GEOLOGICAL SURVEY OF NEW JERSEY

Annual Report

OF THE

State Geologist

FOR THE YEAR

1897

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CONTENTS.

ILLUSTRATIONS.

PLATES.

FIGURES.

ERRATA.

Page 37, ninth line, read ' 1896" instead of "1897."

Page 78, seventeenth line, read "are" instead of "is"

Page 84, tenth line, read "formation" instead of "functions"

Page 87, twentieth line, read "down" instead of "above."

Page 115, thirty-sixth line, omit comma after the word "fault."

Page 130, tenth line, read "dislocation" instead of "dislocations."

Page 145, twenty-second line, read "may have been" instead of "were."

Page 228, second line from bottom, read "one and three-fourths miles" instead of "three miles"

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To His Excellency John W. Griggs, 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 present herewith the Annual Report of the Geological Report for 1897.

Respectfully submitted,
JOHN C. SMOCK,
State Geologist.

TRENTON, N. J.,
November 30, 1897.

ADMINISTRATIVE REPORT.

The work of the Geological Survey has been carried forward on the same general lines of investigation as in 1896, and the organization has been practically the same as it was last year. The surface formations have been studied by Prof. R. D. Salisbury and the mapping has been about completed. Dr. H. B. Kümmel has continued the survey of the Red Sandstone belt—the rocks of the Newark System—and has finished the work in that belt. Mr. C. C. Vermeule has been in charge of the topographic work and has prepared a supplemental report on the Hackensack and Newark meadows. The artesian well records have been continued by Mr. Lewis Woolman. In co-operation with the United States Geological Survey, Dr. J. E. Wolff has spent some time in further surveys of the crystalline schists in the vicinity of Franklin Furnace, and Prof. Wm. B. Clark has contributed a report on the Upper Cretaceous Formations. The forest surveys are in charge of Mr. Gifford Pinchot, consulting botanist and forester. Mr. Irving S. Upson remains in charge of the work of distribution of topographic maps.

SURFACE GEOLOGY.

The survey of the formations which make the surface of the country constitutes the field of investigation of the division of the Geological Survey which has been termed Division of Surface Geology. The work has been done under the direction of Prof. Rollin D. Salisbury, and has been in progress since 1891. It has been carried forward steadily and the whole State has been traversed in the prosecution of the survey. Professor Salisbury was in the field from the 1st of April to July, and gave a large part of the time to the southern part of the State. He has been assisted by G. N. Knapp, who was in the field to the end of November. The boundaries of the various formations have been traced and the data necessary to making an accurate map of these formations, on a scale of one mile to an inch, collected, and a large mass of material has been gathered for publication in form of reports on the Surface Geology.

The report of progress here given is a description of the surface formations as mapped on a scale of fifteen miles to an inch. The difficulties in making such a map are not so apparent at the first glance as when revealed by closer scrutiny. Without any characteristic fossils some of these sands, clays and gravels have no certain marks of identification, and in the southeastern part of the State it is almost impossible to be altogether sure of one's determinations. In other cases, as in the southwestern part of the State, there is apparently little to distinguish the Pensauken from the Bridgeton formations. The difference between the decomposed rock or residuary earth but little removed from the parent rock and drifted materials, is in some cases perplexing. Again, the mixture of the materials by erosion and subsequent shifting on the surface further adds to the complex conditions of the problem.

The location of the boundaries of the formations is in places doubtful, and the shading of one into another or the thin surface layer makes it almost impracticable to draw lines between formations thus overlapping or intermingled. In spite of these difficulties the results are such as to enable the Survey to prepare maps of these surface formations in detail, greater than has been done elsewhere in the country, and far more accurate than the maps of the underlying or rock formations. New Jersey is the first State to make so detailed and elaborate a survey of the whole of its surface formations.

The map accompanying the report shows the extent of the formations of the surface and their general distribution. It is not on a large scale to justify its use in the field in tracing out all the irregularities of outline or locating every outcrop. In fact, it is historical rather than geographical, as it shows the areas of the formations at successive epochs from the Triassic period to the most recent. The older formations at the surface are grouped as pre-Triassic. One of the latest formations has been appropriately named from Cape May county, whose peninsula is all of this epoch, excepting the beaches or sand dunes and the tidal-marsh accumulations of mud, both of which are in progress.

The report is devoted to a description of the map, and is also a clear and concise history of the State since the beginning of the Triassic period or from the end of what is known as the Palæozoic era. The changes which have taken place in the limits of the State are indicated by the map and described in the report. It is hoped that the general reader will find in it a most interesting chapter of geological history, not going back so far as to be shrouded in difficulties and doubts, but descriptive of the middle and later geological time and down to the most recent.

The publication of the maps of the surface formations on the scale of the topographic sheets is to begin as soon as they are gotten ready with the descriptive text, which will be issued in the form of one or two volumes of the "Final Report" series. The base to be used is that of the topographic sheets. It has been delayed a long time, but the delay has enabled the Survey to give more care to the questions of form of publication and the technical details in representation of the various surface features. It will also afford time for further investigation of economic questions, so that with the scientific details there may be practical data given, bearing upon the soils and their origin, the beds of clays, sands and gravels whose materials are of value in the arts, and other materials of importance. The value of an accurate knowledge of the surface beds in their relation to these economic products, to water-supply, to forest reservations and to the complex problem of climate, and to the conditions of life generally, will justify the delay and will make the final report of value in the further development of the State.

The new series of maps which is proposed is in sheets of smaller size than that of the atlas of New Jersey, but having the same base. They will join and not overlap as do the latter.

The map accompanying the report is from the establishment of Julius Bien & Co., New York.

RED SANDSTONE—TRIASSIC—NEWARK SYSTEM OF ROCKS.

The survey of the Red Sandstone Formation, or Newark System of Rocks, as now known, which was begun in 1895, has been carried forward and the whole belt from the Delaware river to the New York line has been traversed. The report for this year covers the whole territory, although not of the character of a final report or monograph.

Dr. Henry B. Kümmel, who has been in charge of this division of the survey work, was in the field from June 25th to September 15th. The preparation of the report occupied a part of his time after the field season ended. The work of the season was mainly in the northern part of the belt, and in Union, Essex, Hudson, Bergen, Passaic and Morris counties. Compared with last year, the results have been comparatively meagre, on account of the extensive sheet of glacial drift, which covers and conceals the rocks, particularly in the valley of the Upper Passaic. The accurate differentiation of the horizons or subdivisions of the belt is not possible in this drift-covered part of the belt, as it is southwest of the terminal moraine. The division at the southwest, as made out last year, was a threefold one, and was shown on the map accompanying the report for that year. As traced to the northeast, changes have been discovered in the rocks of these subdivisions or series. The black argillites and flags of the Lockatong horizon disappear and the shales of the Brunswick series become sandstones and conglomerates. The three subdivisions so clearly marked on the Delaware river are not recognized in the northeastern part of the State. The Stockton horizon, however, is seen at the base of the Palisades range and at some points on its northwest slope. The characteristic arkose or coarse-grained feldspathic sandstone is recognized at many outcrops.

The survey of the year has shown the intrusive origin of some of the trap-rock sheets and the extrusive origin of others, so that the several ranges and outcrops of trap-rock can be classified accordingly as they have been formed by lava-flows cutting across the beds of shale and sandstone or have moved over and between them.

Many observations on the nature of the rocks at the contact of the trap and the sandstones and shales have been made and have been incorporated in this report. The alterations in the rocks in color, texture and hardness are in many places remarkable, and apparent to the casual observer. They have the aspect of well-burned clays or bricks in some cases; in others, they are dark-colored and hard, with a metallic ring when struck with a hammer. Some characteristic examples of alteration or metamorphism are to be seen along the base of the Palisades. They are also seen on the Sourland mountain on both sides of the trap-rock sheet. The contact phenomena in the Watchung mountains do not indicate such alteration, and the unaltered shales are found underlying the trap-rock and also overlying it. Mr. Kümmel has devoted a large part of the report to the contact phenomena and the observations connected with them, and to the origin and age of the trap-rock sheets.

Some interesting additional information on the dislocations of the beds or faulting of the strata is given, particularly in the Palisades range, and the large number of faults observed in the trap-rock is suggestive of the query as to the extent to which the shales and sandstones have been faulted, and the further question of the total thickness of the formation. The illustrations of sections at Arlington and in Garrett rock, at Paterson, are instructive and helpful to the general reader, though not determinative as to the extent to which the beds of the belt may have been faulted.

Some recently-bored wells on the trap-rock ridges have afforded measures of the trap sheets, and their records have been discussed by the author in generalizations on the the thickness of these sheets. They are somewhat thicker than they have been heretofore thought to be, and the evidence appears to be conclusive. The Palisades sheet is shown to be 364 to 950 feet thick; First, or Orange mountain trap sheet, 580 to 675 feet; Second mountain, 840 to 990 feet; the Long hill and Hook mountain sheets, 300 to 400 feet.

