find water southward of a certain line that runs east and west."

We scarcely however expect that a fault occurs here as intimated by the R. R. company's engineer, if the term fault is used with its geological meaning, but we believe the true explanation will be learned when the exact stratigraphical positions and relations of the various beds at this point shall have been ascertained.

ARTESIAN WELL AT HOLLY BEACH.

Elevation, 10 feet; diameter 4½ inches; depth, 326 feet.
Water rises within 18 inches of the surface.

Early in the year Uriah White completed the drilling of a 4½-inch well for Frank E. Smith, nearly adjacent to Holly Beach station, ¾ of a mile south of Wildwood on Five Mile Beach. The data noted above were furnished by the contractor who also saved specimens of the borings which, however, were afterwards lost so that they were not received by the Survey. We are however informed that a blue clay was passed through between the depths of 260 and 290 feet and that this was succeeded by white sands and gravels in which were interbedded some thin clay seams.

Water, which however was always salt, was found on the sands and gravels all the way down to 260 feet. The water, however, from the bottom of this well (depth 326 feet) proves to be fresh and of a satisfactory quality. It has been used during the year for the manufacture of ice, which has been supplied to the boarding houses and hotels along Five Mile Beach, the patrons expressing themselves much pleased with its quality. This water-horizon has not been noted in the records furnished of former wells on this beach but it probably, however, underlies the entire beach, although as a water-bearing stratum it may possibly vary somewhat in thickness.

The detailed stratigraphical record of this well would doubtless be nearly the same as that of the strata to the same depth in the much deeper wells bored a few years since at Wildwood, which wells have been noted in the annual report for 1894 and 1895. The report for 1894 is illustrated with a lithographed vertical section of a much deeper well (depth 1,244 feet). The record in the report for 1895, of a well not so deep (depth 665 feet) is however more accurate for the first 400 feet, owing to a special apparatus having been employed in drilling which enabled unusually reliable specimens of the earths penetrated to be obtained. We therefore in a somewhat more condensed form re-introduce this record so far as the depth of 343 feet, which covers and slightly exceeds the depth (326 feet) attained by this well.

Beach sands,	0	feet	to	30	feet.
Blue clay with ***marine diatoms,*** recent species,	30	"	"	32	"
Sand and medium fine and coarse gravels,	32	"	"	61	"
Bluish and brownish clays, ***sponge spicules*** and both ***fresh water*** and ***marine diatoms*** mixed in the upper part,	61	"	"	91	"
Sand and gravel with ***fossiliferous*** Silurian and Devonian pebbles,	91	"	"	98	"
Bluish clay with a mixture of ***marine*** and ***fresh-water diatoms,*** among the latter ***Polymyxus coronalis.*** L. W. Bailey,	98	"	"	132	"
Sand and coarse gravel with large pebbles,	132	"	"	152	"
Sand with some lignite at intervals,	152	"	"	268	"
Drab-colored sandy clay,	268	"	"	296	"
Greensand marl,	296	"	"	310	"
Sand and gravel beds separated by seams of non-diatomaceous clays. ***Water-bearing*** in the lower part at Holly Beach and probably also at Wildwood,	310	"	"	329	"
Clay underlying the water-horizon of the Holly Beach well,	329	"	"	343	" +

The water-bearing sands of this well (310 to 329 feet) we name the Holly Beach water-horizon.

Notes Upon the Stratigraphy of the Cape May Peninsula.

Includes Known and Predicted Water-Horizon.

Following these notes we introduce data respecting a number of wells to greatly varying depths that have been put down in Cape May County, especially in the region near the Cape.

As the underground structure of the Peninsula of Cape May probably, at least for some of the upper beds, presents a later phase of development than the beds at similar depths near the coast to the northward, we have thought it might be well to note the more salient geological facts that have been ascertained from a study of the records that follow and from an examination, especially microscopically, of specimens of the borings which we have received from some of these wells.

We will first notice the water-horizons.

From the annual report for 1879, pages 143 and 144*, we learn through a quotation from a letter from R. B. Swain, C. E., that before the town was closely built an ample supply of water was had from "uniformly good surface wells of depths varying from 5 to 12 feet. As building increased it was found that surface wells became contaminated, when recourse was had to artesian and driven wells as a means of reaching to lower strata of water." From this same letter we further learn that at that time 1¼-inch tubes were driven to depths of 25 to 30 feet, according to the variable surface of the ground, and that these wells yielded from 7 to 10 gallons per minute.

R. B. Swain also says that seven 8-inch artesian wells had up to that time been put down within a period of 24 years to depths varying from 87 to 92 feet, according to the elevation of the land at the point where each well was located, developing a stratum of fine fresh water, each well yielding about 75 gallons a minute. He further says that the water from all deep wells will rise to a point at which water will stand in an open or surface well.

There were thus demonstrated three water-horizons, none of them at very great depth. Recapitulating they are as follows:

First water-horizon—*Surface wells,* dug to depths of *5 to 12 feet.*

Second water-horizon—*Driven wells,* to depths of *25* to *30 feet.* This is the same horizon as that of some 14 wells put down much more recently for the city water department to an average depth of 38 feet as also stated in this report, page 126.

Third water-horizon—*Artesian* or *bored wells,* to depths of *87 to 92 feet.* This is the same horizon as that of some 19 wells

* R. B. Swain's letter in the Annual Report for 1879; this was again printed verbatim in the Annual Report for 1882, pages 151 and 152.

put down quite recently for the water department to depths, as stated in this report, page 126, of from 79 to 106 feet.

To these horizons we may add probably two other much deeper water-horizons, one of which may perhaps exist, while the other, the deeper of the two, almost certainly does exist. These are as follows:

Fourth water-horizon—A *fourth water-horizon* may possibly occur at the depth of *about 350 feet.* This, however, remains yet to be proven. Its existence is suspected from the development the past year at Holly Beach at about that depth (326 feet) of a satisfactory supply of water which is used for the manufacture of ice at that place.

It may be, however, that the occurrence of this horizon at Holly Beach is only due to a local thickening of the sand and gravel stratum which holds the water, and that the bed may thin out or be entirely wanting at other localities not far distant.

For further data respecting this well and its water-horizon see this report, page 119.

Fifth water-horizon—The great 800-foot Atlantic City water-horizon, though not as yet reached by boring at Cape May, probably however exists at the depth of about 925 to 950 feet. It occurs at Avalon* between the depths of 870 and 925 feet, and at Wildwood† between the depth of 887 and 931 feet. The thickness of this water-horizon, from Avalon to Atlantic City, and still farther northward is quite certainly at least 40 feet and attains at some points a maximum thickness of 60 feet.

Below the first three of the water-horizons noted above there probably exists across the lower part of the peninsula a unique‡ diatomaceous clay bed, say below the depths of 90 or 100 feet. The well records at Wildwood show this bed between the depths of 61 and 132 feet, and at Sewell's Point show a clay bed probably the same, between the depths of 90 and 124 feet. Specimens from this bed were, however, not obtained from the Sewell's Point well, while they were from the Wildwood well. Examina-

*Annual Report, 1898, page 78.

†Annual Report, 1894, page 159, and 1895, page 86.

‡Unique for reasons noted in the succeeding paragraphs and also because it contains a diatom Polymyxus coronalis L. W. Bailey which is not found in the diatom bed that exists above it in Cape May County nor in the two Miocene diatom beds that are known to occur below it. See Holly Beach record, page 120.

tion of those from Wildwood show the bed to contain, associated with some sponge spicules, an abundance of diatoms of numerous species, some of which do not occur in the great 300 to 400-foot Miocene diatom bed, the top of which occurs say 225 to 275 feet lower. Judging from the similarity of depth this bed has also been met with at Avalon (depth of 70 to 100 feet). At this place, however, it is not rich in diatoms, showing mainly and only a few sponge spicules. From our studies of the numerous borings, ranging from Sea Isle City to Asbury Park, which have been placed in our hands, we are of the opinion that this bed is entirely wanting north of the Cape May peninsula.

It may further be noticed, however, that this bed has so far been revealed only upon the ocean or shore margin of Cape May County. Presumably it may extend across and underlie the whole peninsula, but specimens that may be obtained from future borings that may go sufficiently deep will be needed to certainly prove this.

What is probably another or separate deposit but of synchronous age occurs at Rock Hill, Md., on the eastern side of Chesapeake Bay. It was found in a well-boring there, occupying approximately the same interval of depth next above 130 feet from the surface and containing the same peculiar assemblage of diatoms.* See Annual Report 1898, page 117.

At about the depth of 250 or 275 feet we judge the deeper borings that have been made in Cape May County have certainly entered the Miocene formation. In the extreme south of the peninsula, at about 320 to 360 feet at Cape May Point, and at about 400 to 425 feet at Wildwood, an assemblage of Miocene molluscan shells occur which we list on page 130, and which, relying upon the judgment of Dr. W. H. Dall and Prof. A. Heilprin, we have regarded as indicating the existence of the St. Mary's Miocene which occurs stratigraphically higher than most of the Chesapeake Miocene, and which is by some considered as the upper member thereof.

Well-borings at Wildwood penetrated the great 300 to 400-foot Miocene diatomaceous clay bed between the depths of 370 and 793 feet, while borings from Lewes, Del., show the same bed between the depths of 407 and 772 feet. It therefore appears likely that at about an average depth of 400 feet the top of this

*Among the diatoms is Polymyxus coronalis, L. W. Bailey.

great diatom bed would be found beneath the entire lower part of the peninsula. It however doubtless exists beneath the whole peninsula as it does beneath all of New Jersey east of an irregular line which runs near to Asbury Park, Hammonton, Vineland and Bridgeton. But in the northern portion of the county back from the shore its depth would not be so great.

We now insert individual records of wells at Cape May and vicinity.

TWO OF THE EARLIEST ARTESIAN WELLS AT CAPE MAY.

At Congress Hall.* Elevation 10 feet. Depth 95 feet. Water rises within 4 feet of the surface and 6 feet above high-water mark.

At the Mount Vernon House.† Depth 81 feet. Water rose 2½ feet above the surface of the meadow.

Water-horizon of these wells the equivalent of that now supplying the deeper wells (depths 79 to 108 feet) of the city's water department.

In Prof. Geo. H. Cook's report of 1857 on the Geology of Cape May County, page 23, there are vertical sectional drawings to scale of two wells at Cape May with descriptions of the various beds penetrated. One of these was at Congress Hall and reached a depth of 95 feet, the other was at the Mount Vernon House and attained a depth of 81 feet. The data noted above as to the rise of the water in these wells was obtained by measurement of the scale for these drawings—the level of the same in each well being clearly indicated.

We copy the records below—the same water-bearing gravel was evidently found in both wells. This horizon is also probably the equivalent of that of the deeper of two series of wells recently put down for the water department of the city, which, as noted in this report, page 126, have depths ranging from 79 to 106 feet.

RECORD OF STRATA IN THE WELL AT CONGRESS HALL.‡

Gravelly sand,	25 feet	= 25 feet.
Black and muddy sand,	10 "	= 35 "
Gravel,	15 "	= 50 "
Clay somewhat sandy,	40 "	= 90 "
Cemented sand and gravel,	5 "	= 95 "

* Prof. Cook's section notes this well as at Congress Hall, while a paragraph in the text appears to refer to the same well as at the United States Hotel.

† The Mount Vernon House was afterwards burned to the ground and has not been rebuilt.

‡ See first foot-note, above.

At the depth of 90 feet or at the base of the 40-foot sandy clay bed what is described as a "cedar stump" was found.

RECORD OF STRATA IN THE WELL AT THE MOUNT VERNON HOUSE.

Marsh mud,	6 feet	= 6 feet.
Black sand,	21 "	= 27 "
Shells and salt water.		
Clay somewhat sandy, containing decayed wood,	40 "	= 67 "
Gravel with pebbles like those at Cold Spring,	14 "	= 81 "

The decayed wood noted in this section in the 40-foot sandy clay bed tends to show the identity of this bed with a bed of similar thickness and character penetrated by the well at Congress Hall in association with which the "cedar stump"(?) above noted was found. The lignite noted on page 126 in the report of two wells at the Columbia House, at the depths of 87 feet and 90 to 93 feet, also indicates the same horizon there.

From the text on page 25 of Prof. Cook's report, we infer that these wells were put down by J. N. Bolles, of Baltimore, Md.

ARTESIAN WELL AT CAPE MAY, AT THE COLUMBIA HOUSE.

Depth, 224 feet.

From the Annual Report for 1879, page 144, we learn that R. B. Swain, C. E., had furnished Prof. G. H. Cook with specimens of borings showing the strata penetrated to the depth of 224 feet by two wells that had been put down at the Columbia House at Cape May. These specimens have recently been found among the collections of the Survey at Trenton. Below we present the record as made by us from an examination of the same:

	Intervals of depth.
Gravel,	1 foot to 5½ feet.
Yellow sand,	5½ feet " 22 "
Gravel and irony crusts,	22 " " 28 "
Specimen wanting,	28 " " 30 "
Yellow gravel,	30 " " 38 "
Sand,	38 " " 40 "
Clayey sand, ochre color,	40 " " 41 "
Clay, no micro-organisms,	41 " " 54 "

	Intervals of depth.
Clay, with sponge spicules,	54 feet to 66 feet.
Specimen missing,	66 " " 76 "
Sand,	76 " " 86 "
Lignite in second well at	87 "
" " at	90 " " 93 "
Specimen missing,	93 " " 97 "
White sand,	97 " " 98 "
Whitish, sandy, clayey lumps, no micro-organisms,	98 " " 99 "
White sand,	99 " " 138 "
Brownish or drab-colored clay,	138 " " 143 "
Sand with black specks,	143 " " 151 "
Sand, slightly yellow,	151 " " 167 "
Brown sand with lignite,	167 " " 190 "
Brown sand, no lignite in this specimen,	190 " " 202 "
Brownish, clayey sand, with one specie of marine Diatom, a Pleurosigma,	202 " " 224 "

It is stated in the Annual Report for 1879, page 145, that salt water was struck at the depth of 224 feet, also that had the boring been suspended at the proper point an excellent well could have been had. This point was, doubtless, that of the deeper of the two water-horizons more recently developed by the water department's wells (see next record). This horizon in this well, we judge from the above record, to have occupied the interval between 76 and 98 feet.

The upper horizon of the water department's wells was also probably passed in this boring between the depths of 30 to 40 feet.

CITY WATER DEPARTMENT'S ARTESIAN WELLS AT CAPE MAY.

14 wells—diameter of each, 4 inches; average depth, 38 feet.
19 wells—diameter of each, 4 inches; varying depths of 79 to 106 feet.

During recent years there have been put down by Joseph H. Hanes a series of thirty-three wells for the supply of water to Cape May City. The wells are near the pumping station north of the city, and are arranged in a line near to and approximately parallel to the West Jersey Railroad. Fourteen of these wells are comparatively shallow, having an average depth of 38 feet. The other nineteen are deeper, varying in depth from 79 to 106 feet. All the wells have six-foot Cook strainers at the bottom.

The borings from two of the deeper wells (Nos. 8 and 19) are displayed in vertical sections in the office of the water department in the City Hall.

After a careful examination of these, we are able to present the following records, which show that both these wells penetrated practically the same succession of material, and that in the process of boring, the nineteen wells of the deeper series revealed not only the water-horizon at their bases, but also the higher water-horizon of the fourteen wells of the more shallow series:

RECORD OF WELL NO. 8.

Yellow soil,	1 foot	= 0	to	1	foot.
Yellow gravel,	1 "	= 1	"	2	feet.
Gravel, *water-bearing,*	17 feet	= 2	"	19	"
Fine white sand,	16 "	= 19	"	35	"
Fine gravel with *water=horizon* of shallow wells,	5 "	= 35	"	40	"
Hard blue mud,	30 "	= 40	"	70	"
Blue mud and sand,	4 "	= 70	"	74	"
Gravel and mud mixed,	2 "	= 74	"	76	"
Coarse sand,	14 "	= 76	"	90	"
Fine sand,	5 "	= 90	"	95	"
Coarse sand and fine gravel. *Water-horizon* of the deeper wells,	11 "	= 95	"	106	"

RECORD OF WELL NO. 19.

Yellow loam and gravel,	25 feet	= 0	to	25	feet.
White sand,	7 "	= 25	"	32	"
Yellow gravel,	3 "	= 32	"	35	"
Fine gravel with *water=horizon* of shallow wells,	5 "	= 35	"	40	"
Fine brown sand,	15 "	= 40	"	55	"
Hard blue mud,	25 "	= 55	"	80	"
Brown sand, *water-bearing,*	13 "	= 80	"	93	"
White sand, *water-bearing,*	2 "	= 93	"	95	"

Since preparing the foregoing Joseph H. Hanes writes that these wells "extend some 1,500 feet along the W. J. R. R.," and that they "are bored on the R. R. right of way." He says, "Within that distance we crossed a swamp that has water in it in wet times. I found in approaching this swamp we found less water, and I finally abandoned two wells as not having water enough, and in one case I bored down to 135 feet with no better result."

ARTESIAN WELL AT CAPE MAY FOR THE CAPE MAY BRANCH OF THE N. J. S. R. R.

Six wells—Diameter of each, 3 inches; depth, about 20 feet.
One well—Diameter, 3 inches; depth, about 80 feet.

M. F. Bonzano, Assistant Manager of the New Jersey Southern Railroad, informed us in 1895 that at that time they had at Cape May six 3-inch wells to a water-horizon which was found at the depth of about 20 feet, and one 3-inch well to a second water horizon occurring at the depth of 80 feet. He says the six 3-inch wells to the first "spring" will pump nearly 500 gallons per minute. The two water horizons developed by these wells are evidently the same as those supplying the city water works, and reported on page 126.

ARTESIAN BORING AT SEWELL'S POINT.

Diameter, 3 inches; depth, 130 feet.
Clay probably diatomaceous at 90 to 124 feet.
The equivalent of diatomaceous clay at Wildwood at the depths of 61 to 132 feet.

A 3-inch well was drilled during the summer of 1898 at Sewell's Point, the location of this well being about three miles east of the wells of the water department of Cape May City, just reported on the preceding pages.

Of C. B. Speace we have received the subjoined record:

Beach sand,	38 feet	= 0 to	38 feet.
Marsh mud, slushy,	16 "	= 38 "	54 "
Sand,	4 "	= 54 "	58 "
Greenish mud or clay,	7 "	= 58 "	65 "
No water below this depth.			
Very hard greenish mud or clay,	13 "	= 65 "	78 "
Sand, very dark, almost black,	12 "	= 78 "	90 "
Blue clay,	34 "	= 90 "	124 "
Light-colored coarse sand, no water,	6 "	= 124 "	130 "

In this well the sands and gravels of the upper water-bearing horizon of the Cape May water department's wells are wanting, their place being apparently occupied by the beach sands and the underlying marshy or slushy mud. The lower water-horizon of the water department's wells seems also to be wanting here.