One of the most interesting chapters to the general reader is that on "The Conditions of Formation." The discovery of foot-tracks in the shales at the Hook mountain quarry, at Milford and also at Tumble Station, has arrested the attention of all students of geology in our country as well as that of the people generally, and has stimulated the inquiry as to the conditions at the time when these shales and sandstones were deposited. The fish remains and the thin seams of bituminous coal also have attracted attention to this subject. The famous so-called "bird tracks" of the Connecticut valley, which are found in the formations of the same geological age, have aroused a general interest in these rocks and in the question of their origin, far beyond our State. Prof. Henry D. Rogers discussed the origin of the red sandstone formation in his final report, in 1840.* He gives the source of the material as at the southeast. The late Professor Cook, State Geologist, in the "Geology of New Jersey," described in some detail the various features of the formations and referred the origin of the materials of the lower beds of the southeast border to the

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*Fin. Rep., Description of the Geology of New Jersey, Philadelphia, 1840, pp. 166-171.

crystalline schistose rocks known to occur on the southeast of the belt. The conglomerates on the northwest border were said to have been formed from the limestones, quartzites and crystalline rocks of the Highlands. He referred to the evidence of shallow water at the time when these deposits were made.* The sun-cracks, ripple-marks, raindrops and footprints, so common and on successive layers or beds, show that they were once mud or soft earth, capable of receiving such impressions—probably the exposed mud flats of a sound or estuary, or the broad strand of a more open body of water on which the tides ebbed and flowed. The estuary or sound must have had streams flowing into it, and they are indicated by the conglomerates and the amount of other material derived from the crystalline rocks of the adjacent formations. Shallow-water conditions appear to have prevailed throughout the whole of the time of this deposition, and a subsidence must have been in progress to make such conditions. The uplifting, folding and faulting are shown by the beds as they now appear and as they are known to have been in the later geological periods of time. The studies of Prof. William M. Davis, of Harvard University, are highly suggestive in relation to this history, and Mr. Kümmel has referred to them in this chapter on "The Conditions of Formation." The observations in the State, made by Prof. I. C. Russell, of Michigan University, and by N. H. Darton, of the United States Geological Survey, and Mr. F. L. Nason, formerly of the Geological Survey of the State, are referred to by several foot-notes giving the publications containing descriptions of these formations.

The importance of the economic resources is shown by the large number of quarries both of sandstone and of trap-rock. The Newark, Belleville and Little Falls stone on the eastern side of the State has long been famous for its excellence as building material. Other quarries of large size are at Paterson and Martinsville. The full list is given in the report. On the Delaware there are extensive quarries at Wilburtha and Stockton. The beds are practically inexhaustible and capable of great development.

The use of trap-rock and its excellence as road material are noteworthy here, because there are so many outcrops of the trap, and they are so situated that the material can be carried by rail or by water to all parts of the State and to the adjacent large cities. The location of the trap ridges and the lines of railway and of canal are shown on

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*Cited, pp 332-338.

the two local maps accompanying the report. The growth of the business of quarrying rock for road-building in the State is remarkable, but it does not appear to have reached its full development. The supply of excellent trap-rock is inexhaustible.

Copper-mining is referred to in a few sentences, as the industry is dead.

The report is commended to all who wish to learn of the geology of the belt of Red Sandstone or Newark System, because it describes in some degree of detail the outcrops and the phenomena characteristic and common in this belt. It is the local geology applicable to Union, Essex and Hudson and to nearly all of Somerset, Hunterdon and Bergen and to large parts of Mercer, Middlesex, Morris and Passaic counties.

ARCHÆAN GEOLOGY.

The work in the study of the crystalline schistose rocks of the Highlands is done by the United States Geological Survey, and is in charge of Dr. J. E. Wolff, of Harvard University. His report for the year is here presented.

Report on Archæan Geology.

BY J. E. WOLFF.

The work in this department during 1897 consisted principally in the preparation of the Franklin Furnace folio of the geological atlas of the United States and in the classification and study of the material and observations accumulated during several years of work in the field. The mining developments at Franklin Furnace have also been closely followed in connection with the folio, and the mines revisited in September. The stripping of the surface and subsequent sinking, to remove the entire mass of ore and rock between the east and west veins, at the Buckwheat mine, promise interesting exposures.

An examination was also made of the openings of the Federal Hill mica mine, near Bloomingdale, Passaic county, and a report made to the State Geologist.

An extended historical and descriptive paper, embodying our own observations on the age of the white limestones of Sussex county, was prepared with Alfred H. Brooks for the Eighteenth Annual Report of the Director of the United States Geological Survey.

CRETACEOUS FORMATIONS.

The Cretaceous and Tertiary formations of the State have been the subject of investigation by the Geological Survey, in co-operation with the United States Geological Survey, since 1891. Prof. William B. Clark, of Johns Hopkins University, has had entire charge of the survey, and, aided by several field assistants in the different years, has accumulated a large amount of valuable and interesting material. No financial help was given to the work during the last year, but Professor Clark has presented for publication in this annual report a summary of his studies and field observations in the Upper Cretaceous or Greensand marl formations, both in New Jersey and in the extension of the marls in Delaware and Maryland. His summary forms Part III. of this Report. The introduction gives an interesting account of the numerous publications descriptive of the formations and the fossil forms of life in them, showing a long series of papers from the visit of Peter Kalm, in 1749, to the present. It is a chapter of history suggestive of the great attention which these greensand marls and their rich remains of life-forms have drawn to them.

The several formations are described in their general character of materials, stratigraphic relations and fossils. The interpretation of the geological record shown by the nature of the materials is given and their probable marine condition of origin is stated as a result of the studies.

The correlation of the New Jersey beds with the formations in the eastern Gulf States shows some common occurrences of fossils throughout, indicative of a continental sea border in which these beds were laid down, and in comparatively deep and still waters where but little land sediment could reach the sea bottom or floor.

The economic products are referred to with a short historical note on the use of the greensand marls. A concise summary of all the leading generalizations is given at the end. The general reader or student will find in this report a remarkably condensed description of all that is known of our greensand marls.

The decreasing use of greensand marl in some parts of the State may appear to lessen the interest in these marl beds, but their remarkable extent in the State and their wealth of fossil forms of life must continue to attract all earnest inquirers and students of geology and many others who do not give special attention to the natural sciences. The report is a readable one to all these classes.

ARTESIAN AND OTHER BORED WELLS.

The records of deep-bored wells for the year are given in Part IV. of this year's report. Mr. Lewis Woolman has continued to collect all data relating to the depth, strata penetrated, water-bearing horizons and volume of water, and the report for 1897 is an important addition to the large mass of valuable material already in hand and published since 1889 in the successive annual reports of the Geological Survey. The importance of getting accurate details of the strata and the depth of the water horizons is recognized by the business firms engaged in boring wells and by all who are seeking for additional supplies of water. The Survey appreciates the courtesy and labors of these firms who so kindly give information about wells put down by them, and the data thus obtained is published as promptly as possible, that it may be helpful in stimulating the extension of the artesian-well system and in developing the resources of the State.

Among the important contributions for the year may be mentioned the well records from Matthews Brothers, of Red Bank. The wells reported on Rumson Neck and along the Navesink river and at Seabright all appear to have struck thick sand beds in the Matawan or Clay-marls division of the Cretaceous formation. The deep well at Brookdale farm, west of Red Bank and near Leedsville, also is remarkable for the great thickness of the Clay marls or Matawan member of the greensand marls.

The well on Mount Laurel also is noteworthy, in the discovery of a fossil bed at 150 to 160 feet, containing many shells like those found in the Reeve clay bank at Lenola. The species have been determined by Mr. C. W. Johnson, of the Wagner Institute, Philadelphia.

Another remarkable discovery in boring wells is that at Daretown, where the order of succession in the beds indicates the presence of the several members of the "Upper Marl Bed" of the Survey reports or the Manasquan and Shark river formations of Professor Clark. The locality is about twenty miles southwest of Clementon, where the most southwestern outcrops occur. The discovery is important, both as showing the extension of the bed to the southwest and the value of careful well records, with specimens of the materials from the beds passed through in boring.

The same well also confirms the survey of outcrops, in the absence of the Red sand bed (Red Bank bed of Professor Clark).

The extension of the system to the supply of a city, as Camden water-supply, by means of ninety-eight wells, is also worthy of note. The result of putting so many wells within a comparatively limited area is anticipated with interest, as it is suggestive of application to other localities where the conditions are favorable. The wells at Union, in the glacial drift formation, for the Elizabeth city water-supply, is another example of numerous wells in close proximity to one another. Continuous pumping from so many in small areas must tend to some interference, unless the subterranean supply be extraordinarily large, draining from a large outside territory, or the volume pumped be not greatly in excess of the volume of ground water of the area affected by the wells. The total rainfall upon any given area and the percentage of that precipitation which goes down into the sub-surface formations are easily computed, and there is no other source unless there is a draught from the adjacent formations or the strata of the country adjacent thereto. That wells do drain the subterranean waters from distant areas is well known from observations of artesian wells in this State as well as in other States and countries. How far they may affect the water-supply of adjacent districts is not easy to determine nor the extent of this effect. The deep-bored well will, in its rapid extension and multiplication, meet with the objection of robbing the waters which belong to others, and the question of rights of ownership will have to be met. The diversion of underground waters may become as important as that of surface waters. Thus far in New Jersey the large supply of deep-lying waters and the comparatively long distances between wells has made it unnecessary to refer to the subject. The number of water horizons in any given district or area is as yet unknown, or, rather, is limited to the depth of the wells. Until the limit of boring is reached the number cannot be known. It is possible, therefore, to draw from one or more horizons, as is done at Atlantic City. In this way the capacity of the artesian well system may be enlarged and made to serve the needs of localities for many years. As has been said in previous reports, there can be almost as many wells as there are localities, but there may be a limit in any one locality or area.

TOPOGRAPHIC WORK.

Mr. C. C. Vermeule, consulting engineer, has had charge of the topographic surveys and has been assisted by P. D. Staats in the field. A detailed survey of a small area at Hamburgh, Sussex county, was made in the early part of the season. This survey of a remarkable group of drift hills is to be used by Professor Salisbury in a report on the Surface Formations of the State.

The necessity for a revision of the topographic maps of the Survey, particularly in the more densely populated parts of the State, where many new streets are being opened and new avenues and roads are being laid out, as well as new lines of steam and electric railways, has been referred to in the annual reports in order to maintain the usefulness and value of these maps. The publication of the topographic maps dates as far back as 1887 in the case of several sheets, and the revision made for new editions has been confined to railway lines only. Re-surveys are, therefore, essential to new editions of maps of value, and the increasing use of topographic maps demands that the new editions shall include the data furnished by new surveys. The publication of maps on a larger scale has been considered as desirable wherever the density of population makes good maps helpful in laying out streets, roads, railway lines, aqueducts, sewers and other public improvements. In order to a fair experiment to ascertain the cost of making a survey in detail of a small area and the value of a map based on a survey of this kind, work was begun late in the autumn, in the vicinity of Newark and Belleville, and was continued up to the end of the season. The streets and roads were measured as also the fence and hedge-lines, and all the larger structures. Although not a cadastral survey, it embraces all the more important features of the surface and the contour lines within five-feet limit. Maps based on surveys made in such detail become valuable records of the culture of a district and are of historical value. Our appreciation of them may be greater if we refer to the old maps of New York City and their importance as historical records. The cost of making surveys with this detail is large and the rate of progress slow. The necessity for them is limited to the suburban districts around the cities, and the extension to the rural parts of the State is not wanted. The data accumulated in this field work will be useful in the revision of sheet No. 7 of the topographic maps. The large cost may make it desirable to change the plan and omit some of the details, in order to carry forward the work and prepare the maps needed in our city and suburban districts. A new series of maps of this kind would supplement the present topographic sheets.

DRAINAGE.

The Geological Survey is authorized by law to make surveys and plans for the drainage of tracts "subject to overflow from freshets, or which are in a low, marshy, boggy or wet condition," whenever application is received from at least five owners of separate lots of land in any tract which it is proposed to have drained. Under the general drainage laws, as amended by supplementary acts, these provisions of the law are applicable to tide-marshes also.

The Passaic drainage work has been referred to in the annual reports of the Geological Survey, and some of the advantages have been mentioned in these general statements. It is not necessary to repeat them nor to urge the importance of completing the proposed drainage improvements as soon as possible. Malarial influences have been as bad as ever before experienced, and the floods in the valley have destroyed a large amount of property. The aggregate loss of 1897 to the farmers of the valley, caused by these floods over the growing crops has been said to be nearly equal to the estimated cost of finishing the drainage works. From the geological standpoint the restoration of the old Lake Passaic in part would be better than this irregular alternation of a shallow-pond water condition and a wet meadow land giving off foul odors and malarial exhalations. The present ill-drained valley is not evidence of the best environment for healthful home sites and is a menace to the adjacent country. The agricultural development of the valley demands the improvement.

Mr. George W. Howell, one of the commissioners of drainage, has prepared a short history of the work and a statement of what remains to be done. He gives the reasons for the suspension continued through the year. His report is appended to this administrative part of the report.

RECLAMATION OF THE HACKENSACK AND NEWARK MEADOWS.

Mr. Vermeule has prepared a supplemental report on the reclamation of the tidal marshes and wet meadows of the Hackensack River valley and those bordering the Kill von Kull, between Newark and Elizabeth. In the last annual report of the Geological Survey the subject was discussed in detail in the description of the geographical and hydrographic relations. The several natural divisions were described and a map on a scale of two inches to a mile, showing the water-ways and rivers and the depth of water in them, and also the nature and depth of the mud and peaty earth throughout the belt of marsh land, accompanied the report. The map is not reprinted, as copies of the last annual report are still in stock and are supplied on demand. The readers of this second report of Mr. Vermeule are referred to that map for illustration of its descriptions.

The reclamation of these marshes and the removal of conditions which threaten to become unsanitary and possibly dangerous to the healthfulness of this part of the State, lead to a repetition of the statements on the practicability and importance of their drainage. Looking at this map, it is possible to conceive of a bay occupying the place of these tidal marshes, and bordered by the bold shores of the northern and eastern sides, and these shores covered by cities and towns and suburban hamlets, and the whole rivaling in beauty and commercial accessibilty the Greater New York, across the Hudson river. The conception may be regarded as fanciful, and yet it is scarcely more striking a picture than is warranted by the changes which would appear were this tract diked, drained and improved. With Bayonne, Jersey City and Hoboken on the east; Hackensack on the north and Englewood not far away; on the west, Newark, Harrison, Kearny and Arlington, and Passaic not a mile distant, and Elizabeth at the southwest; there is almost a continuous city about this tract.

The remarkable water-way of the Hackensack river, with its great depth of water from near its mouth to Little Ferry and prolonged northeast in the Overpeck creek, is suggestive of a magnificent, deep canalized river, such as parts of the Waal and of the Rhine in Holland. With a deepened way through the Newark bay the navigable water-ways of the Hackensack and the Passaic would go far toward the realization of our New Jersey city not on a bay but on highways for ocean-sailing vessels. The careful study of the map shows also the course of the Hackensack midway the tract and the tributaries so necessary for the natural drainage of each side.

The great cities of the world are in large part on level, marshy land. Chicago, Berlin and London, in part, have covered many square miles of flat ground, needing careful attention to drainage and sewerage. All the large cities of Holland are on piles driven in the wet lands below high-water level. The meadows are not therefore an insuperable objection to city advance over them. The famous Back Bay district of Boston is a wet border of the Charles river improved. It may be said that there is ample room on the adjacent hills, but they are further from railway and tide-water lines, and the elevation requires so much more power to carry materials to and from them. For extensive manufacturing sites these more accessible level tracts will be preferred and will come into use. The ultimate development will probably be a city covering a large part of this tract, assuming the continued and steady growth of this part of the State and country. It is, however, not probable that this stage of growth can be expected in a long time, but the future possibilities should be considered in any discussion of plans for improvement. It would be short-sighted to overlook them and simply drain these wet lands for market-gardening or for pasture lands, although so well adapted for these uses when properly improved. The cost of their improvement, as stated by Mr. Vermeule, would amount to $2,500,000, and the annual charges would be $7.75 per acre, making a first cost of $100 per acre in round numbers. No doubt the interior drains and the necessary ditches for any use in agriculture would add $50 per acre to the cost, making a total of $150 an acre, and an annual tax of $7.75 would be equivalent to $150 additional. Large as this sum appears, it is not greater than the value of some of the lands of Hudson county not naturally so fertile, which are devoted to market-gardening. Some of the famous wet lands on the New York and Erie railroad line near Goshen, in Orange county, New York, yield an annual rental equal to this valuation.

The neglect, as it were, to drain and improve these meadows might appear invidious in a comparison with what has been done in the Netherlands in reclaiming waste lands, or even in the Nieman delta of East Prussia, Germany, where 44,500 acres have recently been protected by great dikes at a cost of $510,000, were it not known that capital here has so many other attractive outlets that drainage schemes are overlooked. The difficulty has been that the meadows have been looked upon as agricultural in great part, and the more important and ultimate use as a city site has not been considered as within the limit of practical possibility. It is to this more valuable use that attention is again urged to their reclamation.

More important than agricultural or even urban considerations are the sanitary advantages which must issue from the diking and proper drainage of the meadows and the adjacent, bordering upland. The growth of these cities and towns requires some systematic treatment of both the natural drainage and the sewerage from this upland to and through the water-ways of the meadows, either to the Passaic and Hackensack rivers or the more distant sound or bay. Without some system of draining the land and caring for the sewage, these meadows must become the receptacle of the polluted waters from these borders and the conditions unsanitary, with slow-moving, stagnant water-ways, loaded with the refuse of manufacturing establishments and the more dangerous sewage from the border as well as that of the population on them. Conditions so disagreeable and dangerous will require ultimate treatment, and the betterment may be only at great cost and with difficulty, if not to some degree impossible in the end. Therefore, as a protective measure to the health and comfort of the residents of the cities and towns adjacent, the reclamation needs to be directed according to some comprehensive plan which shall include the several subdivisions as parts more or less closely related, and shall embrace a systematic drainage scheme for all the waters flowing naturally to the meadows and the rainfall on them, and channels for the proper transportation of all the sewage which may have to be disposed of through such outlets to the bay or sound.