The clays below 90 feet in this well would probably also have been found at the locality of the water department's wells had the borings there been continued below the second or deeper water horizon of that locality.

The contractor, Joseph H. Hanes, states that what water was found in drilling this well was always salt.

The 34 feet of blue clay between the depths of 90 and 124 feet appear to be stratigraphically the equivalent of the unique diatomaceous clay bed that occurs at Wildwood between the depths of 61 and 132 feet, but as no specimens of the borings were received from this well we are unable certainly to determine this point.

ARTESIAN BORING AT CAPE MAY POINT, AT THE CARLTON HOUSE.

Elevation 10 feet ± Depth 700 feet.

A number of wells have been bored at different times and at various points in and about Cape May City to somewhat greater depths than the lower of the two fresh-water horizons noted in the report of the water department's wells, pages 126, 127, but these, after passing the fresh-water horizons just noted, have generally, if not always, found only salt water. Some of these salt-water wells have been noted in the Annual Reports for 1879 and 1882. Besides the wells noted in these two Annual Reports, there have appeared records in the Annual Reports for 1885, page 140, and for 1894, pages 157 and 158, of the deepest boring so far made at Cape May. This was an unsuccessful one at the Carlton House, at Cape May Point, put down, as stated in those reports, to a depth of 456 feet. A gentleman who at the time this boring was made was in the office of the contractor who drilled the well has quite recently stated, from memory only, however, that the well actually reached a depth of 700 feet before the work was abandoned.

Respecting this well, Prof. Cook states in the Annual Report for 1885, page 140, that shells were found between the depths of 420 and 460 feet. At a later date the writer collected from the material brought out of the well, and which was still lying around its mouth, a number of shells presumably the same as those referred to by Prof. Cook. We copy below, from the Annual Report for 1894, page 158, the list of species as then identified, and also a few succeeding paragraphs giving our views at that time:

*Crepidula sp? fragments.
Cardium sp.? fragments.
Venus mercenaria Linn.
*Mactra modicella Conrad, young.
Arca sp.?
Pecten sp.?
Lucina crenulata Conrad.
Melanopsis Marylandica Conrad.
Nassa (Tritia) trivittata Say.
Solen, fragment.
Eulima sp.?
Turritella plebeia Say.
Turritella variabilis Conrad.
*Pleurotoma limulata Conrad.
*Terebra inornata Whitfield.
*Terebra simplex Conrad.
*Ptychosalpinx, probably Multirugata Conrad.
*Corbula, probably nasuta Say.
*Cœcum glabrum Mont.
Trochita sp.?
Barnacles = Balanus.

"The specimens marked with an asterisk (*) were identified by Dr. W. H. Dall, who states that 'the horizon of nearly all these species is that of the St. Mary's beds, St. Mary's county, Maryland, of the Chesapeake Miocene.'

"In the identification of the remaining forms the assistance of Prof. Angelo Heilprin was had.

"By far the most numerous of all the mollusks was the Melanopsis of a species which is especially characteristic of the St. Mary's bed. This same specific form of Melanopsis has been again discovered* at a little greater depth in a well put down at Wildwood, on Five-Mile Beach.

"A workman was recently seen who assisted in boring the first 270 feet of this well, and who says that, at that depth, they were in a white, marly clay, with green lumps in it; that mud was found at the depth of twelve feet, salt water at thirty-five feet and wood at 125 feet. The depth of 270 feet probably marks the top of the Miocene.

"From the sands and clays around the mouth of the well there were also extracted a considerable number of diatoms."

Records of wells at Wildwood, N. J., and at Lewes, Del., indicate the probability that at or just below the depth of 400 feet this

* In 1894. See also Wildwood record in the Annual Report of that year, p. 173.

well had entered the top of the great 300 to 400-foot Miocene diatomaceous clay bed, beneath which, either immediately or a short distance below, there has invariably been found beneath the beaches in New Jersey, from Harvey Cedars southward, the copious and excellent 800-foot Atlantic City water-horizon, and which, had this boring been continued, would almost certainly have been found here at the depth of about 900 or 950 feet. This water-horizon has a thickness ranging from 40 to 60 feet.

BORED WELLS AT CAPE MAY COURT HOUSE.

Elevation, 15 feet; diameter, 3 inches; depth, 44 feet.

Jos. W. Pratt informs that he has put down a 3-inch well for A. R. Springer at Cape May Court House to the depth of 44 feet, where a black mud was encountered, on which the boring was stopped. He says, "Water was obtained just above this black mud in a mixture of sand and gravel having the color of a good quality of brown sugar."

ARTESIAN WELL AT FORT MOTT.

Elevation, 10 feet ±; diameter, 8 inches; depth, 320 feet.
Water overflows at the surface 50 gallons per minute.

Early in the year P. H. & J. Conlan drilled a well for the U. S. government at Fort Mott, on the Delaware river, north of Salem. They courteously saved a full series of the borings taken every five feet to the depth of 110 feet, and every ten feet thereafter. From an examination of these we make the following:

STRATIGRAPHICAL AND GEOLOGICAL RECORD.

Thickness of Strata.		*Intervals of Depth.*	*Age*	
25 feet.	Yellow sand and gravel, ..	0 feet to 25 feet.	Comparatively Recent, 25 feet.	
25 "	Black sandy clay, ...	25 " " 50 "	Matawan Clay Marls, 97 feet.	Cretaceous.
15 "	Coarse sand, ...	50 " " 65 "		
40 "	Dark hard clay, ...	65 " " 105 "		
17 "	Dirty whitish clay, transition layer, ...	105 " " 122 "		

Thickness of Strata.		*Intervals of Depth.*		*Age*
8 feet.	Whitish clay, lighter shade,	122 feet to 130 feet.	Raritan Plastic Clays, etc., 198 feet.	Cretaceous.
18 "	Medium coarse bluish gray sand,	130 " " 148 "		
6 "	Fine white sand,	148 " " 154 "		
36 "	Red sand clay,	154 " " 190 "		
30 "	Red(?)*sand, medium coarse,	190 " " 210 "		
10 "	Fine yellowish sandy clay,	210 " " 220 "		
65 "	Red sandy clay,	220 " " 285 "		
15 "	Red plastic clay,	285 " " 300 "		
9 "	Medium coarse white sand,	300 " " 309 "		
11 "	Coarse whitish gray gravel,	309 " " 320 "		

The strata are water-bearing from between the depths of 300 feet and 320 feet.

We will consider the various strata of this well in their relations to those of the next succeeding record of a well on the opposite side of the river at Fort Dupont, Delaware, in the concluding paragraph descriptive of the well at the latter point (see pages 133 and 134).

ARTESIAN WELL AT FORT DUPONT, DEL.

Elevation, 10 feet ±; Diameter, 8 inches; Depth, 700 feet.+

Late in the year P. H. & J. Conlan commenced drilling an 8-inch well for the U. S. government at Fort Dupont, Del., and as this goes to print have reached a depth of 700 feet. This well is on the opposite side of the Delaware river from the well just reported at Fort Mott, N. J. The contractors, as with the Fort Mott well, again courteously saved and furnished the Survey with a full series of the borings taken in this instance from below the depth of 140 feet at intervals of ten feet apart; for the portion above that depth they furnished a minutely detailed record. From this data and from an examination of the specimens on hand we compile the following record:

*The specimen of this sand received was red in color, but it occurs to the writer that this red color may have been derived from the coloring of the water used in the wash-out process employed, by the red clay next above.

Dark sandy loam,	0	feet	to	1	foot.		
Light red sandy loam, some clay,	1	foot	"	5	feet.		
Black sand, some gravel, with thin 6-inch water vein,	5	feet	"	6	"		
Red loose loamy sand and gravel,	6	"	"	13	"		
Fine dark sand, almost a quicksand,	13	"	"	17	"		
Coarse gray sand and gravel,	17	"	"	25	"		
Black marl,	25	"	"	37	"	Matawan Clay Marls. 123 feet.	Cretaceous.
Gray marl,	37	"	"	44	"		
Thin layer of sand rock.							
Gray sand and gravel with shells,	44	"	"	59	"		
Stiff blue clay,	59	"	"	69	"		
Black marl, very dry, alternating with light gray sticky marl,	68	"	"	140	"		
Thin alternating layers of white sand and white clay,	140	"	"	145	"		
"Black sand and gravel,"	145	"	"	148	"		
Alternations again of thin layers of white sand and white clay, the latter called by the driller "white marl" (?),	148	"	"	153	"	Raritan Plastic Clays and Sands, &c. 552 feet.	
Whitish sand and clay mixed,	153	"	"	167	"		
Red clay and sand,	167	"	"	177	"		
Very coarse and fine sandy reddish clays alternating,	177	"	"	207	"		
Very red clay,	207	"	"	217	"		
Red clayey sands and sandy clays alternating fine to coarse,	217	"	"	277	"		
Red clay,	277	"	"	287	"		
Sand and clay,	287	"	"	307	"		
Red sand,	307	"	"	317	"		
Coarse clayey sands and fine clay sands alternating, varying shades of red from dark to light,	317	"	"	397	"		
Reddish, very fine floury sand,	397	"	"	427	"		
Red sand with lignite,	427	"	"	428	"		
Hard sticky clays, dark red to blood red in shade,	428	"	"	488	"		
Very coarse sandy red clay,	488	"	"	498	"		
Red plastic clay, varying somewhat in shade from blood red to dark red,	498	"	"	608	"		
Reddish clayey sand,	608	"	"	635	"		
Red clay,	635	"	"	680	"		
Whitish sand,	680	"	"	700	"		
Lignite at				700	"		

The boring of this well has not yet been completed.

Comparison of this record with that of the well at Fort Mott, N. J., shows the Matawan clay marls to be slightly thicker, and also that this well has penetrated a decidedly greater thickness of the Raritan plastic clays and associated sands and sandy clays. We arrange these facts in tabular form, thus:

	Fort Mott, N. J. Thickness.	*Fort Dupont, Del. Thickness.*
Superficial beds,	25 feet.	25 feet. ?
Matawan clay marls,	97 "	123 feet.
Raritan plastic clays, &c.,	198 "	552 " +
Total depths,	320 feet.	700 feet.—

Inasmuch as these wells are nearly upon the line of strike, as long since established in New Jersey, for the base of the marl series, it seems remarkable that the coarse water-bearing gravel furnishing a supply to the well at Fort Mott should be altogether wanting at a similar depth at Fort Mott; in fact, no such gravel has been found so far as this well has as yet been prospected.

The Fort Mott and the Middletown, Del.,* wells and those at Jobstown† and Mount Holly,‡ N. J., indicate a very great thickness for the Raritan formation.

ARTESIAN WELL AT PITMAN.

Elevation, 130 feet; diameter, 3 inches; depth, 129 feet.

A well has been put down for Elmer H. Crane, at Pitman, to the depth of 129 feet, the drilling being done by Jos. W. Pratt, who has furnished specimens of strata and information respecting the same, from which we compile the following:

Orange or yellow sands,	0 to 91 feet.	Mainly Beacon Hill. (?)
Dark clay,	91 " 110 "	Miocene (?)
Lime sand with Echinus spines and numerous Bryoza,	110 " 129 "	Cretaceous.

Water was found at the base of the well in the Bryozoan lime-sand.

This well draws from the same horizon as a number of wells at and around Lindenwold, which, like this one, are finished in

* Annual Report [illegible], page 1[illegible]7, and [illegible], page [illegible].
† Annual Report [illegible], page [illegible], and [illegible], page [illegible].
‡ Annual Report [illegible], page [illegible].

the lime-sand that overlies the Middle Marl. This horizon has been named in former reports the Lindenwold water-horizon. The well is outside of and to the eastward of the Methodist camp meeting grounds, commonly known as Pitman Grove, within which, on somewhat lower ground, a deeper well (190 feet) was put down a few years since, as noted in the Annual Report for 1896, page 128. This deeper well penetrated the lime sand, and then went entirely through the marl series and draws from the Marlton water-horizon, which lies next beneath the marls. These two wells indicate that there are two water-horizons at this point that can be utilized.

Allowing for the difference in the elevation of the surface at the two wells, the records of the strata down to the lime sand in each may be considered as at identical depths below a common datum.

ARTESIAN WELL AT NATIONAL PARK.

Diameter, 6 inches; depth, 80 feet.

Joseph W. Pratt reports having bored a well at National Park to the depth of 80 feet, ending in a very coarse, heavy gravel, of which he has furnished specimens. From the character of the various pebbles composing this gravel we judge that this well was finished in the basal beds of the Raritan division of the Cretaceous.

FOUR ARTESIAN WELLS AT GLOUCESTER.

Elevation, 2 feet above mean tide.

No. 1—Diameter, 8 inches; depth, 167 feet.	Paired wells.
No. 2—Diameter, 8 inches; depth, 97 feet.	
No. 3—Diameter, 8 inches; depth, 178 feet.	Paired wells.
No. 4—Diameter, 6 inches; depth, 82 feet.	

Water overflows at high tide, does not at low tide.
Tidal rise and fall in the wells, 18 inches.
Tidal rise and fall in Newtown Creek (adjacent), 5 feet, 6 inches.

Four artesian wells were put down in the early summer of this year at the water works at Gloucester, Senator George E. Pfeiffer being the contractor, the diameter and depth of each being as noted above.

These wells are additional to thirteen wells previously put down at the same locality, eleven of which (of 4½ inches diameter) were noted in the Annual Report for 1893, page 405. The depths of these were as follows:

(A) Three with depths ranging from	67	to	79	feet.
(B) Four with depths ranging from	85	"	96	"
(C) Three with depths ranging from	146	"	162	"
(D) One with a depth of			270	"

As we noted in that Annual Report "the wells of group A draw from bluish gray gravels at the base of the clay marls. Those of group B draw from transition layer between the clay marls and the plastic clays, while those from groups C and D draw from the yellowish-white gravels interbedded at the base of the plastic clays."

Of the wells put down the past year numbers 2 and 4 draw from group B, while numbers 1 and 3 draw from group C, being however continued somewhat deeper therein than were the wells put down thereto in 1893.

The four wells developed the past year were put down by the old drill and sand-bucket process, which permits the obtaining of better specimens than the various hydraulic or jetting methods. From continuous and careful examination of these specimens as the drilling progressed, W. H. Boardman, C. E., made an unusually accurate detailed record which he has kindly furnished and which we insert verbatim. The wells are located about 350 feet apart from each other, and like the former thirteen wells are on the banks of Newtown Creek, east of the W. J. R. R. station at Gloucester, and between the creek bank and the railroad to Mount Ephraim which at this point parallels the creek.

Black mud,	0 feet	to	6	feet.
Dirty black sand,	6 "	"	10	"
Clean coarse white sand,	10 "	"	13	"
Yellow clay,	13 "	"	14	"
Fine clean light yellow sand,	14 "	"	21	"
Fine clean white quicksand,	21 "	"	30	"
Clean light yellow gravel,	30 "	"	36	"

Fine clean white quicksand,	36	feet	to	40	feet.
Very coarse white gravel,	40	"	"	43	"
Dark fine sand,	43	"	"	45½	"
Dark clay,	45½	"	"	46	"
Clean coarse gray sand,	46	"	"	55	"
Fine gray sand,	55	"	"	57	"
Clean coarse gray sand,	57	"	"	59	"
Dark sandy clay,	59	"	"	60	"
Coarse dark gray sand,	60	"	"	68	"
Clean coarse white sand,	68	"	"	73	"
Very clean white sand and pebbles,	73	"	"	79	"
Very clean coarse white gravel with plenty of water,	79	"	"	85	"
White clay,	85	"	"	85½	"
Fine slushy white sand,	85½	"	"	90	"
Very coarse white clean sand and gravel,	90	"	"	104	"
Coarse white clayey sand,	104	"	"	113	"
White plastic clay,	113	"	"	114	"
White clayey sand,	114	"	"	115	"
White clay,	115	"	"	116	"
White plastic clay, like putty,	116	"	"	121	"
Fine clean white sand,	121	"	"	138	"
Coarse white clean sand,	138	"	"	162	"
Very coarse clean gravel,	162	"	"	165½	"
Wells No. 1 and 3 are supplied from these strata from between the depths of 146 to 166 feet.					
White plastic clay,	165½	"	"	168	"
Red plastic clay,	168	"	"	174	"

ARTESIAN WELL NO. 2 AT U. S. NAVY YARD, LEAGUE ISLAND, PHILADELPHIA.

Elevation, 10 feet +; diameter, 10 inches; depth, 906 feet.
In Raritan Cretaceous beds between 79 and 260 feet.
In gneiss rock below the depth of 260 feet.
Water-horizon found at the depth of 536 feet.
No increase of water below this depth.
Water rises within 28 feet of the surface.
Incidental notice of other borings at the same point.

In the Annual Report for 1896, pages 114 and 185, and also in that for 1897, page 270, there occur records respecting a well for water-supply drilled at the United States Navy Yard, League Island, Philadelphia, to the depth of 600 feet. In the report for 1899, pages 117 to 121, there is a record respecting a number of shallow borings at the same place to the depths of 25 to 38 feet.

During the last month of the year 1899 there was completed the boring of the second *deep* well at this Navy Yard for water-supply. The work was done by Thomas B. Harper.

From C. C. Walcott, C. E., U. S. Navy, in charge of the engineering work at the Navy Yard, we have the information tabulated above and much of that incorporated below. To his courtesy we are also indebted for the opportunity to examine a full series of the borings which were taken every five feet and carefully preserved in his office.

From the surface to the depth of 260 feet where micaceous rock was entered the record is substantially the same as set forth in the record for the first well in a former report (1896).

Both records show that below the superficial deposits of marsh mud and underlying Pensauken gravel there occur the plastic clays and associated heavy gravels of the Raritan division of the Cretaceous, which division lies at the base of the unconsolidated beds of the coastal-plain portion of New Jersey and which also underlies southern Philadelphia, as has been frequently noted in recent Annual Reports of the survey.

As already stated, the former deep well (No. 1) was drilled to a depth of 600 feet, while this well (No. 2) was drilled a total depth of 906 feet.

According to C. C. Walcott water was found in the first well at the depth of 572 feet, while in this one it was found at 536 feet or 36 feet higher. No appreciable increase of water in either of these wells was caused by boring below these levels.