The improvements of the water-ways in their entirety is not essential to the removal of the dangers arising from sewage-choked streams, pools of polluted water and pestilential dumps on the borders. The diking of the tidal water-ways and the digging of border lines of drains and their proper laterals and the construction of pumping-works to drain off the surface waters and maintain a proper flow of the waters in these canals and water-ways will put away the dangers of this kind and leave the surface in a condition to be improved either for agricultural uses or for building sites.

The necessity of a comprehensive plan of drainage and of control in the management is mentioned by Mr. Vermeule, and is enforced by the references to the costly and disastrous schemes in the Sacramento Valley of California, where individual and associated enterprise has attempted the reclamation of parts instead of a whole district of marsh land. Millions of dollars have been spent and the abandonment of diked meadows has discouraged and retarded the reclamation generally. The lack of any well-matured plan, and the improvement of separate tracts regardless of the natural relations of adjacent tracts and water-ways, must lead to waste of capital and contention, owing to the different conditions and the various objects in view when the direction and management are in the hands of separate companies.

The existing drainage laws of the State would be adequate for the diking and partial improvement, but the large cost of pumping works, and of the discharge of the water from the diked districts, and the necessity for a permanent management, appear to make some amendments to these laws necessary to carry out the work. The distribution of the cost over a larger territory and permanent control are imperative. Whatever plans may be adopted, and whatever changes in legislation may be made, the importance of reclaiming the whole of the Hackensack tidal-lands belt and the improvement of the navigable water-ways should be kept prominent in making them. Mr. Vermeule has suggested a State commission to direct and maintain the reclamation work. The same objects can scarcely be accomplished by any private associated effort, even if aided by legislation, particularly in the future control of the improvements. A great deal, however, might be done in the improvement of the lands and in the utilization of the more valuable sites for building purposes and the various business enterprises which might use them. The larger and more comprehensive objects would probably be neglected, particularly those bearing upon the sanitary conditions of the district. The function of the State is to direct in conditions of this nature where municipal and associated capital cannot control without interference and consequent inactivity. The Geological Survey has given the information illustrated by a map, and has suggested the importance and necessity of State direction. The attention of capitalists has been directed again to the subject, but with the necessary limitation of public direction and management in the interests of all the northeastern part of the State.

FOREST SURVEYS.

The surveys and studies of the forests in the southern part of the State have been in the charge of Mr. Gifford Pinchot, consulting botanist to the Survey. He has had two assistants for a part of the season. His investigations have been in the rate of growth of the more common trees of the forests in various parts of the "pines" belt and on different soils in that belt. The capabilities of the several kinds of soil in the production of wood have been ascertained from the rate of growth and also from actual measurements and statistics of wood cut on given areas. The comparative yield of tracts protected from the ravages of fires and of lands where fires have swept over the country makes a most suggestive mass of statistics and an argument for protection of a practical nature. So much of an extremely general character has been written on forest fires and protection against them that these figures of Mr. Pinchot are refreshing as well as forceful in suggestion. They show that the so-called "pines" belt is able to produce a yearly income of considerable amount and emphasize the importance of protection from an economical standpoint.

Mr. Pinchot has elaborated a protective scheme under State direction which aims at the solution of the problem by fighting fires at the outset and stopping them at once. Some system of the kind appears to be necessary to meet the requirements of vigilant watchfulness and care in arresting fires before they have gotten a headway, and in bringing to punishment the offenders who, through carelessness or possibly malice, start them. The guaranty of adequate protection is demanded in order to encourage any individual enterprise in caring for woodland and in making wood a crop. This protection is a matter of public care, either local by the township or county or by the State. The details of such regulations are, properly, subjects of legislative consideration and enactment in making laws to meet the requirements of the conditions.

The report on forestry is in course of preparation and is to be given to the Legislature next year. The want of scientific data on the distribution of trees in the State and the relation to the geological formations led to the further engagement of Prof. Arthur Hollick, of Columbia University, to continue studies of the distribution of the tree species and to trace the history of migrations and discover the causes which have been active in restricting their limits, as well as the effects of changes in the land and sea within the later geological epochs. The disappearance of some species from certain districts and the strange outlines of territory marked by the occurrence of others are a part of the studies which have been undertaken by him. The geological divisions of the State, in particular the more recent formations, have been carefully mapped, enabling the Survey to make this study of the range of species in relation to the geology eminently practicable.

Professor Hollick's report is here inserted :

Report of Progress on the Relation Between Geology and Forestry.

BY ARTHUR HOLLICK.

During the past season the investigation begun last year was continued along the general lines indicated in my previous report, besides which several points of special interest received attention.

Several writers have at different times incidentally noted and commented upon the fact that certain species, constituting more or less well-defined floral aggregates, occupied certain areas or belts, quite sharply coterminous with certain geological formations, but special investigations with this fact in view have been rare. The scope of my inquiry, especially as relating to the State of New Jersey, may therefore be considered as covering a new field of observation.

With this end in view my investigations were conducted on the theory that the most important and striking changes in the character of the vegetation in New Jersey, independent of climatic conditions, ought to be found in crossing over the outcrops of the different geological formations, or, in other words, in traveling along lines at right angles to the lines of strike of such outcrops.

In this respect the State of New Jersey is particularly well fitted, as it represents, in a comparatively limited area, a number off different geological formations whose outcrops extend in a series of narrow belts across the State in a general northeast and southwest direction, besides which a large portion of the northern part is covered to a greater or less extent with a mantle of glacial drift.

It is also fortunate, for the purposes of this investigation, that the outcrops do not follow the lines of latitude, as it might then be contended that the distance north or south of such lines, in other words the climatic conditions and not the geologic conditions, were the cause of limitation of certain species.

The more the matter was studied, however, the more evident the fact became that certain species in their geographic limits followed lines which were closely coincident with the lines of strike of the geologic formations and were independent of the lines of latitude, and this fact was still further emphasized if the lines of limitation were extended beyond the State.

The general method of field-work pursued was therefore to start from some locality where the geologic formation was well represented and thence to travel in a direction which would cross the outcrop of each succeeding formation, noting the appearance or disappearance of any species on the way.

The following sections were thus completed, mostly on foot, but occasionally by horse and wagon:

1. Lakewood to Eatontown, via Farmingdale, passing from Tertiary gravel to marl.
2. Farmingdale to South Amboy, via Red Bank and Matawan, passing from Tertiary gravel and marl across Cretaceous marl and clay marl to clay.
3. South Amboy to Metuchen, via Perth Amboy, passing from Cretaceous clay to Triassic shale, and thence to the terminal moraine.
4. Sand Hills (Monmouth Junction) to Farmingdale, via Jamesburg and Freehold, passing from Triassic trap or shale, across Cretaceous clay, clay marl and marl, to Tertiary marl and gravel.
5. Easton to Belvidere, passing from Archæan and Silurian rocks to the terminal moraine and extra-morainic drift.

In addition to the above, the following localities of special interest were also visited:

1. Morristown—Triassic shale, sandstone and trap, Archæan rocks and terminal moraine, all in a limited area.
2. Trenton—Glacial river gravels.
3. Wildwood, Anglesea and Holly Beach—Recent sea beach and sand dunes.
4. Bridgeton—Tertiary sandstone (Miocene?) containing fossil leaves.

5. Asbury Park—Buried swamps exposed by the action of the waves on the beach.
6. Newark meadows—Living bald cypress.
7. Cape May—Occurrence of *Pinus Tæda.*

It was soon ascertained that the most significant facts were to be found in connection with the more recent formations, and that the changes noted on the older formations in the northern part of the State were comparatively few and unimportant. The mechanical character of the soil seemed to be the most important factor in limiting the distribution of certain species, although other species seem to exist and flourish under the most diverse of conditions, and to be independent of soil, climatic and physiographic conditions.

Critical observations were therefore limited to a few well-defined species which were clearly susceptible to the influence of their environment. Details in regard to such species will be given in my final report.

These investigations, while conducted primarily on account of their scientific interest, will almost certainly result in conclusions of economic importance when the true significance of the facts is fully understood, showing as they will, the areas over which certain species attain their greatest natural growth and the probable reasons for it.

Finally, if the study of the fossil floras seems to warrant it, an attempt will be made to trace the origin of the living flora from these, and to infer from them the changes which have occurred, and are now occurring, which have served to modify and alter the floral elements from early times up to the present.

THE IRON-MINING INDUSTRY.

Mr. George E. Jenkins, of Dover, has continued his work of collecting notes on the iron mines which have been at work during the year, and his report is given in Part VI. of this Annual Report of the Survey. The notes in last year's report were published with a view to their usefulness in answer to inquiry for iron ores, but the history of mining in the State, for 1897, shows that no such inquiry has developed into any extension of the iron-mining industry, and that there has been no extraordinary demand for ores. The mines which were at work in 1896 have been actively worked and the output has been nearly the same as it was in that year. The continuance of these mines as steady ore-producing points is evidence of their advantages in nearness to the great markets of the coast and to the anthracite coal region, as well as in the extent and accessibility of their ore bodies and the richness of their ores. The increasing cost of mining in some of the great iron-ore producing districts of the country which now compete with the mines of the coastal belt, and the ever-increasing consumption of iron, must tend to make conditions not less favorable than at present, and enable the mines of New Jersey to continue as ore producers. If it were possible for the ore-concentrating plants to become producers on a large scale, the great deposits of lean ores in this Highlands iron-ore district would help largely in making the total production of the State again what it was a decade ago. Indirectly, by the utilization of side products and through adventitious conditions, they may yet become important factors in the iron-mining industry. It is to be hoped that the energy and capital put in them may yet result in successful issue.

The total output of the iron mines, according to the reports received through the collection of notes by Mr. Jenkins, amounted, in 1897, to 257,235 gross tons of iron ore.

CLAYS AND CLAY-USING INDUSTRIES.

The rapid development of some branches of manufacture using clays and clayey materials and the large increase in the common brick or red brick business suggested the importance of collecting such data as would indicate this development and growth, and in pursuance of this object, Mr. George E. Jenkins was engaged to visit the several brick and tile and terra-cotta works and collect notes on the deposits worked, the extent of works, the number of men employed and the amount and value of the output. In the traverse of the State, Mr. Jenkins obtained much important information. His notes appear in Part VI. of this Report. The list of brickyards and other works using clay is as nearly complete for the counties traversed as was possible to make it. Important help was had from "A List of Producers of Brick, Pottery and Other Clay Products in New Jersey," furnished the Survey by the editor of "The Mineral Industry," New York. The statistics collected show an extension of these industries in the southern part of the State and to some extent in the northern part.

The Middlesex county clay district was visited by Prof. William S. Myers, of Rutgers College, as also the adjacent parts of Monmouth and Union counties. The list of Professor Myers is given without notes. The statistical part is incorporated in the Summary under the head of Mineral Statistics. From the reports by districts it is evident that the Middlesex county or the Raritan river and Woodbridge clay district is not producing as much fire-clay and clays for ware and paper as it did fifteen and twenty years ago, although the decrease in production has not been at all important or suggestive of a decline in the business generally.

The most notable change is in the utilization of the non-refractory clays in the manufacture of vitrified brick, pressed brick and terra-cotta, and tiles for decorative use as well as roofing-tiles and other wares of clay.

The large increase in the production of the brickyards is also notable, and the output of nearly 300,000,000 of common brick shows the importance to the State of this industry. The superior quality of the brick which are made for front construction and for interior use and for ornamental decoration also deserves particular reference in this general notice. The use of shale at the Pittsburgh terra-cotta works, at Washington, Warren county, is one of the important departures from the use of clay in the terra-cotta and structural brick manufacture in the State.

In the southern part of the State the large works at Winslow constitute an important feature in this development. The works at Clayville, near Vineland, and at Mays Landing also may be mentioned.

That there are other large deposits of clay in the southern part of the State, yet undeveloped, is well known. The clays of the Miocene formation referred to in previous reports, extending from the ocean southwest to Delaware bay, crop out at many points and some of them are near tide-water and railway lines.

These lists of brickyards and other clay-using works and these notes of Mr. Jenkins are given as preliminary to a survey of the clay beds and deposits and a report on them and their use in the arts and industries of the country. It is hoped that they may elicit such criticism and suggestion as may tend to help the work of making an exhaustive report within the next two years.

CHEMICAL WORK.

The chemical work of the Survey has been done by Prof. William S. Myers, at Rutgers College. He has examined several fine sands with reference to their value as filtration material for city water; made assays of pyrites from near Boonton; partial analyses of earth, supposed to be umber; nickeliferous earths from West Portal; rocks from mica mine near Pompton, and quartz from Trenton.

As the Survey has no laboratory, no complete chemical analyses are made, but such partial determinations only, as may indicate the value of natural products for uses in the arts.

GEOLOGICAL ROOMS.

The Geological Collections of the Survey remain in the third-story room of the rear extension building of the State House. The minerals which were at the World's Columbian Exposition are to be arranged in table cases in this room, and Mr. W. F. Ferrier, formerly on the staff of the Geological Survey, now Mineralogist to the Geological Survey of Canada, has been engaged to arrange the mineralogical collections and to secure additional specimens to fill gaps in the representation of minerals from the State. His experience in museum technique, and his acquaintance with localities of occurrence in New Jersey, and his thorough knowledge of the subject, make the engagement one promising the best results. The scanty collections and the inferior character of many of the specimens belonging to the State, as compared with the many beautiful New Jersey minerals in private and in other public collections, suggest the enlargement of the Survey collections and a better representation of the mineral localities of the State.

PUBLICATIONS.

The publication of the year was the Annual Report for 1896.

Of the Final Report Series, Volume IV. is in press and nearly all printed. This report on the physical geography of the State is the work of Professor R. D. Salisbury, and is adapted to the use of the students in the high schools and academies and colleges of the State.

The relief map which is to accompany it is printed, and a few copies are distributed in advance of the text. The map is designed to fill a place in every school-house in the State. It is a graphic picture of the relief of the surface, and shows the shape of the country, with its hills, mountains, table-lands, valleys and plains, and the courses of the streams draining these forms of the land surface. The distribution of the map among the public schools of the State is desired in order to its largest usefulness to the people. The appendix consists of valuable tables of elevation, geographical position, areas and magnetic declination, reprinted from Volume I. of this series of reports, revised and prepared for publication by Mr. Vermeule. The edition of Volume I. is exhausted, so that the new volume will fill the place of that one and save the cost of reprinting.

The demand for the publications of the Survey continues to be as active as ever, and some of the editions of earlier reports are nearing exhaustion.

The sales of the topographic maps amounted to $400 for the year. The maps are sold at twenty-five cents a sheet.

STAFF OF THE SURVEY.

PROF. ROLLIN D. SALISBURY is in charge of the survey of the Surface Formations. He is assisted by G. N. KNAPP.

HENRY BARNARD KÜMMEL, of Lewis Institute, Chicago, has continued the surveys of the Red Sandstone or the rocks of the Newark System.

CORNELIUS C. VERMEULE, Consulting Engineer and Topographer, has directed the topographic work and made the report on Hackensack meadows. PETER D. STAATS is assistant.

In co-operation with the United States Geological Survey, DR. J. E. WOLFF has continued the studies on the crystalline rocks of the Highlands.

IRVING STRONG UPSON, at New Brunswick, has charge of the sales of the maps and is the disbursing officer of the Survey.

HATFIELD SMITH is general assistant in the office and geological rooms, Trenton.

PASSAIC RIVER DRAINAGE.

BY GEORGE W. HOWELL.

An act to provide for the drainage of lands was passed by the New Jersey Legislature and approved March 8th, 1871. The act provides that the Board of Managers of the Geological Survey, on application of owners of lands subject to overflow, may examine such lands and cause surveys to be made, and shall devise a plan or system of drainage for the same, and report such surveys and plans to the Supreme Court of the State. The court, after due notice and hearing, shall then appoint three Commissioners whose duty it shall be to carry out such system of drainage as devised by the Board of Managers and approved by the court.

After the completion of the work the Commissioners are to assess the cost of the same upon the lands and proceed to make collections.

In case lands are taken for the improvement, or water-power damaged or destroyed, the Commissioners are to appraise such damages and add the same to the cost of the work to be assessed on the lands embraced in the scheme.

To enable the Commissioners to carry on the work they are authorized to borrow money on bonds issued by them and to pledge for the repayment of such bonds the assessments before mentioned.

A supplement, passed in 1877, permitted the Board of Managers to alter or amend the system of drainage.

The Board of Managers adopted a system of drainage devised by the late Dr. Geo. H. Cook, State Geologist, and reported the same to the Supreme Court. The plan was approved and three Commissioners were appointed in 1873. The Commissioners had about closed negotiations with a certain party who promised to take bonds at par and advance the money to do the whole work and pay all damages, but the great financial depression of that year suspended all operations.

The scheme was revived in 1886. One Commissioner had died in the interval and another had resigned on account of age and infirmity. To fill these vacancies two new Commissioners were appointed in March, 1886.

The new board organized on May 14th by appointing Caleb M. Harrison, of Essex county, President; George W. Howell, of Morris, Secretary, and Jacob H. Blauvelt, of Passaic, Treasurer. During the summer and fall of 1886 the Commissioners held many sittings to hear testimony in relation to the amount of damages sustained by the Beattie Manufacturing Company, at Little Falls by the proposed lowering of the dam of the said company seven feet, as contemplated by the scheme adopted.

In December the Commissioners made appraisement of such damages in the sum of $55,000. From this award appeal was taken and numerous sittings were held in hearing the appeal.

Pending the trial of the appeal a modified plan was proposed and discussed, and under the advice of the State Geologist and with the approval of William E. Worthen, Consulting Engineer of the Commission, was finally agreed to by the parties in interest. The new plan was adopted by the Board of Managers and approved by the Supreme Court.

The principal departure from the original plan affects the work at Little Falls only. The first plan involved the payment of damages to the Beattie Company and the reduction of the dam at the expense of the Commissioners. By the modified plan no damages were to be paid, the dam was to be reduced in height twenty inches and a gateway equivalent in capacity to a rectangular orifice twenty-five feet wide and sixteen feet deep was to be constructed in the dam, to be operated in times of freshet, and all at the expense of the mill-owners. The Commissioners, however, were to provide a free flow below the dam to make the gates effective.

Both plans contemplated the removal of two rock-reefs at Little Falls, above the dam, a bar of earth and boulders at Two Bridges and a cut-off channel at Pine Brook.