These two wells are 156 feet apart, being situated on either side of the pump house; No. 2 to the east and No. 1 to the west of the same. Engineer Walcott states that pumping from either well so as to lower the head of water in the well pumped does not affect the level of the water in the other well.

A pump placed in the present well (No. 2), at the depth of 225 feet secures a supply of 53 gallons a minute.

We are informed that analyses made by two different chemists show the water to be satisfactory in quality, a fact confirmed it is said by actual daily use.

From our examination of the borings from well No. 2 we present the following record of the same:

Marsh mud contains a mixture or *marine* and *fresh-water diatoms*,	0 feet to	20 feet.	Recent.
Gravel with large pebbles and cobbles,	20 " "	40 "	Pensauken.
Fine brownish gravel,	40 " "	79 "	Age. ?
Red variegated plastic clay,	79 " "	135 "	Raritan Cretaceous.
Fine gravel or coarse sand,	135 " "	145 "	
Red sandy clay,	145 " "	155 "	
Red clay,	155 " "	170 "	
Red fine clayey sand,	170 " "	190 "	
Coarse gray sand with large pebbles,	190 " "	205 "	
White clay containing large pebbles,	205 " "	225 "	
Coarse gray sand,	225 " "	250 "	
White sandy clay,	250 " "	260 "	
In well No. 1, micaceous gneiss rock, With *water-horizon* at 572 feet.	260 " "	600 "	Age. ?
In well No. 2, micaceous gneiss rock, With *water-horizon* at 536 feet.	260 " "	906 "	

The marsh mud or recent alluvium at the top of these two deep well borings it may be noted presents only a thickness of 20 feet, while the same mud farther out on the river margin of the island ranges from 25 to 40 feet in thickness, as has been noted in the record already referred to in the Annual Report for 1899, of a number of test borings made preparatory to the construction of a dry dock.

It will therefore be seen that the specimens of earths from these two deep wells and from the test borings just referred to reveal a depth of alluvium or quite recent mud or clay along the Delaware river front, on east side of the mouth of the Schuylkill, varying from about 20 feet to 38 feet. This alluvium contains, throughout its entire vertical extent, the siliceous cases or remains of single-celled plant organisms, known as diatoms. The diatoms of this deposit present a mixed assemblage of fresh-water and marine species, among the latter being a triangular form, *Triceratium favus, Ehr*, which is found living to-day in the Delaware river at the latitude of Philadelphia, and also occurs in the muds on the river margin from the Breakwater northward to that city, but which the writer has been unable to find, either buried in the muds or living in the water, at Burlington. This particular fossil is indicative of deposits of quite recent geological age, say Pleistocene, and possibly also Pliocene; this Navy Yard alluvium being, however, certainly *decidedly late* Pleistocene.

It may be interesting, for comparison, to note the depth of similar alluvial deposits at the debouchure into the Delaware of other tributaries, all of which exhibit a similar mixed assemblage of marine and fresh-water deposits. They are as follows:

Location.	*Depths of marsh in feet.*	*Noted in Annual Reports for*
Newtown Creek, Gloucester well record, ...	15*	1893, page 404.
Pensauken Creek, ...	25 to 41	1898, page 111.
Hog Island, at Tinicum Creek, ...	40	1896, page 115.

We now present the detailed results of our examination of the test borings, copying the same from our record thereof in last year's report. The first column on the right gives the number of the test borings in the order of the time when they were made, while the second gives the depth, in feet, of each specimen examined.

Result of Microscopic Examination of Late Pleistocene Alluvium (marsh mud) in Test Borings at Philadelphia Navy Yard, League Island, Pa.

No. of Boring.	Depths of Specimens.	
IX.	2 feet.	*Pinnularia* and some discoid diatoms.
IX.	2 "	*Eunotia* and circular discoid diatoms; also pin-head sponge spicules.
IX.	4 "	Diatoms, fairly plentiful.
IX.	6 "	Diatoms.
IX.	8 "	Diatoms, circular discoid forms noticeable.
IX.	10 "	Diatoms fairly plentiful in a fine, sandy, micaceous silt.
III.	10 "	Diatoms and a few sponge spicules.
IV.	10 "	Diatoms.
III.	12 "	No diatoms observed; silt quite sandy.
IX.	12 "	Diatoms, a few small discoid forms.
IV.	12 "	Diatoms, a few, with a few sponge spicules in fine silt.
IV.	14 "	Diatoms, a few.
IX.	14 "	Diatoms.
III.	14 "	Diatoms and sponge spicules.
IV.	16 "	A few sponge spicules; no other micro-organisms observed.
IX.	16 "	Diatoms. Large discoid forms plentiful.
III.	16 "	Diatoms.

* This boring was made quite close to the inner margin of the marshy flat; had it been farther out toward the stream and the center of the marsh, it would probably have shown a still greater depth of alluvium.

No of Boring.	Depths of Specimens.	
V.	17 feet.	Diatoms.
IX.	18 "	Diatoms in a very fine sandy silt.
III.	18 "	Diatoms *Eunotia*, &c.; also a few sponge spicules.
IX.	20 "	Diatoms.
IV.	20 "	Diatoms, large discoid forms.
III.	20 "	Diatoms.
V.	21 "	Diatoms, a few.
IV.	22 "	Sponge spicules; no diatoms seen.
IX.	22 "	Diatoms.
III.	22 "	Diatoms and sponge spicules.
V.	23 "	Diatoms, *Triceratium favus*, &c.
IX.	24 "	Diatoms.
III.	24 "	Diatoms fairly plentiful.
IV.	24 "	Diatoms fairly plentiful.
V.	25 "	No micro-organisms seen—sand and very sandy clay.
V.	29 "	No micro-organisms seen; very sandy, gravelly clay.
IX.	26 "	Diatoms, a few.
III.	26 "	Diatoms, a few in a mixture of gravel and sand, with a little clay.
IV.	26 "	Diatoms.
V.	27 "	No micro-organisms seen; very sandy clay.
IX.	28 "	No micro-organisms seen; coarse sand with a little clay.
IV.	28 "	Diatoms.
IV.	29 "	Diatoms and sponge spicules.
IV.	30 "	No micro-organisms; gravel and sand.
IX.	30 "	No micro-organisms; sand, with a little clay.
IX.	32 "	Diatoms, a few. } Coarse sand, with a little clay.
IX.	34 "	No micro-organisms. } Coarse sand, with a little clay.
IX.	36 "	No micro-organisms. } Coarse sand, with a little clay.
IX.	38 "	No micro-organisms. } Coarse sand, with a little clay.

The nature of the coarse gravel next below this alluvium and occupying the interval in the two deep wells between the depths of 20 and 40 feet was well and indeed better seen in some dredgings into the same that were made in the back channel that separates the island from the main portion of the city. After a personal examination of these gravel dredgings where they were spread out over the ground we have no hesitation in referring them to the Pensauken formation.

The age of the gravels filling the next lower interval, viz., between the depth of 40 and 79 feet, we hold in reserve. All however below 79 feet to the top of the micaceous rock we place in the Raritan Cretaceous.

Considerable water was found in the Pensauken gravels, but tests showed much contamination thought to be derived from oils and other objectionable matter contributed to the Schuylkill river from oil refineries and other manufacturing establishments a few miles further up on the banks of the same.

The sands and gravels interbedded in the Raritan plastic clays would probably furnish water, but we have not learned that any tests were made either as to quality or quantity. These Raritan water-horizons are probably essentially the same as those furnishing water plentifully and of satisfactory quality to the cities of Camden and Gloucester.

Red plastic clay was found at the depth of 40 feet in the test borings of apparently the same nature as that found at the depth of 79 feet in the deep wells. If the same bed it indicates considerable irregularity of the surface of these Cretaceous clays. We cannot, however, be certain but that the clay revealed in the dry dock borings may represent a higher and different stratum.

This boring clearly demonstrates that the basal beds of the Raritan Cretaceous of New Jersey underlie southern Philadelphia.

ARTESIAN WELL FOOT OF PENN STREET, CAMDEN.

Elevation, high-water mark in the Delaware River.
Diameter, 8 inches; depth, 76 feet to micaceous rock.
Yield, 300 gallons per minute.

W. H. Boardman, C. E., furnishes the following record of an eight-inch well, sunk by George Pfeiffer, Jr., for the Quaker City Morocco Works, at the foot of Penn street, Camden, the elevation of the surface of the ground being the same as high water in the Delaware river:

Surface sand,	0	to	7	feet.
Mud,	7	"	9	"
Pebbles and cobbles,	9	"	17	"
Coarse sand and yellow gravel,	17	"	29	"
Coarse clean sand,	29	"	38	"
Clean gravel and pebbles,	38	"	50	"
Blue clay,	50	"	61	"
Clean white coarse gravel,	61	"	76	"
Micaceous rock at			76	"

This well was finished with "a strainer at the base 13 feet 6 inches in length, and was tested by pumping 300 gallons per minute."

ARTESIAN WELL AT HEDDING, ONE MILE SOUTH OF MOUNT EPHRAIM.

Elevation, 70 feet ±; diameter, 3 inches; depth, 215 feet.

This well was drilled by Joseph W. Pratt, on the property of John F. Harned, near Hedding toll-gate, about one mile south of Mount Ephraim. It was put down as the continuation of a well that had been previously drilled to the depth of 43 feet.

From information and specimens furnished we are enabled to make the following record:

Bottom of previous well,	43	feet.
Green, micaceous, stiff marly clay, with plenty of greensand grains,	at 167	"
Olive-colored stiff clay mixed with greensand grains,	167 to 187	"
Stiff black clay, a few greensand grains. *Foraminifera,* also *Dentalium* and some other molluscs,	187 " 195	"
Olive gray medium sand, very clayey,	195 " 200	"
Coarser gray sand, not olive in shade,	200 " 205	"
Stiff, very sandy clay, dark color,	205 " 214	"
Coarse gray sand, some pebbles large as peas. *Water-bearing,*	214 " 215	"

This well was finished with a strainer 9 feet long at the base, and is, the contractor says, "a very fine well." In advance of the completion of this well the writer predicted from other well data in his hands a water-bearing stratum at 220 feet. This was found, as already noted, at 215 feet, a close approximation. The water-horizon is within the Matawan clay marls.

ARTESIAN WELL WEST OF MOORESTOWN.

Elevation, 60 feet; depth, 130 feet.

We have been furnished by W. C. Barr with a record, which we place below, of a well put down by him on the farm of Edw. Harmer, west of Moorestown, on the road from East Moorestown to Riverton:

Top soil,	11 feet	=	11 feet.
Red sand with water,	3 "	=	14 "
White sand with water,	2 "	=	16 "
Red (?) fine clay,	2 "	=	18 "
Green sandy clay, Black clay,	77 "	=	95 "
Chocolate "stony" clay,	24 "	=	119 "
Black clayey sand with iron pyrite and lignite,	11 "	=	130 "

This boring has not opened a satisfactory water-bearing stratum. It is probably mostly, if not entirely, in the clay marls, except, perhaps, the first eleven feet.

ARTESIAN WELL AT MOUNT HOLLY.

Elevation, 20 feet; diameter, 8 inches; depth, 562 feet.
Correlation of five subdivisions of the Matawan Clay Marl Series.

The Mount Holly Water Company had a deep-test well put down late in the year. The drilling was done by Thomas B. Harper, to whom and to B. Haywood Shreeve, of the water company, we are indebted for a full series of the borings and for data respecting the well. From a study of these borings and comparison of the same with the data furnished we compile the record introduced below. This boring passed through the greater part of the Matawan clay marl formation, say 320 feet, and penetrated 242 feet further into the next underlying Raritan formation. In the Annual Report for 1898, page 35, Prof. R. D. Salisbury notes a five-fold division of the Matawan Clay Marls, to which he recognizes and applies the names which had been given them, he states, by Mr. Knapp. We re-introduce these names in their order from top to bottom, numbering them, however, in accordance with Mr. Knapp, from base to top, viz.:

No. 5. The Wenonah bed, a sand.
No. 4. The Marshalltown bed, a marly-clay sand.
No. 3. The Columbus bed, a sand.
No. 2. The Woodbury bed, a clay.
No. 1. The Merchantville bed, a marly clay.

We recognize all of these beds except the uppermost, the Wenonah sand, which is evidently wanting in this boring.

This well is located on the banks of the Rancocas, at an elevation of about 20 feet. The Wenonah sand bed probably at one time existed here, but has been carried away by stream erosion, since a sand, probably this bed can be seen on the hill at Mount Holly between the levels of 50 and 100 feet above tide.

The Marshalltown bed occurs between the depths of 12 and 57 feet. In its outcrops southwestwardly it contains fossil molluscs; none, however, were detected in the specimens of the borings.

The Columbus sand occurs between 57 and 97 feet, and yields a plentiful supply of water, but its quality is too *irony* to be considered potable. This water-bearing stratum has been known at Mount Holly for many years, other wells* of 40 feet or more in depth having reached it, but its use has generally, if not always, been discarded. This Columbus sand-bed was so named because it outcrops about Columbus. It is the same bed that constitutes the Cropwell water-horizon, as named by the present writer, from the fact that its existence as a water-yielding stratum became first known from the development of a well at Cropwell.

The Woodbury clay-bed appears to occupy the interval between 97 and 193 feet. No water-bearing sands were reported in this bed, and, unfortunately for our purpose, but few specimens of the borings were taken for this interval. Farther southwest this division of the clay marls is more or less inter-laminated with sands, which there constitute the Woodbury-Wenonah water-horizon of the present writer.

The Merchantville marl and marly clay bed, the basal bed of the clay marls, seems to cover the interim between 193 and 320 feet, although the lower 30 feet may, perhaps, be regarded as transitional between the Matawan clay marls and the Raritan plastic clays, since our specimens for this 30 feet consist of whitish, pinkish and reddish clays, with a considerable admixture of green sand grains. This bed, at its outcrops southwestwardly, contains the casts of large Ammonites and other fossil molluscs; none, however, have been detected in the borings. If they exist at this

* Some of these wells are on lower ground than is the well now being reported.

locality, the process of drilling should be expected to obliterate them.

All of this boring below 320 feet, as above stated, we regard as belonging to the Raritan formation. At the top of this division, between the depths of 320 and 340 feet, is a sand which, unfortunately, yielded too little water for the requirements of the water company. This is the same bed that has been heretofore named by the writer the Sewell water-horizon, and is the same as that which supplies the water company's well at Columbus, and the more shallow well (338 feet) on the Jobstown stock farm. At the lowest depth reached by this well, between 539 and 562 feet, occurs a bed consisting of a mixture of sand and gravel; this, however, yielded likewise some water, but too little for the needs of the company. This horizon may be regarded as belonging to the Raritan group of water-horizons, which have been more extensively and successfully developed further southwest, say at Camden water plant, at Morris Station and at Gloucester. Though the writer thinks it probable that the water-horizons at the two last-named places may belong nearer the base of the Raritan formation, and it may be that these water-bearing coarse sands and gravels lie at a greater depth in, around and about Mount Holly than has been reached by any borings so far made in that region.

We now insert the record:

Surface material, say	0	feet to	12	feet.			
Dark gray sand, somewhat micaceous, and with green sand grains at ..			12	"	Marshalltown bed.	Matawan (Clay Marl) formation. 308 feet.	Cretaceous.
Marly clays, ...	12	" "	57	"			
Olive-yellowish sand with water, Cropwell water horizon, ...	57	" "	97	"	Columbus bed.		
Dark sandy clay, ...	97	" "	122	"	Woodbury bed.		
Clay with gravel at			122	"			
Very fine dark marly clay,	122	" "	193	"			
Green sand marl, ...	193	" "	235	"	Merchantville bed.		
Coarse dark sandy clay,..	235	" "	275	"			
Pinkish very clayey sand,	275	" "	290	"			
Clayey white and green sand mixture, ...	290	" "	300	"			
Reddish clay with green sand grains,...........	300	" "	305	"			
Dark clayey white sand and green sand mixture,	305	" "	320	"			
Whitish sand with some water, contains some lignite, equivalent of the Sewell water-horizon,..	320	" "	340	"		Raritan (Plastic Clay) formation. 242 feet.	
Yellowish fine gravel, ...	340	" "	342	"			
Dark micaceous sandy clay, ...	342	" "	350	"			
White sand, some mica,..	350	" "	368	"			
Sand and fine gravel, dark gray, ...	368	" "	370	"			
Clayey sand and fine gravel, olive colored,...	370	" "	394	"			
Hard sandy lumps, almost stone, at			394	"			
Pinkish sandy clay, ...	394	" "	500	"			
Reddish clay, less sandy,.	500	" "	539	"			
Sand and gravel with some water, ...	539	" "	562	"			

ARTESIAN WELL AT RUNYON FOR PERTH AMBOY WATER WORKS.

Elevation, 5 feet; diameter, 6 inches; depth, 212 feet.

"Water overflows 500 gallons per minute," and will rise 16 feet above the surface.

Kisner & Bennett report that in the early summer they completed the boring of a well at Runyon for the supply of water to

Perth Amboy. This well is five miles south of South Amboy and two miles northeast of Old Bridge and a short distance east of the Camden and Amboy R. R. The contractors furnish the following detailed record of the strata penetrated, to which we have added upon the right our interpretation of the geological age of the beds:

57	feet.	White sand,	=	0	feet	to	57 feet.	Raritan Cretaceous. ?
7	"	White clay,	=	57	"	"	64 "	
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 an abundance of water,	=	188	"	"	212 "	

This well overflows at the rate of about 500 gallons a minute.

In the Annual Report for 1897, page 246, there is a notice of another well at this place, put down at that time for the same water-works, which had a depth of only 185 feet. That well evidently stopped just within the top of the water-bearing stratum, whereas this well was evidently continued some 20 feet further into the same. A test made in 1897 shows that the water will rise 16 feet above the surface.

In the Annual Report for 1895, page 94, there is a notice of still another well at this same locality, but with a depth of only 160 feet. This boring, however, was not successful, as it was not continued to a sufficient depth, a fact which we noted in our report at that time, an observation which has since been verified by the two deeper wells since put down, as noted above, one in 1897, and the other during the present year (1900).

TWO ARTESIAN WELLS AT LAKEWOOD.

No. 1—Elevation, 35 feet; diameter, 6 inches; depth, 621 feet.
No. 2—Elevation, 35 feet; diameter, 6 inches; depth, 616 feet.

Kisner & Bennett, about the close of the year, finished two six-inch wells for the Lakewood water-works. These wells are respectively 621 and 616 feet deep, and flow about 60 gallons a minute. A record of the strata penetrated was not furnished, but it would doubtless be substantially the same as that published in the Annual Report for 1898 of a well at the same place at the "Laurel-in-the-Pines." We re-introduce the same below, together with the introductory paragraphs then written respecting the microscopic fossils, Foraminifera and Coccoliths, &c., contained in some of the beds.

RECORD OF WELL AT "THE LAUREL-IN-THE-PINES."

We would call attention to the fact that in the records of this well at Lakewood and of a well at Farmingdale* there are noted the occurrence, in association with the marls of the marl series, of Foraminifera comprised mainly in the genera Nodosaria, Crestellaria, Frondicularia and Vittrewebbina. Those of the first three genera are large forms, while the Vittrewebbina is much smaller and occurred in chains on the surface of the Frondicularia. The specific forms of the Frondicularia and Vittrewebbina are figured by R. M. Bagg, Jr., in Bull. U. S. Geol. Survey No. 88, Plate II.

In both the Farmingdale and the Lakewood wells the ash-colored clays, constituting Prof. G. H. Cook's ash-marl or middle layer of the upper marl bed, contain Coccoliths and Rhabdoliths.

* Annual Report for 1898, pp. 98 to 100.

Surface sands decidedly orange colored at the base, ...	0 ft. to 60 ft.	Recent. 60 feet.		
Brown clayey sands and sandy clays, "Rottenstone" of the well drillers, ...	60 " " 119 "	Miocene. 59 feet.		
Greensand marl, ...	119 " " 138 "	Blue marl of Prof. G. H. Cook, or upper layer of Upper Marl.	Shark River formation Eocene. 19 feet.	Upper Marl Bed.
Ash-colored clay, ... contains *Coccoliths.*	138 " " 240 "	Ash marl of Prof. Cook.	Manasquan formation Cretaceous. 142 feet.	
Very dark clay, ...	240 " " 280 "	Green marl of Prof. Cook or lower layer of Upper Marl.		
Ash-colored clay mixed with some greensand; contains large foraminifera of the genera *Frondicularia, Cristellaria, Nodosaria and Vitrewebbina,*	280 " " 318 "	In part equivalent of the Bryozoan limesand or upper layer of Middle Marl.	Vincentown Sand Cretaceous. 38 feet.	Middle Marl Bed.
Nearly pure greensand marl, some undeterminable shell fragments, no foraminifera, ...	318 " " 337 "	Lower or Greensand layer of Middle Marl.	Rancocas marl Cretaceous. 73 feet.	
Dark dull-green marl, *Nodosaria and molluscan* shell fragments, .	337 " " "391 "			
Mixture of white quartz sand and greensand marl; shell bed at 404 to 410; *Exogyra costata, Terebratulina plicata, Corimya tenuis, Dentalium, Pecten,* &c., ...	391 " " 427 "	Red Sand and Lower Marl.	Monmouth formation Cretaceous. 92 feet.	Lower Marl Bed.
Micaceous clayey sand, ..	427 " " 483 "			
Micaceous sandy clay, ..	483 " " 518 "	Clayey Marls and Sands.	Matawan formation Cretaceous. 123 feet.	Clay Marls.
Greensand marl, ...	518 " " 548 "			
Olive-colored clayey sand at	548 " " —			
Yellowish quartzose sand at	606 "			

The water-horizon of these wells is equivalent of that at the depth of 550 to 575 feet at Asbury Park.

Wells in Cretaceous Beds Reported by W. R. Osborne.*

The following records of wells at four localities in Monmouth county, all of which draw water-supply from Cretaceous strata, are furnished by W. R. Osborne.

TWO ARTESIAN WELLS AT MAURER.

No. 1—Elevation, 20 feet; diameter, 4 inches; depth, 79 feet.
No. 2—Elevation, 5 feet; diameter, 4 inches; depth, 53 feet.

Two wells were bored in this locality for Henry Maurer & Sons. W. R. Osborne, who put them down, has furnished the following record of strata and other information respecting them:

Well No. 1.—This is a four-inch well, and is located about 200 yards west of the R. R. station at Maurer. The depth is 79 feet, and the strata penetrated are:

Drift,	12 feet	= 12 feet.	Glacial.
Clay of various colors,	42 "	= 54 "	Raritan Cretaceous.
Sand, varying from fine at the top to coarse at the bottom, with a large supply of water,	25 "	= 79 "	

Well No. 2.—This is likewise a four-inch well. "It is located within 100 feet of the culvert under the Pennsylvania R. R., near Spa Springs.

"This well started in very soft, slushy material, almost salt meadow. After a depth of 18 feet clay was found, which ran down 37 feet from the surface," then the same fine sand that was encountered in the first well was again found. This changed, as before, to a very coarse fire-sand, within which at the depth of 53 feet "a large supply of water was found." Tabulated this record would be as follows:

* For other wells reported by W. R. Osborne, but not in the Cretaceous, see pages 158 to 161

Slushy material, almost salt meadow, &c.,	18 feet	= 18 feet.
Clay,	19 "	= 37 "
Sand, fine on top and coarse at bottom, water-bearing,	16 "	= 53 "

It may be noted that these two wells, although of different depths, draw from the same water level, the difference in depth being due to difference in elevation of the surface.

W. R. Osborne states that "Well No. 2 is five feet higher than tide, while Well No. 1 is 20 feet higher than same level. These wells were finished with Cook strainers, and are pumped by compressed air. The distance from the factory where the compressor is located to the farthest well is 3,500 feet."

BORED WELL AT LAWRENCE HARBOR.

Elevation, about 5 feet; diameter, 4 inches; depth, 155 feet.
Water rises within 6 feet of the surface.

This location is on the road from Morgan Station to Keyport, and about one mile from Morgan, the elevation being about five feet above tide.

The well is in the "mucky salt meadows," at an elevation of, say, about five feet above tide. The record as furnished by W. R. Osborne, the contractor, is as follows:

Rotten clays and sands. Clays would not stand without casing,	Surface to	85 feet.	Raritan.
Very fine sand with first water at		85 "	
Very coarse sand, also with water, at		155 "	

"The water came within six feet of the surface, and pumped on a trial test 40 gallons per minute." W. R. Osborne remarks, "This is undoubtedly the same level as [supplies wells] at Keyport and Matawan."

BORED WELL AT KEASBY'S LANDING.

Diameter, 4 inches; depth, 92 feet.

This well was put down at Keasby's School-house. Boring was commenced in the bottom of a dug well at the depth of 26 feet, below which clays of various colors were penetrated to 92 feet, where good water was found in "fire-sand underlying fire-clays."

ARTESIAN WELL AT PERTH AMBOY.

Elevation, 10 feet; diameter, 4 inches; depth, 36 feet.

This well was put down for the Marcy Stove Repair Co. "It was finished with a Cook screen in coarse gravel and sand at the depth of 36 feet. A large supply of water was obtained." The location "is, perhaps, 10 feet higher than tide."

[End of W. R. Osborne's Cretaceous well records.]

Wells in the Cretaceous, Reported by Matthews Bros.

The three following wells in Monmouth county, all of which draw from Cretaceous strata, are reported by Matthews Bros., who drilled them:

ARTESIAN WELL AT EAST OCEANIC.

Elevation, 22 feet; diameter, 3 inches; depth, 253 feet.

Respecting this well Matthews Bros. write as follows: We copy them verbatim.

"In the spring of 1900 we drilled a 3-inch artesian well for Frank McMahon, whose place is situated at East Oceanic, N. J. The elevation above tide level is about 22 feet. This well we drilled to the depth of 253 feet.

"The strata drilled through were:

"15 feet	red clay,	0	feet	to	15	feet.
22 "	sand,	15	"	"	37	"
19 "	clay,	37	"	"	56	"
45 "	brown sand and clay,	56	"	"	101	"
42 "	marl,	101	"	"	143	"
5 "	shells,	143	"	"	148	"
43 "	dark sand,	148	"	"	191	"
19 "	marl,	191	"	"	210	"
43 "	white sand,	210	"	"	253	""

ARTESIAN WELL AT CHAPEL HILL.

Elevation, 150 feet; diameter, 6 inches; depth, 301 feet.
Water rises within 146 feet of the surface.

Matthews Bros. report that "Early in the fall of 1900 we drilled a 6-inch artesian well for Mrs. Barclay Parsons, at the Eunice Home, Chapel Hill, N. J. The well was drilled about 40 feet below the crown of the hill. The hill is about 160 feet above tide level.* The water in the well rises to within 146 feet of the surface. The depth of the well is 301 feet. In drilling this well we passed through a water-bearing stratum between the depth of 170 and 204 feet, but the sand was so fine it would draw through a 60 mesh well point, which made it necessary to drill to the lower water-bearing stratum. Pumping continuously with a deep well cylinder, the well yields a supply of 40 gallons per minute, which is the capacity of the cylinder.

"The strata passed through were:

"22 feet	red clay,	0	feet	to	22	feet.
8 "	brown sand,	22	"	"	30	"
48 "	marl,	30	"	"	78	"
38 "	white sand,	78	"	"	116	"
14 "	black marl rock,	116	"	"	130	"
40 "	marl,	130	"	"	170	"
34 "	white sand, water-bearing,	170	"	"	204	"
57 "	blue clay,	204	"	"	261	"
40 "	white sand and wood, water-bearing,	261	"	"	301	""

*Chapel Hill is 200-210 feet.—J. C. S.

ARTESIAN WELL AT RED BANK, MONMOUTH COUNTY.

Elevation, 18 feet; diameter, 6 inches; depth, 187 feet.
Water rises within 15 feet of the surface.

Respecting this well Matthews Bros. write: "In the fall of 1900 we drilled a 6-inch artesian well for the Town Water Commissioners of Red Bank. The location is about 1-16 of a mile from the pumping station. The elevation above tide level is about 18 feet and the water rises to within 15 feet of the surface. The supply obtained from this well was 104 gallons per minute and was drilled by the Matthews Company.

"The strata passed through were:

"18 feet	sand,	0	feet	to	18	feet.
11 "	gravel,	18	"	"	29	"
21 "	marl,	29	"	"	50	"
12 "	shells,	50	"	"	62	"
15 "	marl,	62	"	"	77	"
28 "	sand,	77	"	"	105	"
5 "	marl,	105	"	"	110	"
35 "	sand and clay,	110	"	"	145	"
13 "	marl,	145	"	"	158	"
29 "	sand,	158	"	"	187	""

[End of Matthews Bros.' records.]

II. Wells in Northern New Jersey, with a few Outside the Limits of the State*.

Sec. 1. Bored Wells Reported by P. H. & J. Conlan.†

P. H. & J. Conlan have courteously furnished the following report of wells put down by them during the year:

WELL AT FORT GREBLE, N. Y.

"In submitting our last report we mentioned the well at Fort Greble being in progress. We sunk this well to a depth of 762

*The descriptions of rocks, in the notes of wells in this section II of this Report, are given as reported by the several parties communicating the information. No specimens have been received by the Survey for verification.

†The wells reported by P. H. & J. Conlan are in northern New Jersey and at points near that division of the State in the States adjacent except two; one of which is in southern New Jersey on the Delaware river, and the other opposite thereto, in Delaware.

feet and encountered mica and slate. The supply was moderate and the quality was good."

WELL IN NEW YORK CITY.

"We have completed a well for the firm of G. Sidenberg & Co., on Mercer street, N. Y. Depth of well is 32 feet and a good supply of water is procured."

WELL AT GREENPOINT, BROOKLYN, N. Y.

"We put down a well for the American Cordage and Mfg. Co., of New York, at their factory Greenpoint, Brooklyn, N. Y., to a depth of 80 feet and found brackish water."

WELL AT PORT CHESTER, N. Y.

"We put down a well for Geo. C. Clausen at his residence, Port Chester, N.Y. Rock was met with at 40 feet from the surface. Total depth was 417 feet. The quantity and quality of water is excellent."

WELL AT WHITE PLAINS, N. Y.

"We put down a well for Howard Willets at White Plains, N. Y., to a depth of 252 feet and found a good supply of potable water."

WELL AT SOUTH AMBOY.

"We put down a well for the International Smokeless Powder and Dynamite Co., at South Amboy, N. J., to a depth of 71 feet. The supply was fair and the quality excellent. Formation consisted of clay and sand."

WELL AT RAHWAY.

"We also did some testing for the Carteret Mfg. Co., at Rahway, N. J. The formation was red shale."

THREE WELLS AT PATERSON.

"We have put down two wells for the firm of Auger & Simon Silk Dyeing Co., of Paterson, N. J., to depths of 120 feet each, and found the quality and quantity of water very good. We are at present putting down a third well for the same firm."

TWO WELLS AT SOUTH PLAINFIELD.

"We put down two wells for the Middlesex Water Co., at South Plainfield, N. J., recently and found a good supply of potable water. The respective depths of these wells are 200 and 250 feet."

WELLS AT RIDGEWOOD AND HOHOKUS.

"We have also put down 4 wells at Ridgewood, N. J., and one at Hohokus for the Bergen Aqueduct Co. The well at Hohokus was sunk to a depth of 220 feet, yielding a good supply of excellent water.

"The wells at Ridgewood yield an extra good supply of water. The quality is excellent."

WELL BETWEEN SHORT HILLS AND MILBURN.

"We are now about completing a plant for Stewart Hartshorn between Short Hills and Milburn, and have obtained over five million gallons daily. The quality of the water is excellent. The wells vary in depth from 60 to 100 feet. The water was found mainly in gravel."

WELLS AT EAST NEWARK AND GARFIELD, N. J., AND AT IRVINGTON, N. Y.

"We are at present putting down a well for Bimbler & Van Wagene Co., of Newark, N. J., at their slaughter house in East Newark; also one for the Hammerschlag Mfg. Co., at Garfield, N. J., and one at Irvington on the Hudson, N. Y."

WELL AT FORT MOTT.

"We sunk a well for the U. S. Government at Fort Mott, Salem, N. J. The formation consisted of clay and sand. The depth of this well was 300 feet. The yield was superb, while the quality is excellent. The water overflows to the surface over 50 gallons per minute."

[For geological details respecting this well, see record, page 131.—L. W.]

WELL AT FORT DUPONT, DEL.

"We are at present putting in a well for the U. S. Government at Fort Dupont, Delaware City, Del., and are down to depth of 507 feet. We expect that, judging from the formation, a good well will be developed."

[For detailed geological record of this well, see page 132.—L. W.]

Sec. 2. Wells Reported by W. R. Osborne.

In response to our request W. R. Osborne has courteously furnished the records of wells put down by him in New Jersey during the past fifteen months. These wells are, as he says, "scattered within a radius of 10 or 12 miles from Metuchen," his place of residence. Such of these wells as are in the Cretaceous belt eastward of Metuchen are noted elsewhere with the Cretaceous wells in Southern New Jersey (see pages 151 to 153). Those in the Newark red shale and sandstone district east of Metuchen are now introduced.

W. R. Osborne pertinently notes respecting some of these that "in some respects they are interesting as showing the depth of [glacial] drift overlying the [Newark] red shale in the Short Hills district."

THREE WELLS AT SEWAREN.

Diameter of each, 4 inches; average depth, 25 feet.

W. R. Osborne reports the boring of "three 4-inch wells for the Vulcan Metal Refining Co., at Sewaren, and also states that the wells are near Boynton Beach Station, Central R. R. of N. J., and average 25 feet in depth. Water in large quantity was found in coarse gravel. The wells were finished with Cook screens." This well is immediately north of the terminal moraine, and probably draws its supply from stratified glacial drift.

TWO BORINGS NEAR FRESH PONDS, SOUTHEAST OF DEAN STATION, PENNSYLVANIA R. R.

No. 1—Depth, 60 feet. No water.
No. 2—Depth, 40 feet. No. water.

Two wells in Middlesex county, located as above noted, were put down for Frederick Dreer.

Well No. 1 was commenced on the bottom of a dug well, at the depth of 30 feet entering clay that continued to the depth of 60 feet, when trap-rock was found. No water, however, was obtained. This trap-rock outcrops at the brook near the Black Horse tavern, on St. George's road.

Well No. 2 was drilled to the depth of 40 feet and abandoned in the clay before reaching the trap, no water being obtained.

BORED WELLS AT PERTH JUNCTION, METUCHEN, AND AT FRANKLIN PARK.

W. R. Osborne states at the close of the year, "I am now drilling three wells for the Central Electric Co., at Perth Junction, Metuchen, also one for Mr. Voorhees, near Franklin Park, about seven miles southwest of New Brunswick. All these wells are in red shale, and may have to go to 100 feet for a large supply of water."

BORED WELL TWO MILES EAST OF PLAINVILLE.

Elevation, 150 feet; diameter, 4 inches; depth, 210 feet.

This well was bored for Mr. C. L. Wright, of Plainville, farm on the road from Avon Park to Dog Corners and about 2 miles east of Plainfield. The location is 150 feet higher than tide. The record is as follows:

Sand and gravel, drift,	Surface to 160 feet.
Red shale,	160 feet " 210 "

The well was finished with water of good quality standing at 130 feet from the surface.

BORED WELL NEAR TWO BRIDGES.

Diameter, 4 inches; depth, 98 feet.

This well was put down for Mr. Terry near Two Bridges, Union county, and beyond Dog Corners from the above well.

The record is:

Sand and gravel,	Surface to 79 feet.
Red shale,	79 feet " 98 "

The water rises to within 20 feet of the surface and is of good quality.

BORED WELL AT MOUNT PLEASANT, NEAR POTTERS STATION, LEHIGH VALLEY R. R.

Diameter, 4 inches; depth, 116 feet.
Water rises within 18 feet of the surface.

W. R. Osborne states that this well was drilled seven years ago to the depth of 69 feet, through the same sand and gravel formation as was penetrated by the two wells just previously noted. [At Two Bridges and near Plainville.] Water was then found in the gravel. Since then the well having become choked up it was decided to deepen it. The pipe or casing was driven to 90 feet, where red shale was found in which the well was finished at the depth of 116 feet, the water rising to within 18 feet of the surface.

Note on the Three Preceding Wells.

"On top of the shale in all of the three preceding wells there was perhaps 5 or 10 feet of a mixture of muddy sand and shale very different from material on top of the shale at Metuchen."

BORED WELL THREE MILES FROM NEW BRUNSWICK.

Diameter, 4 inches; depth, 58 feet.

"This well was drilled for Stephen G. Wiliams on his farm on Middlebush road, three miles from New Brunswick and just north of Millstone Branch, Penna. R. R. Red shale was penetrated to a depth of 58 feet, where a large supply of excellent water was found.

BORED WELL, ONE MILE FROM NEW BRUNSWICK, FOR THE LONG DISTANCE TELEPHONE COMPANY.