The Commissioners then proceeded to issue bonds and place them on the market. Bids were solicited for the work, to be paid for part in cash and part in bonds. Seven bids were received and the work was let to Alfred B. Nelson, of New Brunswick, at fifty-five per cent. cash and forty-five per cent. in bonds. Mr. Nelson began the work in the summer of 1889.

Soon after the work began the Commissioners, as well as the entire State, sustained the great loss occasioned by the death of Dr. Cook, the State Geologist, whose brain had conceived and whose guiding hand had thus far directed this among many other schemes for the public benefit.

In February, 1890, Mr. Nelson surrendered his contract and was relieved from the further prosecution of the work. For several months the work was carried on by the Commissioners, until in September, 1890, a contract was made with the Morris & Cumings Dredging Company, of New York City, for the removal of the rock below the dam at Little Falls. They commenced work in October, 1890, and prosecuted it continuously till April, 1892, when their contract was completed.

Further legislation was considered desirable. A bill was introduced in the Legislature during the session of 1893, but it was crowded out by the press of other business. It was passed, however, at the next session, and in the summer of 1894 bids were solicited and received for completing the work. These bids were, in the judgment of the Commissioners, too high to warrant their favorable consideration and they were consequently rejected. Since that time nothing has been done further than arranging the terms of the final settlement with the Morris & Cumings Dredging Company.

The territory embraced in the scheme of drainage extends along the Passaic river and its tributaries for over twenty miles above Little Falls and comprises over thirteen thousand acres. These lands are situated in the townships of Millburn, Livingston and Caldwell, in Essex county; in Chatham, Hanover, Montville and Pequannock, in Morris county; and in Wayne and Little Falls, in Passaic county.

The work already done has cost as follows:

By Alfred B. Nelson	$4,304 59
By the Commissioners	2,882 12
By the Morris & Cumings Dredging Co	94,689 00
Total	$101,875 71

The work remaining to be done consists of about 3,000 yards of rock at Little Falls, blasted, but not removed from the bed of the river; 6,000 yards of rock not yet disturbed; 30,000 yards of earth and boulders at Two Bridges, and 50,000 yards of muck and clay at Pine Brook. This will cost probably $50,000.

The Commissioners have from the first met with difficulty in placing their bonds, first from the nature of the bonds themselves, being guaranteed only by the lands affected, and second, through the inimical influence of opponents to the scheme. Certain large expected sales failed of accomplishment, it is believed, from this latter cause. Third, owing to the stringency in the financial world, bonds of this character could not be active when high-grade securities moved but slowly.

Certain parties interested in the meadow lands have attempted to revive the old plan of changing the course of the river from Pine Brook to the Deepavaal, and have advocated the abandonment of the scheme adopted. At the very beginning this plan was most carefully considered by the Geological Survey and discarded by them. Later examinations and calculations have only tended to confirm the wisdom of their decision.

The unavoidable delays in the prosecution of the scheme are greatly to be deplored, and it is the earnest wish of the Commissioners that they may be able to complete the work, now more than two-thirds finished, during the coming season.

It is a matter of congratulation that a revival of interest in the scheme is manifested by the appointment of a committee of the land-owners, whose purpose it is to aid the Commissioners in the placing of bonds and in any other way possible for the successful carrying out of a plan, which, when finished, will undoubtedly reclaim thousands of acres of valuable land, and moreover will exert a salutary influence on the sanitary condition of the territory in question and also on the surrounding regions.

PART I.

SURFACE GEOLOGY.

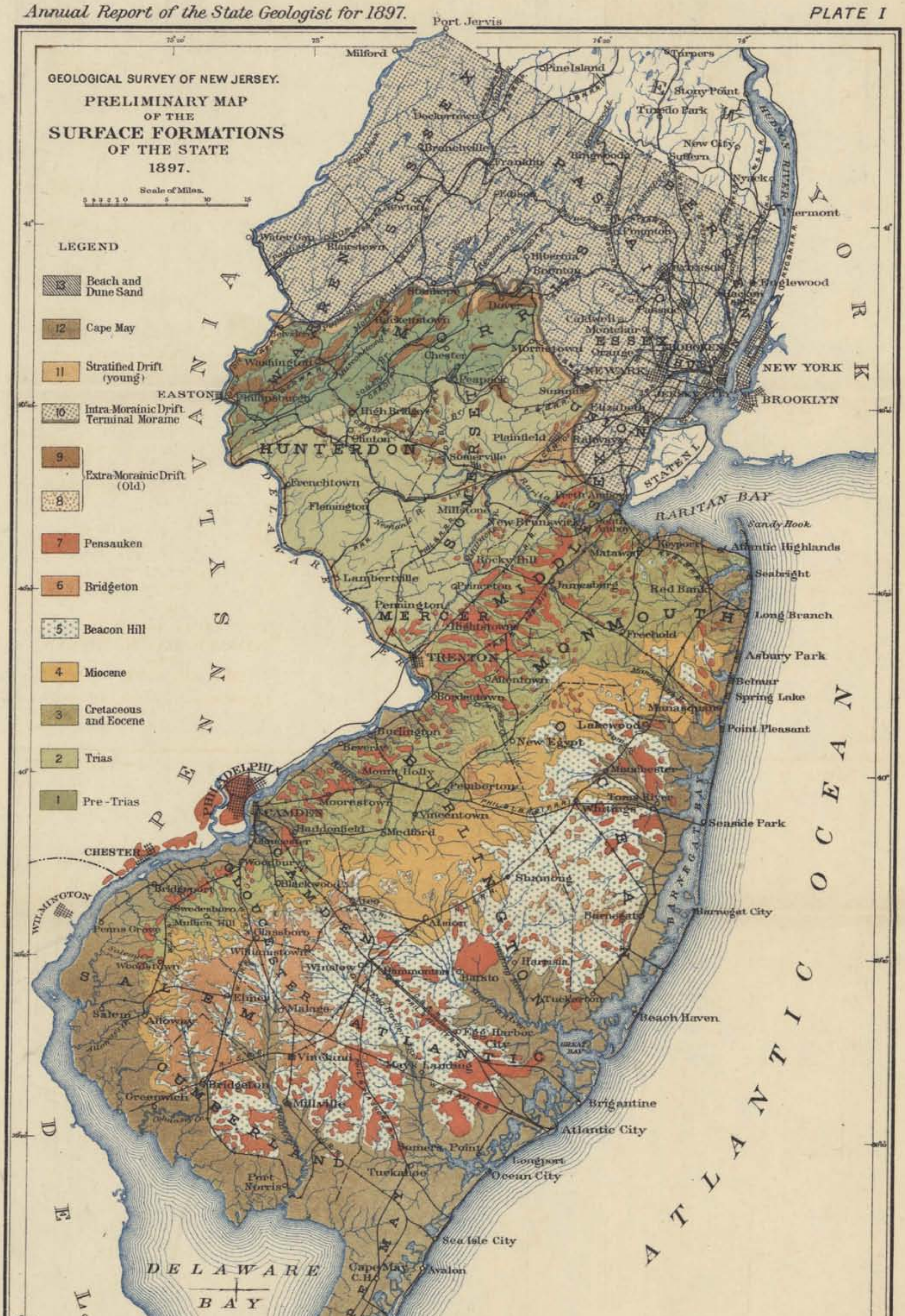
Report of Progress, 1897,

BY

ROLLIN D. SALISBURY.

Annual Report of the State Geologist for 1897.

PLATE I



MAP OF THE SURFACE FORMATIONS.

The work of preparing a geological map of the surface formations of New Jersey was undertaken by the Survey some years since. Reports showing the progress of this work have been made from year to year since 1891, and published in the annual reports of the State Geologist. With the field season of 1897, the field work necessary for the preparation of such a map was essentially completed. The whole area of the State has been studied with this end in view, and a very large body of facts gathered. The work has not been prosecuted with equal detail in all parts of the State. In tracts which are thickly settled, that is, where the land is cleared and utilized, there are frequent exposures resulting from the excavations incident to culture. In such regions the study of the surface is more easily prosecuted, both because of the exposures, and because the absence of forests allows the surface to be more easily seen. At the same time the value of the land in these tracts is such as to warrant careful work, and here it has been carried on in relatively great detail. In forested regions, on the other hand, where the population is sparse and excavations few, the returns for the time spent in investigation are so meagre, that, considering the relatively slight value of the land, and the slight use that would be made of the data gathered, it has not been thought wise to prosecute the work in the same detail. Even here, however, the surface has been studied with sufficient care to gather essentially all the data now available concerning the surface formations. The only way in which more elaborate results could be obtained would be by making an elaborate series of excavations, and the results would hardly warrant the undertaking.

In the prosecution of the study of the surface formations of the State, some of the problems concerning the origin and relations of the surface formations have been defined and settled in a satisfactory manner. For the solution of other problems connected with the same formations, the available data have been found to be far less satisfactory, and all conclusions based upon them must be looked upon as open to question. While they may be as mature as the present data warrant, it is possible that fuller investigations in the future may reveal facts and relations which are as yet undiscovered. In the pine districts of the southern part of the State, for example, extensive excavations might throw much additional light on the problems which are there presented. While therefore some of the problems connected with the surface geology of the State have been worked out, others must for the present remain open. Even in these cases, however, it is believed that the problems have been recognized, and that the lines along which their final solution must lie, have been defined. This is often the most serious and important part of an investigation.