Diameter, 4 inches; depth, 58 feet.

"This well is on the Franklin Park road, one mile from New Brunswick. The material passed through was red shale from the surface to the bottom, at the depth of 58 feet, where water was had, which rose to within five feet of the surface.

BORED WELL AT NEW DURHAM.

Depth, 63 feet.

"This well was drilled for A. B. Osgoodby, near New Durham school-house. Red shale was penetrated from surface to the bottom, at the depth of 63 feet, where plenty of water was obtained.

BORED WELL NEAR ISELIN STATION, PENNSYLVANIA RAILROAD.

Diameter, 4 inches; depth, 96 feet.

"This well was drilled for F. W. Vom Hoffe, near Iselin station. It was commenced on the bottom of a dug well at the depth of 23 feet. Red shale was encountered from thence all the way to the bottom at 96 feet from the surface, when there was had a good supply of water."

Sec. 3. Wells Reported by Stotthoff Bros.

BORED WELL AT SWARTSWOOD FOR J. J. VAN RENSELLAER..

Limestone,	65 feet.

BORED WELL AT NEWTON, SUSSEX CO., FOR W. C. WHITTINGHAM.

Diameter, 8 inches.
Water overflowed 3 gallons per minute.

This well is in Sussex county, west of Springdale, and two and one-half miles southwest of Newton. It is located in a gully, at the foot of a natural waterfall, which has a drop of 35 feet. It is the only well we have put down in this county that has overflowed.

Earth and gravel,	6 feet.	
Shaly slate,	12 "	
Cement rock,	47 "	= 65 feet.

Water overflowed four feet above the surface, at the rate of three gallons per minute, and pumped five gallons per minute.

TWO BORED WELLS AT SPARTA, FOR C. C. COX.

Diameter, 6 inches.

Well No. 1.—Gray rock and limestone to 53 feet. Supply, five gallons per minute.

Well No. 2.—Diameter, six inches.

Quicksand to	15 feet.
Shaly limestone,	15 to 58 "
Blue limestone,	58 " 94 "

Supply, eight gallons per minute.

BORED WELL AT SPARTA, FOR MARTIN DEMEREST.

Diameter, 6 inches.

Sand and gravel to	58 feet.

Supply, 20 gallons per minute.

BORED WELL AT LAKE HOPATCONG, FOR M. F. MOORE.

Diameter, 6 inches.

Earth,	5 feet =	5 feet.
Gray or mountain rock,	70 " =	75 "

Supply, five gallons per minute.

BORED WELL AT BERNARDSVILLE, FOR C. M. CHAPIN.

Diameter, 8 inches to the depth of 51 feet.
Diameter (continued), 6 inches to the depth of 380 feet.

Earth and yellow clay,	51 feet.	
Rock (granite)?	329	380 feet.

Supply, 10 gallons per minute.

BORED WELL AT BERNARDSVILLE, FOR GEORGE B. POST.

Loose stones and earth,	26 feet.
Gray granite with alternating interbedded layers, 2 to 10 feet thick, of a yellowish rock, the latter quite soft,	595 "
Total depth,	621 feet.

This well was shot at 275 feet from the surface. Supply, eight gallons per minute.

BORED WELL AT PASSAIC, FOR SWINSON BROS.

Earth and sand,	47 feet.	
Red sandstone,	50 " =	97 feet.

Supply, 20 gallons per minute.

BORED WELL AT ALDENE, UNION CO., FOR JACKSON ARCHITECTURAL IRON COMPANY.

Diameter, 8 inches; depth, 105 feet.
Water rose within 3 feet of the surface.

Clay,	10 feet =	10 feet.
Quicksand,	18 " =	28 "
Red shale,	77 " =	105 "

Water at the base. This place is near Roselle.

BORED WELL AT ELIZABETH, FOR WILLIAM KRAUSS.

This well is located 350 feet east of Jersey street.

Sand,	66 feet.	
Red shale,	176 "	= 242 feet.

Supply, 15 gallons per minute, at the depth of 80 feet.

BORED WELL AT CARTERET, FOR CARTERET MANUFACTURING COMPANY, BACON AIR LIFT CO., CONTRACTORS.

Diameter, 8 inches; depth, 205 feet.

Earth and red clay to	65 feet.
Red shale,	140 "

Supply, 100 gallons per minute.

BORED WELL AT PERTH AMBOY, FOR THE STANDARD UNDERGROUND CABLE COMPANY.

Diameter, 6 inches; depth, 145 feet.

Earth and clay,	32 feet	= 32 feet.
Gravel,	8 "	= 40 "
Quicksand,	105 "	= 145 "

BORED WELL AT FLEMINGTON, FOR I. H. HILL.

Diameter, 8 inches.

Earth and clay,	12 feet.	
Red shale,	48 "	= 60 feet.

Supply, 17 gallons per minute.

BORED WELL AT PLAINFIELD, FOR MRS. S. A. DU FLON.

Diameter, 6 inches; depth, 176 feet.

Earth, sand and boulders to	134 feet	= 134 feet.
Red shale,	42 "	= 176 "

Supply, 40 gallons a minute, at 36 feet from the surface.

BORED WELL AT NESHANIC, FOR FARMERS' DAIRY DISPATCH COMPANY.

Red shale to	115 feet.

Supply, 12 gallons per minute, at 78 feet from the surface.

BORED WELL AT STANTON, HUNTERDON COUNTY, FOR B. J. BLOYS.

Earth,	10 feet.	
Blue fine grained rock, very smooth and hard, somewhat like impure slate,	63 "	= 73 feet.

Supply, six gallons per minute.

BORED WELL AT SKILLMAN, SOMERSET COUNTY.

Diameter, 12 inches to the depth of 30 feet.
Diameter (continued), 10 inches to the depth of 250 feet.

This well was bored at the Epileptic Village, a State institution, at Skillman, three miles east of Hopewell, Somerset county.

Soft strata,	0 feet to	30 feet.
Red shale,	30 "	" 250 "

Supply, 36 gallons per minute, at 150 feet from the surface.

BORED WELL AT EWING, FOR JAMES M. DONALD.

Diameter, 6 inches.
Bluish rock to the depth of 76 feet.

Supply, 12 gallons per minute, at 45 feet from the surface.

BORED WELL AT TRENTON, FOR JOSEPH PIERSON.

Diameter, 6 inches; depth, 40 feet.

Earth,	24 feet	= 24 feet.
Red shale,	10 "	= 34 "
Sandstone,	6 "	= 40 "

Supply, only two gallons a minute.

BORED WELL AT EASTON, PA., FOR THE NATURAL AND ARTIFICIAL ICE COMPANY.

This boring was commenced in the bottom of a dug well, at the depth of 40 feet.

Depth of former well,	40 feet.	
Limestone,	34 "	= 74 feet.

Supply, 40 gallons per minute.

BORED WELL AT SIEGFRIED, NORTHAMPTON COUNTY, PA., FOR BONNEVILLE CEMENT COMPANY.

Diameter, 8 inches.
Cement rock to 250 feet. No water.

On the New Jersey Central railroad, 28 miles from Easton, and 10 miles from Allentown.

BORED WELL AT NAZARETH, PA., FOR NONPAREIL BRICK AND CLAY COMPANY.

Diameter, 6 inches.
Clay, with sand beneath, at the depth of 65 feet.

Supply of water, 40 gallons per minute.

BORED WELL AT ROXBOROUGH, PA., FOR RICHARD HEY.

Diameter, 8 inches, to the depth of 52 feet.
Diameter (continued), 6 inches, to the depth of 136 feet.

Soils, &c.,	10 feet.
Micaceous rock,	126 "

TWO BORED WELLS AT BRISTOL, PA., FOR THE BRISTOL ICE COMPANY.

Well No. 1—

Diameter, 8 inches; depth, 127 feet.

Earth,	15 feet	= 15 feet.
Sand,	50 "	= 65 "
Clay,	44 "	= 109 "
Soft micaceous rock,	18 "	= 127 "

Water, 12 gallons a minute.

Continuation of soft micaceous rock, ...381 " = 508 "

Practically no water, only four gallons a minute.

Well No. 2—

Diameter, 8 inches; depth, 164 feet.
Location 300 feet from Well No. 1.

Earth and sand to	65 feet =	65 feet.
Micaceous gneiss rock, ...	99 " =	164 "

Supply, 20 gallons a minute.

SIX BORED WELLS AT HINMAN, N. Y., FOR THE LEHIGH VALLEY RAILROAD.

Well No. 1—Depth,	140 feet.	Well No. 4—Depth,	64 feet.
" " 2— "	96 "	" " 5— "	65 "
" " 3— "	44 "	" " 6— "	129 "

Total supply, 700 gallons per minute. Diameter of each well, six inches.

These wells are on a divide, the waters to the west running to Seneca Lake, and those to the east to the Susquehanna. They were put down to supply water to the engines on the Lehigh Valley railroad. The total supply from all the wells is 700 gallons per minute, at 10 feet from the surface. They are located at intervals along a length of 400 feet. Numbers 1 and 6 are at the extreme ends of this space, Nos. 2 and 3 are paired wells, about one-third this distance from No. 1, and Nos. 4 and 5 are also paired wells, about one-third distance from No. 6.

The records of these wells are as follows:

Well No. 1—

	Thickness in feet.	Depth in feet.
Gravel,	21	
Gravel and blue clay, *very little water,*	89	
Soft clayey sand,	30 =	140

Well No. 2—

	Thickness in feet.	Depth in feet.
Gravel and clay,	32	
Gravel with water, *55 gallons per minute,*	11 =	48
Clay and gravel,	10	
Gravel with water, *30 gallons per minute,*	5 =	68
Sand and clay,	10	
Sand with water, *150 gallons per minute,*	18 =	96

Total supply from this well, 235 gallons per minute.

Well No. 3—

	Thickness in feet.	Depth in feet.
Clay and gravel,	10	
Sand with water,	27	
Gravel,	7 =	44

Supply, 150 gallons per minute.

Well No. 4—

	Thickness in feet.	Depth in feet.
Clay and gravel,	8	
Sand with *water, 20 gallons per minute,*	30 =	38
Cemented gravel with no water,	26 =	64

Well No. 5—

	Thickness in feet.	Depth in feet.
Gravel and clay,	50	
Sand and gravel,	10	
Gravel,	5 =	65

Water supply, 150 gallons a minute.

Well No. 6—

	Thickness in feet.	Depth in feet.
Gravelly clay,	44	
Gravel with water, 150 gallons per minute,	10 =	54
Hard, fine sand,	20	
Fine sand with water, 150 gallons per minute,	10 =	84
Gravelly clay,	11	
Soft, sandy clay,	34 =	129

Total supply from this well, 300 gallons per minute.

These wells are interesting since they penetrate the great glacial drift deposit, the same that covers the northern section of our State. They show that considerable water can at some places be obtained from this deposit, a fact which some wells recently put down in this State have demonstrated, as notably those at Chatham and Madison.

Sec. 4. Well Reported by J. P. Cooper.

ARTESIAN WELL AT EAST RUTHERFORD.

Diameter, 6 inches; depth, 189 feet.

From J. P. Cooper we learn there has been put down for the Hazleton Boiler Company, at East Rutherford, a well of six inches in diameter to the depth of 189 feet. The capacity of the well is about 100,000 gallons per day. The location is about 250 feet west of the bridge over the Erie railroad at Montrose avenue, Rutherford, and 75 feet north of the Erie railroad tracks. The record furnished is as follows:

Depth to rock,	48	feet.
Depth in rock,	141	"
Total depth,	189	"

This well is also near one noted in the Annual Report for 1898, page 130, as having been put down for Zahn & Bowly to the depth of 201 feet. The materials penetrated are doubtless the same in both wells. The rock is noted in the report for 1898 as red sandstone, and doubtless belongs to what is geologically known as the Newark formation.

Sec. 5. Wells Reported by Owen Lynch.

FOUR BORED WELLS IN SPRINGFIELD AND ON SPRINGFIELD MOUNTAIN.

Data respecting these four wells has been furnished by the Contractor, Owen Lynch, who put them down for Stewart Hartshorne. We report them separately as follows:

BORED WELL IN SPRINGFIELD.

Diameter, 8 inches; depth, 83 feet.
Through sand to a gravel bed at 83 feet.

Yield, 125 gallons per minute.

BORED WELL IN SPRINGFIELD.

Diameter, 6 inches; depth, 307 feet.

Quicksand and clay to	110 feet = 110 feet.
Shale and brownstone from	110 feet to 307 feet.

Yield, 175 gallons per minute.

BORED WELL IN SPRINGFIELD.

Diameter, 6 inches; depth, 230 feet.

This well is on the side of Springfield mountain, 50 feet higher than the preceding well.

Surface material to rock,	0	feet to	10	feet.
Rock,	10	" "	230	"
Thin "vein of white sand."				

Yield, 125 gallons per minute.

BORED WELL IN SPRINGFIELD.

Diameter, 8 inches; depth, 275 feet.

This well is 300 feet further down than the last preceding well.

Quicksand and clay and stones to rock,	0	feet to	68	feet.
Red shale,	68	" "	275	"

Yield, 20 gallons per minute.

BORED WELL AT MILBURN, FOR THE DIAMOND PAPER MILLS COMPANY.

Diameter, 8 inches; depth, 800 feet.

Clay and boulders,	0	feet to	30	feet.
Blue trap,	30	" "	235	"
White sandstone,	235	" "	285	"
			800	"

Yield, nearly 100 gallons per minute.

BORED WELL AT IRVINGTON, FOR D. C. MEEKER'S DAIRY FARM.

Diameter, 6 inches; depth,

Surface material,	0	feet to	30	feet.
Sandstone,	30	" "	180	"

Yield, 150 gallons per minute.

BORED WELL IN NEWARK AT CENTRAL AVENUE AND FIRST STREET.

Diameter, 6 inches; depth, 150 feet.

Surface material,	0 feet to 20 feet.
Rock,	20 " " 150 "

This well is at Fagin Bros.' coal yard.

Yield, 100 gallons per minute.

BORED WELL AT NEWARK.

Diameter, 6 inches; depth,

Surface material,	0 feet to 20 feet.
Rock,	20 " " 120 "

This well was put down for McKeone Bros., First street near Orange.

Yield, about 85 gallons per minute.

BORED WELL AT NEWARK, FOR THE E. E. HOGAN SHOE MANUFACTURING COMPANY, CENTRAL AVENUE AND DURER STREET.

Diameter, 8 inches; depth, 301 feet.

Sand and gravel surface to	30 feet.
Black sandstone, very hard,	30 feet to 301 "

Yield, 125 gallons a minute.

PART IV.

Mineralogical Notes and Explorations.

By Prof. ALBERT H. CHESTER.

Mineralogical Notes and Explorations.

By Prof. ALBERT H. CHESTER.

During the past year an unusual amount of work has been done on minerals brought in for examination, and there have been two expeditions to the Jenny Jump region made in the interests of mineralogy, the results of which have now to be stated. I also describe here some work done earlier but which as yet has not been noticed in any of these reports.

At the outset attention should be called to the very valuable collection of New Jersey minerals on exhibition in the Geological Rooms at the State House. It is a most beautiful exhibit of these minerals, and is so arranged that it can be conveniently studied. Such study at once reveals some gaps in the list of species known to be found here and also shows that many localities are not represented. Filling up these gaps is now in order and every effort is being made to complete the collection as far as it is possible. The value of such a collection when completed, cannot be over-estimated, affording as it does an opportunity not only for the study of mineralogy in general, but also forming a typical collection which may be used for comparison. A wonderful variety of minerals is found in New Jersey, including some that have been found nowhere else. New species are frequently announced from here, several new ones having been discovered at Franklin Furnace within the last two years. Specimens of these are added to the collection as fast as they can be secured. All friends of the Survey are earnestly requested to remember this collection and send in specimens as they have opportunity.

Considerable attention has been given to this collection during the past year, many characteristic specimens having been added, and every endeavor has been made to complete it. Partly to aid in this work Mr. Valiant has prepared as complete a list as possible of the species and varieties of minerals found in the State, every available source of such information having been used. Comparing this list with a catalogue of the collection some gaps are still noticed, few however among the most important or best characterized species. It has been our constant endeavor to fill these gaps and a number of specimens that answer this end have been placed in the cases in their proper positions. Others are now in hand awaiting such intercalation. This is the case with the new and recently described species from Franklin Furnace, most of which have been secured, including clinohedrite, hardystonite, leucophenacite and hancockite.

With a view to filling some of the gaps in the State collection with minerals from old localities as well as to obtain new information on the mineralogical side Mr. John Manley went last April to examine the Jenny Jump Mountain region and other localities in northern New Jersey, and made collections of whatever minerals he found. He spent nearly two weeks in the field and collected a large number of specimens, which have all been carefully examined. The results of his work are given as follows:

MINERALS AND LOCALITIES.

Phillipsburg, at the Vulcanite Cement Co.'s quarry; calcite, graphitic schist, limestone and their "cement rock," which is a calcareous argillite.

Andover Iron Furnace quarry; dolomite Xd, magnesian limestone and aragonite.

Harmony, at the Steatite quarry; aragonite, calcite, dolomite, talc, phlogopite, serpentine, quartz Xd, pyrite, molybdenite, *celestite* and calcite containing *strontium*.

Harmony, at the iron mine on top of the mountain; serpentine, quartz, talc, hematite and magnetite crystals in the hematite.

Oxford; magnetite, lodestone, pyrite, chalcopyrite, feldspar, albite, pyroxene, hornblende, quartzite, garnet, mica, epidote, calcite and graphite. The lodestone is very good, and is from the Grasshopper mine.

Raub farm; sphalerite, smithsonite, *jamesonite*, galenite, pyrrhotite, serpentine, talc, mica, amphibole, quartz and dolomite. The Hann zinc mine, so-called, afforded no trace of zinc.

Marble quarry; pyrite, chert, amphibole, serpentine and marble.

Kishpaugh and Stinson mines; magnetite, and at the latter, one specimen showing a little rhodonite.

Garrison mine; magnetite, limonite, pyroxene, orthoclase, pink calcite and pseudomorphous quartz, similar to the well-known kind from West Paterson.

Howell Copper mine; malachite, azurite, chalcopyrite, *tetrahedrite,* magnetite which carries much graphite and aragonite.

Davis farm; pyrite, hematite, malachite, mica, asbestos, amphibole, garnet, quartz, serpentine, talc and dolomite.

German Valley (exact locality not given); sphalerite.

Andover mine; chalcopyrite, malachite, azurite, galenite, sphalerite (cleiophan), calamine, *aurichalcite,* magnetite, hematite, martite, limonite, pyrite, pyrrhotite, quartz, chert, jasper, garnet (colophonite), hornblende, orthoclase, mica, asbestos, dolomite, calcite containing *strontium,* apatite and gypsum.

Tar Hill mine; lodestone, pyrite, garnet and calcite.

Roseville mine; chalcopyrite, magnetite, hematite, asbestos, epidote, hornblende, feldspar, talc, chinochlore, calcite with *strontium,* and dolomite.

In October Mr. Valiant, with an assistant, spent a week in the Jenny Jump region to complete the mineralogical examination of that locality, by looking over all the ledges and outcrops, Mr. Manley's work having been almost wholly confined to places that were already known as mineral localities. Neither did he examine the extreme east end of the mountain, near Southtown. All contacts of crystalline limestone and gneiss were also carefully examined for minerals of value and especial search was made for zinc minerals. But no discovery was made of any such kind and the main value of this reconnaissance, from a mineralogical point of view, is in the negative information obtained. How much may have been added to our geological knowledge of the region is yet to be shown, and such results do not belong here. No paying deposits of talc or asbestos were seen, though some of them were considered promising. Nor was there found any reason to think that there could be a possible connection between the formations examined and the zinc-bearing rocks at Franklin Furnace. No signs of veins of any kind were noticed in the rocks examined at any point.

Among the interesting minerals brought back is one from the farm of Isaac Parr, which has all the characteristics of dolomite except that it contains a considerable amount of water. It would be called ***hydrodolomite,*** if we could expect that mineral in large masses. It certainly is a hydrous carbonate of calcium and magnesium, with little else in it. It has a white or creamy color, and a porcelain-like appearance, very much resembling the gurhofite variety of dolomite. It is seen in the stone fences along the road and is also found in the near-by ledges. The layers of dolomite are interstratified with layers of a dark greyish brown, calcareous sandstone, the latter often projecting several inches beyond the former as the result of weathering. This material has been laid aside for more careful and complete investigation. The appearance of the rock as a whole, with its dark and white bands, is very striking.

ARSENOPYRITE.

One object of this second expedition was to locate the arsenopyrite that had been previously reported from this region. It was known that arsenopyrite, with pyrite, in a pyroxenic gneiss had been found long ago "at the north end of Jenny Jump mountain, on the road to Southtown." After considerable search such a rock was found extending along the road for about one hundred feet, looking very much like a dike, but no contact with other rocks was observed. In this rock were seen, besides masses of undoubted iron pyrites, a number of rough, partly oxidized masses, showing a general prismatic shape, and which proved on examination to be arsenical iron pyrites. Some of these are nearly an inch in length and by their shape can easily be distinguished from ordinary pyrite, but the crystals are too much weathered to admit of crystallographic measurement and identification.

At the new opening of the Kishpaugh mine a highly crystalline rock was found composed almost wholly of a dark green and brown augite, somewhat altered and showing adamantine pearly cleavages of a bright yellow bronze color and metallic lustre, on the weathered surfaces, and affording very striking specimens.

At the so-called "hidden mine," which indeed was hard to find, in the Waterfield tract, near Southtown, asbestos of good quality was found and in such amount as to warrant further work there; also, some talc and pyrites. This is called locally an "asbestos and silver" mine, but no silver-bearing mineral was identified. There is a small amount of dark-colored mineral, not yet tested, which must contain the silver, if any is found there.

TETRAHEDRITE FROM THE HOWELL FARM.

Though copper ores have been reported from this locality for a long time, and the mineral now described must have been found, for it lay in numerous specimens on the dump, its identity has apparently escaped notice. It occurs in small masses scattered through a gneissoid gangue which contains calcite and dolomite, and is of the characteristic lead grey color on the fresh fracture, often, however, showing a beautiful blue or purple tarnish and therefore much resembling massive bornite, for which it was at first taken. It does not form a large percentage of the vein matter, but is apparently the most abundant copper mineral there. An analysis resulted as follows:

Insoluble,	3.84	per cent.
Sb,	15.90	"
Cu,	45.20	"
Fe,	5.70	"
Zn,	1.10	"
Bi,	0.22	"
S,	23.28	"
Cl,	0.29	"
CaO,	1.04	"
MgO,	0.30	"
SO_3,	3.43	"
Total,	100.30	"

The absence of even a trace of arsenic in this ore is quite noticeable. *Bismuth* is here reported for the first time from New Jersey. The mineral, though so low in antimony, must evidently be classed as *tetrahedrite,* the first notice of this or any other antimonial sulphide from this State. It is to be regretted that no crystals were found to aid in the identification.

STRONTIUM MINERALS.

No minerals containing strontium have heretofore been reported from this State, therefore considerable interest is attached to the recent finding of *celestite* from near Harmony, at the northeast end of the Marble mountain, and with it a strontium-bearing calcite, the latter being found also at both the Andover and Roseville mines in Sussex county. Celestite was observed in only one specimen, in fine fibres projecting from the enclosing limestone where it had been weathered, and was also left behind when the limestone was dissolved away with dilute acid. It was at first mistaken for tremolite, but its insolubility and its reactions for sulphur and strontium are sufficient for its complete identification. In the accompanying calcite strontium was detected under the usual blowpipe tests, and one of the specimens was analyzed, as follows:

Insoluble,	0.12	per cent.
Fe_2O_3 & Al_2O_3,	1.12	"
SrO,	0.28	"
CaO,	53.32	"
MgO,	2.82	"
CO_2	42.40	"
Total,	100.06	"

The amount of strontium is much less than was expected, from the blowpipe tests, but it is unquestionably present, and so another element is added to those found among the minerals of New Jersey.

JAMESONITE.

Another sulph-antimonide was found by Mr. Manley, at the Raub farm. It occurs there in foliated, semi-fibrous masses of a dark lead-grey color, in a quartoze gangue and strongly suggests Jamesonite. An analysis for its principal constituents resulted as follows:

	A.	B.	C.
S,	15.79	16.19	.506
Sb,	29.60	30.34	.253
Pb,	52.16	53.47	.258
Insol. matter,	1.27		
Total,	98.82		

Column A shows the actual figures of the analysis, B the results when calculated to one hundred per cent., and C the oxygen ratio. No trace of either arsenic or bismuth could be detected. We have here the constitution of *Jamesonite,* but with a somewhat lower percentage of sulphur, the calculated formula becoming $Pb_2Sb_2S_4$ instead of $Pb_2Sb_2S_5$ as it is ordinarily found. But this difference is too slight to found a new species upon, and the substance in question may be considered a basic Jamesonite, thus adding another antimonial sulphide to the minerals of this State.

AURICHALCITE.

A mineral was found at the Andover mine occurring as a bluish green crust on sphalerite, which proves to be a double carbonate of copper and zinc, now noticed for the first time among the minerals of this State. It is undoubtedly *aurichalcite,* for it has all the physical and chemical charcters of that mineral. Although shown on several specimens, it is only as a thin incrustation, and it was with difficulty that sufficient of it for analysis could be removed from the sphalerite on which it lay. But the tests were satisfactory and conclusive.

The following are notes on certain New Jersey minerals which have been examined at this laboratory from time to time during the past two years, but not heretofore reported:

SILVER WITH THE TRIASSIC COPPER.

Native silver was recently discovered by Edgar H. Sarles on the farm of George Drake, at Newtown, near Stelton, in Middlesex county, and specimens were brought here for identification.

It occurs in small flakes and specks on a Triassic sandstone, associated with chrysocolla and cuprite. So far only a few surface specimens have been brought in, and no work has been done there. This occurrence of real silver in appreciable quantities, after the numberless mistaken reports of finding silver in the State, is of great interest, and the locality deserves careful examination, not so much in the hope of developing a paying silver mine as to learn something more of the conditions under which this most interesting mineral has been deposited there. No native copper was observed on any of the specimens found. Since writing the above I have learned that the ore of the American Copper Mining Company, located near Pluckamin, contains a little silver, as is true in general of all the copper ores of the State. But free native silver has not often been observed. This ore is almost entirely native copper, which is often found in broad sheets of some thickness. It occurs in an indurated shale at its contact with the trap, and the silver is occasionally visible to the eye in minute specks or flakes, sometimes on the copper itself.

MARCASITE FROM THE RARITAN CLAYS.

Among the refuse of the clay works the so-called "sulphur balls," which are nodules of pyrite in beautiful crystalline aggregates, are found abundantly. For some years they have been sought for with eagerness by local collectors. In the summer of 1898 Mr. Manley found among them several good crystals of marcasite in the *spear-head* form, the first of this form ever found in the United States. Since then many more specimens have been obtained, but all at the one locality, Edgar's pit, at Sayreville, until quite recently, when good specimens have been obtained at Van Horne's pit, near Piscataway, on the east side of the river. These crystals are usually free, though occasionally they have been found attached to a kind of half consolidated, ferruginous conglomerate, and in one or two instances to the nodules of pyrite. The largest of them are an inch or a little more in length, but the average size is much smaller than that. They form beautiful specimens of the characteristic yellow bronze color, and are worthy of record here as being found for the first time in this country in the spear-head form so common in some foreign localities. No analysis has been made of them as far as I know, but their characteristic shapes in very complicated twins serves fully to identify them.

ILMENITE SAND FROM THE BANKS OF THE RARITAN.

Samples of pure black sand having been brought into the laboratory during the summer of 1899, which proved to consist largely of ilmenite, some pains were taken to locate the deposit. According to Mr. Valiant's report to me, it is to be found in a layer from a mere film to at least an inch in thickness, on the left bank of the Raritan for a distance of two miles or more both up and down the river from this place. It is found just below high-water mark, and his report says, "The soil from which this sand has been separated is a brownish gray sandy loam, resting on a rather coarse gravel consisting of well-rounded pebbles and boulders. The fine sand and clay has been carried off by the river, leaving the heavy iron sand at the base of the loamy deposit." This sand can be collected abundantly in several places, and quite free from earthy matter. When separated by a magnet it is found to consist of about twenty-five per cent. of magnetite, the remainder being ilmenite, as proved by blow-pipe analysis, which shows oxide of iron and titanium in abundance and a small amount of oxide of manganese. The original source of this material must have been much further north, as no such minerals are found in the rocks of this vicinity.

A COPPER-BEARING OCHRE.

A mineral found in cavities in the trap at Chimney Rock, near Bound Brook, showed such peculiarities that it was thought worthy of careful investigation. It is a dark brown, pulverulent substance found in small cavities, associated with the native copper, cuprite and other copper minerals, and looks like some varieties of wad; resembling it, also, in its power of soiling the fingers. Its analysis is as follows:

SiO_2,	58.00	per cent.
Al_2O_3,	20.50	"
Fe_2O_3,	8.30	"
CaO,	1.80	"
MgO,	0.14	"
Na_2O,	0.58	"
K_2O,	1.36	"
Moisture,	1.86	"
H_2O,	1.54	"
MnO,	3.30	"
CuO,	2.52	"
Total,	99.90	"

This analysis shows it to be a clay-like substance or ochre, with the unusual addition of several per cent. of oxide of copper. It, however, cannot be classed as a mineral species.

A VERMICULITE FROM ROCKY HILL.

A few years since my attention was called to a micaceous mineral from Rocky Hill by Mr. Manley, who had discovered it there. It occurs in the old Martin A. Howell quarry, near the railroad station, in a seam of calcite about two inches in thickness, which stands nearly vertical, and has been used as the back of the quarry. The trap has been worked away, leaving the calcite standing in place against the inner wall of the fissure, and here the mineral is found coating the crystals of calcite and filling all the interstices between them. No other mineral has been noticed in this seam, and at one time an abundance of good specimens could be obtained. But by degrees the calcite has fallen down, the quarry having been abandoned, and the rain has washed away the minute micaceous scales, so that it is now hard to obtain good specimens without blasting. A sample of these washed-down scales, quite pure and free from other material, was obtained from a pool of rain-water, where it was found floating on the surface, and looking like bronze paint. Another locality of the same mineral is Moore's Station, on the Reading Railroad. Here there is a seam in the trap, from two to five feet in width, which bears an bundance of stilbite covered with an iron tarnish, and sometimes coated with pyrite, and making most interesting specimens. In this a few specimens have been found quite similar to those from Rocky Hill.

This mineral occurs in minute scales of a yellow-bronze color generally, though a few specimens show a greenish gray or steel color. It very strongly resembles the chalcodite of northern New York, and as the results of an erroneous analysis pointed also to chalcodite, it was announced as a new occurrence of that rare mineral. It has gone into many collections under that name, which it should not bear, for a recent complete examination of this substance, at the laboratory of the U. S. Geological Survey, shows it to be a hydromica, and related to the vermiculites rather than to the chlorite group.

MINERALS FROM FRANKLIN FURNACE.

A specimen from Franklin Furnace was called to my attention by Mr. F. A. Canfield, and other similar ones having been found among a lot collected there by Mr. Manley, it was examined with some care. It came from the Parker shaft, that source of so many new things, and is associated with franklinite, garnet and axinite. It occurs in granular masses, the cleavage faces of the grains having a pearly lustre, and is of a white or slightly grayish color. It resembles the granular brucite from Hoboken, but has a hardness of 5.5 to 6. As the mineral was not identified by ordinary tests, though boric acid was easily detected in it, it was thought worthy of a quantitative analysis, which resulted as follows:

SiO_2,	39.08	per cent.
Fe_2O_3,	3.19	"
Al_2O_3,	16.43	"
MnO,	3.68	"
CaO,	29.88	"
MgO,	0.30	"
SO_3,	0.07	"
B_2O_3,	0.28	"
H_2O at 100°,	0.22	"
H_2O at red heat,	6.61	"
Total,	99.74	"

This analysis shows that the mineral has a close relation to vesuvianite, except for the large amount of combined water. The presence of a little boric acid is not at all surprising, for it is common in the Franklin Furnace minerals, and it has been identified in the vesuvianite from several localities. It resembles vesuvianite also in the fact that it gelatinizes perfectly after ignition. Its specific gravity, however, is low, only 2.78. Indistinct crystals were seen on one of the specimens, but nothing that afforded material for measurement or other means of identification. It is to be hoped that more specimens of this interesting mineral may be found, so that its relations may be positively ascertained.

About the time this mineral came from the Parker mine another was found in considerable abundance, which at first was not identified. It is a massive substance, in structure like willemite, but of a dark brown or mahogany color. Qualitative analysis shows it to contain only zinc and silica, with a little manganese, as is common with the willemite from that locality. It is, then, only a variety of willemite having this unusual color, which disguises it so that it was at first thrown aside as of no value.

HOBOKEN MINERALS.

During the past year a large collection of minerals from Hoboken, recently purchased from Mr. George F. Kunz, has been thoroughly examined and labeled. Though not a great variety is found, the collection well represents all the minerals that have been described from that locality, and from among them we are now able to add two species not heretofore noticed there, nor, indeed, at any other locality in the State. This collection comes from the well-known "Castle Point," which is now completely covered with buildings and other improvements, so that it is doubtful whether any more specimens will ever be obtained there. Among them are many specimens, some of them large and fine, of the mineral hydromagnesite, which is not at all common anywhere. There is also a large number of specimens of nemalite, the fibrous variety of brucite, a mineral almost unknown elsewhere.

DEWEYLITE FROM HOBOKEN.

Among these specimens some were noticed as incrustations on the serpentine, having all the characteristics of *deweylite,* a mineral not heretofore identified from this State, but to be expected in such an association of minerals. Analysis shows it to have the following composition:

SiO_2,	38.20	per cent.
Fe_2O_3,	0.94	"
Al_2O_3,	0.80	"
CaO,	4.76	"
MgO,	31.32	"
SO_3,	0.11	"
Cl,	0.15	"
CO_2,	3.70	"
H_2O, 100°,	7.67	"
H_2O, red heat,	12.09	"
Total,	99.74	"

This mineral is seen as an incrustation, about one-half an inch in thickness, on the serpentine, probably originally filling a seam; is of a yellowish brown color, looking like gum arabic, and is very brittle and crumbly. It has the physical characteristics of deweylite, and its chemical composition, as seen from the above analysis, the specimen analysed showing a small admixture of aragonite, the carbon dioxide and lime almost exactly neutralizing each other, and some other slight impurities. It is proper, therefore, to add this to the list of minerals already found in New Jersey.

MESITITE FROM HOBOKEN.

Another seam in the serpentine is filled with what appears to be carbonate of iron and magnesium, mixed with some other minerals. As it occurs in a seam only about one-fourth of an inch in width, and the other minerals cannot easily be separated from it, it was analyzed as a whole, and an attempt was made to get at the proportions of the various minerals by calculation. The results of this analysis are:

SiO_2,	21.90	per cent.
FeO,	6.97	"
CaO,	1.52	"
MgO,	37.33	"
H_2O, 100°,	6.41	"
H_2O, red heat,	18.56	"
CO_2,	7.10	"
Total,	99.79	"

The lime was first calculated with enough carbon dioxide to make aragonite. The silica then took out its equivalents of magnesia and water to form deweylite, the remaining carbon dioxide was calculated with ferrous oxide and magnesia to *mesitite,* and the remainder of ferrous oxide, magnesia and water, of which latter there is an excess, belongs to the nemalite, which is evidently present. The appearance and blow-pipe characters of part of this material point so clearly to mesitite that I feel justified in accepting the results of this analysis and calculation, which show the filling of the seam, deducting the aragonite, to consist of about 55 per cent. of deweylite, 30 per cent. of nemalite and 15 per cent. of mesitite, thus adding another to our list of New Jersey minerals.

The analyses quoted in this report were all made by Professor W. S. Myers, of Rutgers College, to whom I am indebted for much very careful work. I wish also to express my indebtedness to my assistant, Mr. William S. Valiant, for much valuable assistance in the prosecution of these investigations.

Rutgers College, November 27th, 1900.

PART V.

Chlorine in the Natural Waters of the State.

By WILLIAM S. MYERS.