The difficulties encountered in the study of the surface formations are such as must always be found in this sort of work. They have been found to be greatest in the southern part of the State. This is partly, but not wholly, the result of the lack of exposures. In addition, the surface formations are usually very thin, and made up largely of unconsolidated sand and gravel. These materials are not favorable for the preservation of fossils, even if they were once present, so that this great aid in the correlation of formations cannot be made use of. Again, most of the surface formations have been largely derived from the older beds which immediately underlie them. The underlying formation, after exposure to the action of subærial agencies, was submerged beneath the sea, and the new formation represents the deposits made during submergence. It consists of the materials of the older formation, worked over, re-arranged, and finally deposited on their parent formation. If a formation originating in this way be elevated above the sea, exposed to erosion and again submerged, its surface parts might be again worked over by the waves and deposited anew, constituting another and younger formation. Such a formation, made up of the old materials deposited anew, and in much the same place as before, may so closely resemble the formation from which it was derived, as not to be readily distinguished from it. If this process be repeated a number of times, the complication becomes great, and the differentiation of formations having this origin cannot always be made on the basis of their constitution. This is exactly what has taken place in the Coastal plain of New Jersey.

Again, over considerable areas, the surface formations have been much eroded since the deposition of the last, and the shifting of surface material incident to erosion has helped to complicate still further a series which was already complex. Add to these considerations the fact that in some parts of the State exposures are rare and data unavailable, and this in areas which are crucial, and some conception of the difficulties of differentiation may be gained.

The chief reliance for correlation has been on the basis of the physical constitution of the several formations, and on their topographic relations. These two lines of evidence are often so related to each other that their united weight is much more than twice as great as that of either one, but sometimes one or the other is inapplicable. From the topographic relations and constitution of fragments of formations now widely separated, community of origin may often be inferred with a high degree of probability, and in many cases with absolute certainty. This mode of correlation (homogeny) is not altogether new, and no claim of priority in its use is set up. The method has been recognized by others at various times in the development of geological science, but especial emphasis has been laid upon it of late years by McGee* in his study of the Coastal plain farther south.

The accompanying map† shows the general distribution of the surface formations of the State as now interpreted. The map is on so small a scale that many details are necessarily omitted, but the general relationships are made clear. To meet the requirements imposed by statute on the Survey, the map is prepared before a complete study of all the data gathered has been possible, and is subject to alteration in the light of such study. It is meant to give an approximate idea of the relations of the surface formations as they are now interpreted, and in spite of the possible changes of interpretation in the future, will not give an erroneous idea of the general relationships.

The following pages are devoted to a brief description of this map, the several areas being referred to in the order of their age. This is

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*McGee, Am. Jour. Sci., 3 ser., vol. 40, 1890, pages 36--41.

†The detailed work on which this map is based has been largely done by Geo. N. Knapp, for the Coastal plain, and by Dr. H. B. Kümmel and Mr. Charles E. Peet, for the area north of the terminal moraine of the last glacial epoch.

not to be understood to mean that the area first described is necessarily the oldest part of the State, but rather that it is that part of the State where the formations *which now lie at the surface* are oldest. Generally speaking, the northern part of the State is older than the southern, but the surface formation in the northernmost part is one of the youngest within its borders. Possible departures from chronological order, even so far as the formations at the surface are concerned, are noted in their appropriate places.

THE PRE-TRIASSIC AREA.

That part of the State where the formations now existing at the surface are oldest, is the area colored dark green (1), covering parts of Hunterdon, Warren and Morris counties. This is the area where the older formations (Paleozoic and pre-Paleozoic) of the State have either never been covered by younger beds, or where such overlying beds as once existed, have been worn away by erosion. This does not mean that the solid rocks of Paleozoic and pre-Paleozoic age are bare within this area, but that these rock formations are covered, if covered at all, only or chiefly by the soil which has resulted from their decay. The question may perhaps be raised whether the residuary soil of a region should be represented on a map showing the surface geology. The underlying rock is close beneath, and would be represented on a map showing the sub-surface formations. In answer to such question, should it be raised, it may be said that these old formations and their residual products are at the surface, and therefore should be represented on the surface map. The alternative would be to leave the areas blank. On the map no distinction is made between the several formations of the great groups included within this area.

In the decay of rock, many processes are at work, but the chief among them is the abstraction of their soluble elements by the water falling upon and percolating through them. The abstraction of the soluble elements serves to break up the rock, and the insoluble parts remain behind, constituting the mantle (soil and subsoil) which now overlies the solid rock. Not all the insoluble residue which has resulted from the surface decay of rock formations remains at the surface, but only the excess of that which has been formed, over that which has been carried away by erosion.

Within the area under consideration, the process of decay has been going on for a long period of time, a period which is, perhaps, to be reckoned by millions of years. It is not to be inferred, however, that any part of the *mantle rock* (soil and subsoil) now remaining in this area is necessarily millions of years old. It is possible that all products of decay in the distant past have been carried away by erosion, and that all which now remain are the product of decay within relatively recent times. On this point, however, it is impossible to speak with certainty. It is quite within the range of possibilities that the mantle rock, as such, within the area of very old formations, is younger than the formations now exposed at other points within the State. For example, it is quite possible that the Cretaceous formation, which comes to the surface over a considerable area, was deposited at a time much farther back in the past than that which marks the origin of most of the residuary earths on the surface of the area under consideration. While the residuary earths (or mantle rock) of this area are being continually removed from the surface by wind and water, they are being constantly renewed below by the decay of the rock beneath them. In some places and at some times the first process goes on more rapidly than the second; in other places and at other times the reverse is the case. When the area under consideration is represented, therefore, as having the oldest surface formations, the adjective is to be understood to refer to rock beds, not to the mantle rock arising from them.

It is probable that at least some parts of this area were once covered by younger formations. It can hardly be doubted that the Triassic beds once extended northwest of the line which now marks the boundary of that formation, and that it has since been eroded from such area. It is probable that another formation (the Beacon Hill) now restricted to areas further south, once reached the borders of this area at some points. It is certain that at least one still younger formation (the extra-morainic drift), now largely carried away by erosion, was somewhat generally spread over it. From the fact that this drift has been so largely removed, it is clear that large amounts of mantle rock arising from the decay of the underlying beds may also have been carried away during the same time.

THE TRIASSIC AREA.

The area where the surface formation is next in age is that where the Triassic beds come to the surface. This area lies immediately to the southeast of the preceding, occupying parts of Hunterdon, Mercer, Somerset and Middlesex counties, colored light green (2) on the accompanying map. The area thus designated means that within it the Triassic rock, or the residuary earths which have come from its decay, lie at the surface. If they are covered at all, it is so thinly that the material derived from the Trias controls the soil and subsoil. The Triassic or Newark system is made up of various sorts of beds, including both sedimentary and igneous rocks,* but the whole are here grouped together.

This area differs from the preceding in two or three points which are worthy of mention. In the first place, the basal formations are considerably younger, and their exposure dates from a later time. The mantle of residuary earth is on the whole thinner than that of the preceding area, but this is not because of the lesser duration of its exposure, so much as because the rock decays less readily, and because the residuary earths arising from the decay are more easily carried away. As in the preceding case, it is improbable that any of the mantle rock now remaining within this area dates from the early part of the exposure of the underlying formation. The remarks made above concerning the age of the mantle rock of the pre-Triassic formations, are equally applicable here.

Unlike the preceding area, the Triassic has been very largely covered at some time by some of the later formations. Much of it was covered by the Cretaceous beds or some portion of them, and a still larger part by the Beacon Hill formation. In still later time, considerable areas of the Trias were buried beneath the Pensauken formation, and remnants of it are still seen (see map) at various points within the general area here under consideration. Where these younger formations have been essentially removed, traces of their former existence, too inconsiderable to map, are frequently seen. Except for remnants appearing on the map, the younger formations once covering the Trias have been carried to the sea in subsequent time by subærial erosion. When they were carried away, the rela-

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* See Report of Dr. Kümmel, Part II. of this volume.

tions of land and sea were not what they now are, and some of the sediment deposited in the sea at the time of its erosion from the land, was deposited on areas which have subsequently become land.

Within this area, the soil is relatively thin, and rock exposures may be seen along almost every valley and on nearly every slope where the angle of inclination is considerable. Flat areas only are covered with a mantle sufficiently thick to effectually conceal the underlying strata, and this is true whether the underlying formation is shale, sandstone, conglomerate or trap.

THE CRETACEOUS (AND EOCENE) AREA.

The third area is that where the Cretaceous beds, and small areas of Eocene appear at the surface, or where they have so slight a covering of later material that they, or the products of their decay, control the character of the surface. It was with the deposition of the Cretaceous beds that what may be called the modern geological history of New Jersey began. The strata of the older formations lie at various angles, and show that they have been much warped and twisted in the dynamic movements to which the northern part of the State has been subjected since their deposition; but the Cretaceous beds still lie in an approximately horizontal position, and their relations to the preceding and succeeding formations are such as to show that the central and southern parts of the State have not suffered great dynamic movement, beyond mere uplift and subsidence, since these beds were deposited. These as well as all succeeding beds have a gentle dip in a general southeasterly direction. No attempt is made on the map to distinguish between the various subdivisions of the Cretaceous system.