GEOLOGICAL SURVEY OF NEW JERSEY.
A MAP OF
NEW JERSEY
SHOWING NORMAL CHLORINE
1900
Scale of Miles.
The amount of chlorine is expressed in parts per million and the figures show chlorine which is normal or nearly so
Port Jervis
Milford
Deckertown
Branchville
Franklin
Newton
Water Gap
Blairstown
Stanhope
Hackettstown
Belvidere
Washington
EASTON
Phillipsburgh
High Bridge
Clinton
HUNTERDON
Frenchtown
Flemington
Lambertville
Pennington
MERCER
TRENTON
Princeton
Rocky Hill
New Brunswick
Perth Amboy
Plainfield
Somerville
Morristown
Dover
Chester
Peapack
Paterson
Newark
Jersey City
Hoboken
New York
Brooklyn
Elizabeth
Rahway
Summit
Orange
Montclair
Caldwell
Passaic
Hackensack
Englewood
Pompton
Boonton
Hibernia
Edison
Ringwood
Pine Island
Turners
Stony Point
Tuxedo Park
New City
Suffern
Nyack
Piermont
South Amboy
Matawan
Keyport
Atlantic Highlands
Sandy Hook
Seabright
Red Bank
Long Branch
Freehold
Jamesburg
Hightstown
Asbury Park
Belmar
Spring Lake
Manasquan
Point Pleasant
Lakewood
New Egypt
Allentown
Bordentown
Burlington
Beverly
Mount Holly
Pemberton
Manchester
Toms River
Whitings
Seaside Park
Moorestown
Vincentown
Medford
Haddonfield
CAMDEN
PHILADELPHIA
CHESTER
WILMINGTON
Gloucester
Woodbury
Blackwood
Bridgeport
Swedesboro
Mullica Hill
Penns Grove
Glassboro
Williamstown
Atco
Atsion
Shamong
Barnegat
Barnegat City
Harrisia
Batsto
Hammonton
Winslow
Woodstown
Elmer
Malaga
Salem
Alloway
Vineland
Egg Harbor City
Mays Landing
Tuckerton
Beach Haven
Brigantine
Atlantic City
Bridgeton
Greenwich
Millville
Somers Point
Longport
Ocean City
Tuckahoe
Port Norris
Sea Isle City
Cape May C.H.
Avalon
Holly Beach
DELAWARE BAY
ATLANTIC OCEAN
RARITAN BAY
STATEN I.
PENNSYLVANIA
NEW YORK
SUSSEX
WARREN
MORRIS
PASSAIC
BERGEN
ESSEX
HUDSON
UNION
SOMERSET
MIDDLESEX
MONMOUTH
BURLINGTON
OCEAN
CAMDEN
GLOUCESTER
SALEM
CUMBERLAND
ATLANTIC
CAPE MAY
1.2
0.8
1.1
0.8
0.7
1.8
1.7
2.9
2.8
2.6
2.7
2.9
2.9
2.8
2.1
2.3
2.4
2.4
1.9
2.4
2.9
3.8
4.9
3.8
4.2
2.7
5.3
5.5
4.4

Chlorine in the Natural Waters of the State

By WILLIAM S. MYERS.

Continuing the work for the preparation of a Chlorine Map of the State showing the Iso-Chlor lines for the natural surface waters of the State, we herewith publish further data setting forth, in parts per million, the figures for the content of Total Solids and for Chlorine.

These reported analyses have been made during the last two years, and the data are now sufficiently numerous for the plotting of a partial area covering the main portion of the northern part of the State, and including a part of some of the adjoining counties of New York State.

While the Iso-Chlors are not likely to be changed greatly by further observations, nevertheless the additional data to be secured next season may cause certain modifications in the position and direction of the lines. It is deemed advisable, however, to submit a preliminary map of Iso-Chlors as was promised in last year's report, and with these explanations the map is published.

In keeping with what we wrote last year and bearing on the sanitary importance of this map as determining for the plotted area the sanitary significance of any future analyses therein, we may add that we believe that the map will be of considerable service to sanitary experts in arriving at correct conclusions and practical interpretations of their analytical results, not only in New Jersey but elsewhere along other coasts where similar conditions obtain.

In this connection it is very interesting to note that the result of recent observations at Cirencester, England, at an elevation of 443 feet and 35 miles inland, the average chlorine content of rain water was 3.17 parts per million for a period of 26 years; and that the summer seasons averaged 2.58 parts per million, while the winter rain water ran as high as 3.76 parts of chlorine per million. The rainfall averaged 30 inches, and it is calculated that 36 pounds per acre of salt are added in this manner per annum to the land in that vicinity. It is hoped that our observations may be extended to include this subject in the near future.

Referring to the results of neglect of sanitary authorities to take steps to secure the best and purest water-supplies, it is apropos to reiterate the well-known statement here in this connection that an immense number of our people die every year of preventable diseases, a very large proportion of which are water-borne. The correct knowledge of the precise significance of chemical data as applied to water examinations is here shown to be of the utmost value to our whole commonwealth, and to all its citizens.

The figures for total solids will serve later for study in connection with the examination of the mineral composition of artesian well waters of the State.

In the preliminary Iso-Chlor map herewith published, it will be noticed that in general the figures accord with results obtained in other states under similar conditions.

The samples this year have all been taken by the writer. The data represent in all cases the examination of but one sample. It is expected in certain cases to confirm these observations by further analyses of the same waters. We believe, however, that no material or important changes will be necessary in the figures published.

For many years this subject, the character of water-supplies, has been growing in interest and importance and it has now become a very urgent one in certain localities. The characteristic features of our position in this respect are intensified by the steady and rapid growth of the population of adjacent states. Their cities and towns, as well as our own, are increasing their daily per capita consumption of water, and this rate of consumption is sure to increase with the further enlightenment of our people in regard to the sanitary importance of the free use of pure water. We must expect, therefore, that in the course of time and that probably in the not remote future our neighboring great cities may require to draw upon our supplies to supplement their own, and moreover our own people will ultimately need them all. The careful conservation of all our present surface supplies is therefore of the greatest importance.

While various methods of purification may be used as temporary expedients, and perhaps in some cases as last resorts, *no artificial method yields as desirable conditions as an originally pure source of supply affords,* therefore we should inquire and ascertain by the continuance of these investigations what the best supplies of the State are, and as to how they may best be conserved untouched for the use of our people. Sources of pollution will be more easily discovered when this map is completed, and supplies now considered doubtful may be remedied, once the precise location and degree of pollution is ascertained. Right here our standards will, as set forth by the map, become, it is hoped, most efficient and useful.

The educated public has been taking such an increased interest in the subject of water-supplies since the recent wars in Cuba and Africa and elsewhere, in which more sound and perfectly healthy men have died of water-borne diseases than by bullets; that nearly all our people are now alive to the necessity of maintaining all our water-supplies in a sanitary condition. An immense amount of work remains to be done, however, in educating our people to the point of enlightenment effective enough to execute even our present laws relating to the maintenance of the purity of our water-courses.

Intelligent self-interest will ultimately compel our purveyors of water to do what now may seem an unimportant duty. Those who manage our public supplies must be made to understand that lack of care, resulting from lack of knowledge of the sanitary importance of these subjects, or lack of willingness to apply them, must mean disease and possibly death to large numbers of our citizens.

We believe it to be the duty of our State to emphasize to the fullest extent the importance of wholesome water-supplies to our people. As a part of our mineral resources and as one of our natural products, the subject merits the attention it has always received from the Survey. The natural waters of the State have been made the subject of considerable study and investigation since 1868 in the yearly Reports, and the very full report of 1894, by Mr. C. C. Vermeule, brings the whole subject to a point where the water map will afford very important diagnostic data, and will enable observers to ascertain in a comparatively short space of time what the normal composition for the natural surface waters of the State may be at any point.

We may reiterate that, after all, no devices can adequately substitute for an originally pure supply of water. These data and the map resulting therefrom will give us exact knowledge as to what a pure supply should be for any given place in the State.

The situation calls for the early completion of this work, for the matter is of vital importance to the whole people of the State, and they have a right to the full use of this natural product free from injury to themselves.

The following results have been used thus far in plotting the figures laid down on the accompanying map of iso-chlors. The figures for total solids are also given and are worthy of some attention, and later additions may yield some interesting deductions. The great solvent power of water reflects at once the nature of the geological formation, as mineral analyses of natural waters show. I have also added separate figures for chlorine in sewage, sea water, *in order to show the diagnostic value of the chlorine factor* in natural surface waters, as well as in other waters:

	Parts per Million.	
	Chlorine.	*Total Solids.*
Red Medina 1½ S. W. Wallpack,	0.70	25.00
Lake Mashipacong,	0.80	16.00
Culver's Lake,	0.80	78.00
Lubbock Run,	0.80	108.30
Big Flatbrook,	1.10	30.00
Delaware River, Port Jervis, N. Y.,	1.20	36.40
Sand Pond,	1.20	48.00
Tuxedo Lake, N. Y.,	1.70	23.10
Montclair Supply,	1.90	73.30

	Parts per Million. Chlorine.	Total Solids.
Croton Supply, N. Y.,	1.90	85.00
Kenvil,	1.90	47.00
South Branch Raritan, Neshanic,	2.00	....
Cranberry Reservoir,	2.10	....
Swartswood's Lake,	2.10	71.00
Pequannock River, near Pompton,	2.30	64.00
Lake Hopatcong,	2.30	45.00
Hurd's Hopatcong,	2.40	90.00
Newton,	2.40	80.00
Rockaway River, Berkshire Valley,	2.40	74.00
Budd's Lake,	2.40	100.00
Troy Hills, small stream,	2.40	126.90
Black River at Chester,	2.43	42.80
Paulins Kill,	2.50	85.00
Macopin Lake,	2.60	74.80
Intake Reservoir,	2.70	60.00
Raritan River, above Somerville, after heavy rain,	2.70	95.00
Stream near Williamstown,	2.70	69.30
Clinton Reservoir,	2.80	63.20
Hohokus River, Hohokus,	2.80	90.00
Delaware River, Water Gap,	2.90	48.00
Morristown City, Supply,	2.90	110.00
Rockland Lake, N. Y.,	2.90	73.30
Wanaque River, Pompton,	2.90	74.30
Monmouth Junction,	2.90	53.00
Panther Pond,	3.00	129.30
South Branch Raritan, Bartley,	3.50	64.00
Raritan River, above Somerville,	3.70	120.00
Suffern, N. Y., City Supply,	3.70	105.50
Ramapo River, Suffern, N. Y.,	3.70	85.00
Beaver Dam Brook, Lawrence Brook,	3.80	57.30
East Branch of Bound Brook, Warrenville,	3.80	....
South River, at Old Bridge,	4.20	30.00
Mantua Creek, near Woodbury,	4.40	65.30
Caldwell,	4.50	120.00
Lawrence Brook, New Brunswick, City Supply,	4.90	63.20
South River, Spotswood,	5.30	25.00
Ambrose's Brook, Bound Brook,	5.60	90.00
Colt's Neck, small stream,	5.60	95.30
Yellow Brook, Eatontown,	5.70	71.10
Robinson's Brook,	6.20	167.00
Hop Brook, Eatontown,	6.20	112.00
Matchaponix River,	6.40	55.00
Absecon Creek, Atlantic City,	6.70	35.60
Atlantic Highlands, small stream,	7.10	154.00

	Parts per Million. Chlorine.	Total Solids.
Ice from Silver Lake, near New Brunswick,	1.80	20.00
Dew and Hoar Frost, Rothamstead, England,	5.30	48.70
Rain Water, Cirencester, England,	3.17	34.20
Rain Water, Lands End, England,	218.00	428.00
Dead Sea Water,	136,000.00	223,000.00
Sea Water, average,	20,000.00	36,000.00
Scotland Surface Water, East Coast,	12.60	....
Scotland Surface Water, West Coast,	11.90	....
Unfiltered Sewage,	....	1,210.00
Filtered Sewage,	100.00	760.00
Human Urine,	4,800.00	40,000.00

PART VI.

THE MINING INDUSTRY.

By HENRY B. KÜMMEL.

The Mining Industry.

By HENRY B. KÜMMEL.

The Iron Mines.

The year 1899 witnessed one of the most remarkable revivals in the iron-mining industry in all its history. The year 1900 saw a marked reaction from the high prices of that revival, a reaction which was naturally to be expected. It carried down the price of pig-iron in 1900 for below that prevailing in the latter part of 1899. Consequently, many furnaces which had been in blast during the boom times were shut down, and the revival of iron mining, which reached such marked proportions in 1899, came to a somewhat sudden stop. Prospecting ceased, and some of the mines which had been opened were closed again. The following mines were reported as in operation at the close of 1899: The Hurd, Richard, Edison, Lower Wood and Wharton, on the Hibernia vein, the New Sterling Slope at Irondale, the Ringwood mines, Green Pond, Beach Glen, Ford, Weldon, Kishpaugh, Oxford and Mt. Hope mines. So far as I have been able to learn the following mines were ore producers during 1900: Hurd, Richard, Elizabeth and Taylor of the Mt. Hope mines, Irondale mines, Beach Glen, Crane, Wharton, Green Pond, Slope 3 and Washington at Oxford, Kishpaugh, Ringwood, Black Hills and Edison. Some work was done at the Lower Weldon, but I have not been able to learn how much.

The following notes indicate the work at the various mines during 1900:

HURD MINE, HURD, N. J.

The lessees, Messrs. Pilling & Crane, of Philadelphia, report that much prospect work was done during the year. Some ore was taken from the old workings, the output at the close of the year being at the rate of about 1,000 tons per month, the annual production being about 9,000 tons. Several good faces of ore were prepared for work, and no difficulty is anticipated in continuing to ship ore at about the above rate. Explorations are being continued with a view to discovering, if possible, any large veins which may still exist on the property.

RICHARD MINE.

Mr. B. F. Fackenthal, President of the Thomas Iron Company, kindly furnished the data for the following statement concerning this mine.

The output of this mine since its purchase by the Thomas Iron Co., in 1856, is shown by the following table, in which the figures are made up for fiscal years ending June 30th in each case:

	Tons.	*Cwt.*		*Tons.*	*Cwt.*
1857	4,216	8	1880	32,047	15
1858	8,910	8	1881	37,916	8
1859	8,130	14	1882	41,999	8
1860	8,125	10	1883	64,152	5
1861	7,884	6	1884	44,741	11
1862	20,371	3	1885	51,832	17
1863	20,741	4	1886	71,776	10
1864	15,085	7	1887	79,120	9
1865	13,138	2	1888	79,540	5
1866	16,775	7	1889	67,691	2
1867	16,415	15	1890	67,728	19
1868	15,176	14	1891	76,480	0
1869	13,865	5	1892	52,799	14
1870	16,667	4	1893	62,995	15
1871	15,999	4	1894	64,500	19
1872	18,060	8	1895	79,963	5
1873	15,362	14	1896	112,386	1
1874	18,846	14	1897	100,573	18
1875	21,650	11	1898	106,089	10
1876	18,217	19	1899	95,086	15
1877	29,519	3	1900	90,772	6
1878	23,575	11			
1879	17,838	10	Total	1,844,769	14

During the calendar year 1900 the production was 94,350 tons.

MOUNT HOPE MINES.

Mr. W. L. Sims, General Manager of the Empire Steel and Iron Company, kindly furnished the following data for this group of mines.

Elizabeth Mine.—This mine produced about 15,000 tons of ore during 1900. After working to the "Teabo" boundary, on the western end of the mine, operations were begun on the eastern stope, where it was found necessary to sink deeper in order to follow the main ore-body. The shaft is now down 40 feet below the last level, making a depth of 250 feet. This shaft runs through solid ore, averaging eight to ten feet in width.

Taylor Mine.—This mine was pumped out during the year, and about 6,000 tons of ore mined. As the shaft through which the ore is hoisted is 600 feet away from the stope, it becomes necessary to sink a new shaft on to the main ore-body. This is now being done, and after its completion three hundred tons of ore daily can be easily mined.

The side-hill vein has not yet been pumped out, but it is supposed to contain even a larger amount of ore than the Taylor vein.

THE NEW STERLING MINE, IRONDALE.

The New Jersey Iron Mining Company, through the secretary, Mr. L. C. Bierwirth, reported that the production of the Irondale mines for 1900 was 21,378 tons.

BEACH GLEN MINES.

Joseph Wharton operated this property during the past year up to October 31st, mining out lean ore for his concentrating works at Hibernia.

The method of mining consisted of open cutting, as the deposit is nearly 50 feet high and 60 feet wide. The material as it was mined (16,845 tons) yielded 30 to 40 per cent. in metallic iron, and the concentrates ran about 60 per cent., 6,479 tons of concentrates being produced during the year.

The ore crushes and separates well, and, on the whole, is a desirable material for concentration, provided it can be produced cheaply. It was found, however, during midsummer that the covering of the vein was getting extremely heavy, and the cost of its removal largely increased the cost of mining, so that at the end of October this method of mining was no longer considered profitable, and Mr. Wharton gave up the lease.

In November, however, the owners of the property induced him to take another lease under more favorable terms, and he has now put down a shaft large enough for a double skip-way 120 feet through the cap rock. He proposes going a depth of 100 feet additional for the purpose of proving the property.

LOWER WOOD MINE AND CRANE MINE, HIBERNIA.

The Lower Wood Mine continues to be the outlet for all the ore mined on the adjoining Crane lot, which is now owned by the Andover Iron Company.* The Superintendent, Mr. S. B. Patterson, reports to this effect: The work of actual mining was confined to the Crane mine, and consisted (*a*) in driving stopes No. 19 and No. 20 to the eastward toward the De Camp line; No. 21 to the northeast, and (*b*) in sinking to and opening No. 22 level. There is more or less rock in the vein, which continues to be "bunchy" and irregular. The amount of ore produced during the year was 55,977 tons, most of which was used by the company itself.

DE CAMP MINE, HIBERNIA.

There was no ore taken out of this mine during 1900, but Mr. Joseph Wharton, the present owner, is doing all the necessary preparatory work to get it ready for operation about April 1st, 1901.

*As this report goes to press it is learned that the Andover Iron Company has been purchased by Joseph Wharton, who now controls the entire Hibernia vein.

UPPER WOOD MINE, HIBERNIA.

On this property Mr. Wharton has spent considerable money during the past year in the installation of four 125 horse-power boilers and a duplex air compresser, good for 3,500 cubic feet of free air per minute.

Considerable repair work has been done on the shaft and skip-road, and the pumps have been thoroughly overhauled. It is expected to have everything in readiness for mining ore on this property April 1st, 1901.

WHARTON MINE, HIBERNIA.

This mine has continued to be as great a producer during 1900 (75,000 tons) as it was the previous year, and its future is, indeed, very promising. The mine is now down a depth of 1,100 feet, and has 12 working stopes.

Mr. Wharton is about to place a contract for a large hoisting engine for use on this property, calculated to lift 10,000 pounds at the rate of 1,000 feet per minute.

The new shaft on the eastern end of the property has been sunk to a depth of 225 feet, but no great quantity of ore has been discovered. It has not been worked vigorously during the past year for the reason that there was a shortage of labor.

THE ALLEN MINE.

This mine is now owned by Joseph Wharton. No work has been done on this property during the past year, but it is hoped that before the close of 1901 prospecting work will be commenced.

THE TEABO MINE.

This property was purchased from the Glendon Iron Company by Mr. Wharton during 1898, but no work of any character has been done on the property since he acquired it.

GREEN POND MINE OR COPPERAS TRACT MINE.

The following statement of operations at these mines was obtained from the Carteret Steel Company, of New York. Considerable work was done between January 1st and April 30th, 1900, in repairing and erecting buildings and machinery. Two new boilers, a new Ingersoll-Sergeant air compressor and a receiver were received.

At the same time mining was begun in a temporary manner in shaft No. 1½, while the new machinery and buildings were being erected to provide for operations on a proper scale and in a systematic manner. About 1,200 tons of ore were taken out, of which 1,050 tons were shipped to the company's furnace at Hackettstown and the remainder left on the dock. The work was closed down during May, owing to the general dullness of the ore market, and has not yet been resumed.

OXFORD MINES, OXFORD FURNACE.

During 1900 operations were conducted at Slope No. 3 and the Washington mine on the Oxford property of the Empire Steel and Iron Company. During the year 1901, the company intends to develop these mines further. The total amount mined at Oxford during 1900 was 20,169 tons.

THE BROTHERTON MINE, RANDOLPH TOWNSHIP, MORRIS COUNTY.

During the past year the Brotherton Mine was leased to the Bethlehem Steel Company. They commenced operations about November 1st, but up to the close of the year had produced no ore. The slope has been pumped out and timbered where necessary.

The depth is about 150 feet, and they are now sinking to the vein at the foot of the slope. Indications now are that they will begin to raise ore in the near future.

FELLOWS AND QUEEN MINE.

Mr. W. L. Sims, General Manager of the Empire Steel and Iron Company, reports that there was nothing done at the Fellows Mine during 1900. A shaft on the Queen property was operated a portion of the time and a small amount of ore removed, but the amount mined was insignificant.

KISHPAUGH MINE, DANVILLE.

Messrs. Pilling & Crane operated this mine during the early part of the year, but a disastrous fire destroyed the machinery and outbuildings, and shortly afterwards the mine was flooded from an old opening, full of water. The conditions did not justify the lessees in continuing operations and the lease was surrendered. The mine is now completely dismantled and is probably permanently abandoned. The production for the year up to the time of the accident was about 2,000 tons.

THE RINGWOOD MINES.

These mines have continued in operation during the year, the production being 18,755 tons, most of which was shipped to the Durham furnace of Cooper, Hewitt & Co.

BLACK HILLS MINE.

Data concerning the operations here by the Dickerson Succasunna Mining Company during 1900 were obtained from Mr. Fred. A. Canfield. The company began work in January, 1900. Preparations for mining were first made at one shaft, and later, in July and August, two other shafts were pumped out and examined. Work was stopped during August and was not resumed. About 500 tons of ore were mined and now lie at the shaft. The principal vein has been opened for a horizontal length of 225 feet, at a depth of 100 feet. The average width of the ore is about three feet. It is so mixed with quartz that the percentage of iron is low—43 to 45 per cent. There are six or seven veins or beds.

NEW JERSEY AND PENNSYLVANIA CONCENTRATING WORKS, EDISON, N. J.

During 1900 this company mined and separated 75,206 tons of crude material at its magnetic concentrating plant at Edison, N. J. Of this there were shipped about 10,000 tons of concentrates in the form of briquettes, and 30,000 tons sand. The balance, consisting of concentrates and sand, is still on hand. One thousand Edison briquettes shipped to the Thomas Iron Company, January, 1899, contained 62.83 per cent. metallic iron.

THE SCRUB OAK OR DELL MINE.

This mine, owned by the Andover Iron Company, was leased during the year to Mr. Clinton M. Ball. No mining was done on the property, however, nor is there any development work to report.

The Zinc Mines.

The only productive Zinc mines in the State are those of the New Jersey Zinc Company at Franklin Furnace. The following statement of their operations during the year was kindly furnished by the company through Mr. H. A. J. Wilkins.

During the past year the plants of The New Jersey Zinc Company at Franklin Furnace, New Jersey, have been very active. The open development work or stripping on the extreme southwest end of the lens has been carried far enough to show up the westerly leg of the ore bed and to partially uncover the extreme end of the basin or as it has been termed, the rounding of the spoon. This operation has been continued from the extreme southwest end to the large trap dike. At the southern end of the deposit no work has been done below the tunnel level, excepting the sinking of the slope under the limestone arch in the direction of the Parker mine for the purpose of a second outlet which is possibly to be used later for hoisting ore and filling purposes.

In the Parker mine all of the work done has been in the line of development. The general blocking system has been continued during the year to develop the lens of ore at the northeast end. The development work now reaches from the 1100-foot level to the 750-foot level in height, and in a longitudinal direction about 600 feet north and 900 feet south from Parker shaft. There are no changes in this mine other than the discovery of horses of rock and the usual irregularity of the walls both foot and hanging.

The No. 1 mill has been worked successfully throughout the entire year without interruption. It has produced the usual quantity of ore, possibly a little in excess of the previous year.

The new concentrating plant, or No. 2 mill, commenced crushing and shipping crude ore in February, 1900. The work on the mill was so far advanced by October 1st that the separating department was started.

The total number of tons of ore shipped from the mines of The New Jersey Zinc Company, at Franklin Furnace, for the year 1900, was 194,881.28 tons.

The Stirling Hill mine and plant, at Ogdensburg, was idle throughout the entire year. The old machinery was scrapped, only a small vestige of the former plant being left in position.

The Copper Mines.

The copper mines of New Jersey are not as yet established upon a commercial basis, but during the past year the work in at least two mines has been so important and encouraging that it is expected they will be put on a paying basis during the coming year. Not for many years have the prospects for copper mining in the State been so bright.

THE AMERICAN COPPER MINE, SOMERVILLE.

This mine was somewhat fully described in the Report for 1898. During the past year the development work has been pushed steadily and with good results. Two new tunnels, at moderate distances from the old main tunnel, have been started to follow down the contact of the trap and shale. The old tunnel, which was crooked and narrow, has been enlarged in places, and a new straight tunnel run several hundred feet from the first bend of the old one. Several of the deeper side drifts have been extended. With this deeper work there has been a marked change in the character of the ore disclosed. The oxide and carbonate of copper were the prevailing minerals near the surface, but with the greater depth there is an increase in the amount of native copper found, with strong indications that all the ore at greater depth is of that character. It occurs in thin sheets, ramifying filaments, irregular shape masses and occasionally nuggets. There are some indications that with still greater depths the large nodular masses of copper oxide and carbonate which occur in the upper drifts will be replaced by the native copper, but the workings are not yet sufficiently extensive to permit of a positive assertion on this point. Much of the ore carries minute particles of silver. There is good ground for hope that in the near future this mine will begin to pay its owners returns upon their investment. With the deeper work which will follow in the development of the mine the occurrence of the ore will undoubtedly be so well disclosed that adequate theories as to the precipitation and concentration of the copper can be framed.

A concentrating and leaching plant were completed the latter part of September, and are now in operation. During the past three months five or six hundred tons of ore, which had been taken out in the earlier development work, have been run through the concentrator experimentally, with a view of testing the capacity of the plant and the character of the ore. It is reported by the management that experimental runs have been made with ore of different grades with very satisfactory results in every case.

When in full operation the ore will be hauled from the mine directly to the top of the concentrator, and dumped into a Dodge crusher, having a capacity of 100 tons per day. From the bin beneath the crushed rock is elevated automatically to the dryer, whence it is carried by a screw-feed and elevator to the roughing rolls, by which it is ground to powder. Fragments above a certain size are returned automatically to the crusher. After passing through two roughing rolls and the accompanying sieves, from which the coarser particles are sent back to be re-rolled, the finest material passes into the meal-room, which has a storage capacity of 250 tons. From the meal-room it is carried to two Wilfrey tables, on which the native copper and the ores are mechanically concentrated by running water.

After drying, the concentrates, which contain from 35 to 45 per cent. of ore, are ready for shipment to the smelter. Although by this process of concentration 75 to 80 per cent. of the ore is saved, it will probably be found profitable to treat further the tailings by leaching in dilute sulphuric acid, and precipitating the copper by iron, or to treat them by the copper chloride process. A thirty horse-power engine supplies the necessary power for the steam drills, concentrator and mine pumps.

THE SCHUYLER MINE, NORTH ARLINGTON, N. J.

During the year this old mine was bought by the Arlington Copper Mining Co.,* capitalized at $2,500,000, and considerable work has been done in unwatering the old openings, in testing the ores and in the erection of a large plant. The following details of the operations were kindly furnished by Mr. J. H. Granbery, M. E., who designed the plant and is in charge of the construction work.

On the property embraced by the original mine forty-two shafts had been sunk and three drain tunnels run, known respectively as the North, Main and South drain tunnels. By means of these the mine above the 100-foot level had been kept free from water. Some of the lower levels have been unwatered, down to the 240-foot level, by means of an upraise about 500 feet long connecting with the Main drain tunnel. The North

* The Company was organized February 3d, 1900, by Mr. Chas. L. Dignowity, of Boston, and Mr. Wm. C. Eakins, of Chicago. Mr. William McKenzie, of Passaic, is President; Mr. Henry G. Bell, of Rutherford, Treasurer; Mr. Eakins, Secretary, and Mr. Dignowity, General Manager. Dr. N. S. Keith developed the metallurgical process.

drain tunnel has not been explored, as the shaft which was left for cleaning is now buried under a waste dump. The Main drain tunnel had four shafts for cleaning out, but these are all closed. One additional shaft for the same purpose has been opened. This drain tunnel is about 1,300 feet long and drains the entire mine down to the 100-foot level, with the exception of the small portion drained by the North and South tunnels respectively. The South drain tunnel had two shafts for cleaning out, but both of these are filled up and the tunnel itself is caved between one of these shafts and the workings which it drains. The old workings, which comprise those in the southern part of the original tract, are unsafe, since the ore body lies so near the surface that extensive timbering is here required and the workings, which are quite extensive, are gradually caving and the ground settling. This part of the mine will not be worked by this company. The portion of the mine which the present company will work comprises about 150 acres, and about 75 acres of it, lying mainly in the eastern part of the property, is already traversed by numerous drifts. In some places large chambers, one measuring 670 feet in circumference, have been formed by stoping. Much of the ore taken out of the rock has been allowed to remain in these chambers and drifts in the form of dead walls, as it was of too low grade for the former owners to handle profitably.

The present company have opened two of the old shafts to the bottom; one of these, Shaft No. 1, being used only for ventilation; the other, No. 2, affording an entrance to the large chambers previously mentioned. Shaft No. 4 is now being opened and has reached a depth of about fifty feet. Shaft No. 10 is also being opened and is already five feet below the seventy-foot level, where there are three small drifts with a small chamber stoped out. One of these, which is stopped by a dead wall, probably connects with the Victoria shaft or with workings very near it. Two drifts, the Main and Reserve, have been run along the ore-bearing beds from the face of the bluff overlooking the meadows. The Main drift is now 220 feet long and connects with shaft No. 1, through one of the old drifts.

The Reserve drift is to run through the center of the property, striking the Victoria shaft. Eighty feet of this drift has already been run, although work upon it is at present stopped. The Victoria shaft is said to be 347 feet deep, but it has been pumped out only to the 240-foot level. This shaft was sunk to the hundred-foot level at some time previous to the year 1753, as it was on September 9th of that year that Josiah Hornblower arrived in this country with an engine, which he had built to pump the water out of this shaft. It is probable, however, that the shaft was named by a Wm. Tregaskis, Mine Captain, at about the time of Queen Victoria's coronation. This is reputed to be the first shaft ever sunk in what is now the United States.

The ore itself is not in any vein with well marked boundaries, but occurs in pockets or bunches and seams which ramify through two thick layers of sandstone and a thin bed of shale. There are numerous faults in the deposit and it is at these points and in connection with small trap dikes that some of the richest ore is found. The ore body is being very exhaustively sampled, samples being taken ten feet apart and from top to bottom through the whole system of workings. The rock seems to be ore-bearing wherever it occurs in the form of sandstone. The poorest samples have never in any case run less than ½ per cent., and the actual average of the run of the mine is nearly 2½ per cent. By selecting the ore this percentage can be raised, as there is a considerable shaly slate which assays from 6 to 7 per cent. The actual quantity of ore-bearing rock is, by actual measurement, about 5,000,000 tons.*

The present mill will have a capacity of 125 tons a day, but provision has been made to increase this to 500 tons if it is found advisable to do so.

The mining will be done by running the two drifts through the property, and making cross-cuts, as far as the property lines, so as to remove the ore by these cross-cuts and drifts. This is very similar to the method used in anthracite coal mining.

*These figures were furnished by Mr. Granbery, engineer of the company. The Geological Survey has not been able to make the detailed examinations necessary to the determinations of the per cent. of copper and the amount of ore available.

A cable road will carry the ore-cars from the mine up the incline to the mill. The ore will be automatically dumped into the crusher, where it is reduced to about 1½-inch cubes. From the crusher the material drops into an ore-bin with a capacity of 500 tons, where it is dried and thus prepared for dry rolling and pulverizing. From the ore-bin the material drops into a set of Fraser & Chalmers crushing rolls, and from there, being reduced to about ¼-inch in size, it is conveyed to two pulverizing machines which reduce it so that it will pass through a 40-mesh screen. The resulting sand is then roasted in a furnace with a hearth 10 feet by 200 feet, where it is stirred mechanically and finally discharged into a trough.

Dilute sulphuric acid from two solution tanks above this level is fed directly upon the heated sand, forming a sort of slush, which is washed into four wooden tanks 30 feet in diameter with a capacity of 125 tons each. In these tanks the solution attacks whatever copper may be present in the slush. The resulting solution of copper sulphate is then drawn off from these leaching or lixiviation tanks and is used in large vats as electrolyte.

In these vats electrolytic action is set up by passing a current from one sheet of lead anode plates to a corresponding set of lead cathode plates. The copper is deposited upon the cathode plate, and after reaching sufficient thickness is stripped off and the resulting copper plates are hung in the solution again to receive a thicker coat, thus bringing the sheet copper up to the thickness required for market purposes.

From the time the ore is loaded on the cars in the mine to the time the copper is stripped off the lead plates in the deposition building, the work is designed to be entirely automatic and is either mechanical or by gravity. The buildings are to be of steel and corrugated iron with the exception of the power house, which will be of stone with a steel roof. It is expected that the power house will be under roof and the steel work for the other buildings delivered about the 15th of February.

PENNINGTON AND MENLO PARK.

At various times during the year sensational reports of copper finds near Pennington, and at Menlo Park, east of New Brunswick, have appeared in the papers, but the Survey has been unable to obtain authentic information from persons reported to be interested in these mines. So far as known the copper finds near Pennington are located a few miles west of the village, in the altered shale adjoining the trap-rock of Pennington Mountain. A limited amount of prospecting has been done. The occurrence of the copper here is probably similar to that of the numerous other copper-bearing localities of the Triassic shale area. It is very questionable whether there is any deposit of rich ore, but systematic exploration may show a sufficiently large amount of workable ore to warrant the building of a concentrator. Past experience renders it questionable whether ore rich enough to ship can be mined in paying quantities.

Copper was mined many years ago near Menlo Park, but the workings, as then conducted, did not pay, and were abandoned. It is reported that parties have become interested in these old mines, and propose to pump them out and develop them. It is impossible to say what measure of success may await this enterprise until the mines are open to inspection, and the ore is thoroughly and systematically sampled.

Mineral Statistics

For the Year 1900.

Iron Ore.

The total production of the mines, as reported by the several mining companies, was 407,596 tons.

The total shipments from mines in the State, as reported by the railway companies, to the office of the Geological Survey, amounted to 339,814 tons.

The table of statistics is reprinted, with the total amount for 1900 added.

TABLE OF STATISTICS.

Year.	*Iron Ore.*	*Authority.*
1790	10,000 tons	Morse's estimate.
1830	20,000 tons	Gordon's Gazeteer.
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,	407,596 tons,	" " "

Zinc Ore.

The production of the zinc mines is shown by the yearly shipments of zinc ore. The total shipments of zinc and franklinite ores, as reported by Mr. A. Heckscher, General Manager of the New Jersey Zinc Company, amounted to 194,881 gross tons in 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,	" " "
1883,	56,085 tons,	" " "
1884,	40,094 tons,	" " "
1885,	38,526 tons,	" " "
1886,	43,877 tons,	" " "
1887,	50,220 tons,	" " "

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

1888, ...	46,377 tons, ...	Annual Report State Geologist.
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, ...	" " "

* 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. Copies are supplied to the Board of Managers of the Geological Survey and the State Geologist, who distribute them to libraries and public institutions, and, as far as possible, to any who may be interested in the subjects of which they treat. Several of the reports are out of print, and can no longer be supplied by the office.

The first volume of the Final Report, published in 1888, was mostly distributed during the following year, and the demand for it has been far beyond the supply. The first and second parts of the second volume and the third and fourth volumes have also been distributed to the citizens and schools of the State, and to others interested in the particular subjects of which they treat. The fourth volume includes, in an appendix, all the valuable tables which were in the first volume of this series.

The appended list makes brief mention of all the publications of the present Survey since its inception, in 1864, with a statement of editions that are now out of print. The publications of the Survey are distributed without further expense than that of transportation, excepting the maps, where a nominal charge to cover the cost of paper, printing and transportation is made.

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.

55. 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.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part II. Zoology. Trenton, 1890, 8vo., x+824 pp.

REPORT ON WATER-SUPPLY. Vol. III of the Final Report of the State Geologist. Trenton, 1894, 8vo., xvi + 352 and 96 pp.

REPORT ON THE PHYSICAL GEOGRAPHY of New Jersey. Vol. IV of Final Report of the State Geologist. Trenton, 1898, 8vo., xvi+170+200 pp.

BRACHIOPODA AND LAMELLIRANCHIATA of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1886, quarto, pp. 338, plates XXXV and Map. (Paleontology, Vol. 1.)

GASTEROPODA AND CEPHALOPODA of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1892, quarto, pp. 402, plates L. (Paleontology, Vol. II.)

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 economic 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, HACKENSACK, PATERSON, CAMDEN, ELIZABETH, PLAINFIELD, MOUNT HOLLY, WOODBURY and TAUNTON. 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.

ANNUAL REPORT of the State Geologist of New Jersey for 1877. Trenton, 1877, 8vo., 55 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1878. Trenton, 1878, 8vo., 131 pp., with map. Out of print.

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