It will be seen from the map that the Cretaceous beds, colored yellow green (3) on the map, come to the surface principally in a broad belt running from Raritan bay southwest nearly to Salem, and occupying parts of Monmouth, Middlesex, Mercer, Burlington, Camden, Gloucester and Salem counties. The northwestern part of this area occupies the lowest belt which crosses the State from east to west. Roughly speaking, the Cretaceous area is the lowest, outside the Delaware valley, along the line of junction of these beds with the Triassic. From the line of this junction the exposures of the Cretaceous attain a higher level to the southeast. They, therefore, occupy much of the low belt between the head of Raritan bay and Bordentown, together with the slopes which rise above it to the southeast.

Within this belt, as the map shows, the Cretaceous beds are frequently covered for large or small areas by remnants of later formations, and where the Cretaceous beds are exposed, it is because the younger beds which once overlay them have been carried away. Even within the area here mapped as having the Cretaceous beds at the surface, traces of these later formations, too unimportant to map, are sometimes seen. It is probable that no part of this formation now exposed has been at the surface continuously since its deposition. At least one of the younger formations (the Beacon Hill) appears to have covered not only all of it, but, as already noted, most of the Trias as well. At a much later time, at least one (the Pensauken) and perhaps two (the second being the Bridgeton) later formations also covered much but not all of the area where the Cretaceous beds are now exposed. The subsequent discovery of the Cretaceous is the result of erosion, which has spared numerous remnants of these later formations, the larger ones being shown on the map.

Southeast of the belt where the Cretaceous appears at the surface it dips to the southeastward beneath later formations, and is concealed by them.

THE MIOCENE AREA.

The Miocene formation appears at the surface in a belt lying southeast of that where the Cretaceous beds are exposed, and runs from Monmouth county on the northeast, through Ocean, Burlington, Camden, Gloucester, Salem and Cumberland counties. As will be seen from the map, the belt where the Miocene appears at the surface is much wider in Monmouth, Ocean and Burlington counties, than in those further south. This means that within these counties it has been more widely uncovered by the removal of the younger formations which once overlay it.

In preceding reports the question has been raised as to the separation of the Miocene from the Beacon Hill formation next succeeding. Even now it is not certain that they should be separated. If not, the Beacon Hill formation is to be looked upon as the youngest of the Miocene beds. In any case it seems practicable to separate this youngest bed, which is generally gravel, from those of greater age, even though all be Miocene.

The areas where the Miocene beds come to the surface are in part areas of steep slopes. This is especially true in Camden, Gloucester, Salem and Cumberland counties, where they appear on the slope of the escarpment which marks the drop from the higher lands on the east to the low lands bordering the Delaware. In Monmouth and Burlington counties, where the formation is much more widely exposed, it is by no means confined to steep slopes, but occupies considerable divides as well. The Miocene sands also come to the surface in some of the deeper valleys, as in the vicinity of Millville, where the overlying formations have been cut away.

Like the Cretaceous, the Miocene (exclusive of the Beacon Hill formation) was once completely covered by later beds, and its present exposure is the result of their removal. While the map shows the area where it appears at the surface, it is not to be understood that this is the limit of the formation. The northwest line of exposure marks the limit of its northwestern extension at the present time, though it once extended farther in this direction; but to the southeast of the belt where it is exposed, it dips beneath the younger formations which effectually conceal it, and extends out to and beyond the borders of the State. This formation, like the preceding, but unlike most of those which follow, contains fossils at many points. While the position of the beds is not such as to show at any particular point that they are unconformable on the Cretaceous, their stratigraphical relation to the various members of the Cretaceous series shows them to be so.

At many points within the area marked Miocene on the map, yellow (4) color, there are traces of some overlying formation which has been chiefly removed. In a few places, considerable patches of the later beds still remain. Such patches are usually found capping considerable elevations.

THE BEACON HILL AREA.

The Beacon Hill formation is not known to be unconformable on the Miocene, and may represent but the last phase of the deposition of that period. On the other hand, it appears to have been more widespread than the earlier phases of the Miocene, as if at this time increased subsidence submerged considerable areas not covered by the waters of the earlier Miocene seas.

The areas where the Beacon Hill formation is now exposed, or but very thinly covered, are shown on the map, and in some cases, especially in Monmouth county, the areas are seen to be widely separated from one another. This separation is primarily the result of erosion which has carried away the formation from the areas which now separate its remnants. The northwestern limit of the area where these remnants occur by no means represents the northwestern limit which the formation once attained, for it spread to the northwest not only completely over the underlying Miocene, but over all the Cretaceous beds as well, and over a large part of the Newark (Triassic) system, perhaps even reaching the crystalline rocks themselves at some points.

Along the northwestern border of the area where the Beacon Hill formation outcrops, it constitutes the summits of the most considerable elevations of southern New Jersey. Thus it caps the Navesink Highlands, the Mt. Pleasant hills, the Clarksburg-Perrineville hills, etc. Within this belt, the elevations of the bases of adjacent patches of the formations are harmonious with one another; that is, if at one point the base of the formation has an elevation of 300 feet, at other adjacent points it has an elevation essentially the same. Carried over broader stretches it may rise or decline. Not only are the highest elevations of southern New Jersey capped with this formation, but the formation helps to preserve them; for it consists largely of loose gravel, which, being open and porus, allows the surface waters to sink in readily, instead of running off over the surface. This is one of the conditions under which hills suffer little reduction. In a few localities the gravel is cemented by iron oxide into a firm conglomerate, and this, being very resistant, gives permanence to the tops of the hills. To the southeast the formation is much less largely composed of gravel than to the northwest. In the former areas it was further removed from the sources of gravel at the time of its deposition. It here contains more sand, and even considerable beds of clay.

Within the area here mapped as Beacon Hill, it is possible, perhaps probable, that there is a somewhat widespread but thin and discontinuous formation of later age. If so, it has not been differentiated with certainty from the weathered products of the

Beacon Hill formation itself, though at some points the differentiation is not difficult. Its interpretation, even where it is distinct, is open to question. It may perhaps be simply the alluvial product which has been left on the surface in the course of stream erosion, a process which always leaves more or less such material on the surface, especially on a surface brought down to or toward a base-level.

Like all other formations from the Cretaceous on, the Beacon Hill formation declines to the southeast, and passes under the later beds. Unlike the last two formations which have preceded, it was probably never completely covered by younger beds. This is true of the high remnants in Monmouth county, and perhaps some areas further south. Elsewhere it was probably completely covered by younger beds, which in considerable part, have since been removed by erosion.

THE BRIDGETON AREA.

The Bridgeton formation appears, as will be seen from the map, in a series of isolated patches, sometimes large and sometimes small, lying southeast of the belt of the Miocene outcrops. Its areas are in general small in Ocean, Burlington and Atlantic counties, and larger in Camden, Gloucester, Salem and Cumberland. The now dissevered areas are parts of what was once a continuous formation, and its dissection into remnants is the result of stream erosion.

The differentiation of the Bridgeton formation has been long in mind, though data for its sharp definition have been wanting. Even now they cannot be said to be altogether satisfactory. In some places the formation seems not to be clearly separable from the Beacon Hill formation which preceded, while in others it is not easily distinguished from the Pensauken which follows. In other places, on the other hand, it is distinctly separable from the Pensauken, and in still others from the Beacon Hill. The only question, therefore, concerns the integrity of the formation as a whole, and the data at hand do not demonstrate that that part of the formation which seems to be closely allied to the Beacon Hill formation is not really a part of that formation, and that that part which is with difficulty separated from the Pensauken, is not really Pensauken. On the other hand, these two parts, the one of which seems to have affinities with the Beacon Hill formation and the other with the Pensauken, seem to belong together. The mapping here given is therefore that which seems to be best supported by the data now in hand. Were there more numerous and more extensive exposures in the localities where the relations of the formations are presumably best shown, more certain conclusions could perhaps be reached.

The area where the Bridgeton beds might with some show of reason be referred to the Beacon Hill formation lies west (northwest) of the northeast-southwest divide running through the Coastal plain of New Jersey; the area where it is with difficulty separated from the Pensauken lies (east) southeast of this water shed. The former area is chiefly west of the New Jersey Southern railway, the latter east of it.

In constitution the Bridgeton formation differs somewhat both from the Pensauken and from the Beacon Hill, though the difference is not always great. In general it is a gravel formation, though it contains both sand and loam, and occasionally clay. In constitution it may be said to vary within certain fixed limits, these limits being the constitution of the Beacon Hill formation on the one hand, and that of the Pensauken on the other. These relations are easily explained where it was derived chiefly from the preceding formation, and where the succeeding was derived chiefly from it. It is unlike the Beacon Hill formation in containing bits of iron stone derived from the Cretaceous, or from the Beacon Hill formation itself; it is like it in containing much decayed chert which gives it the appearance of great age. In general it may be said to contain any sort of material which the Beacon Hill formation contains, and some which it does not. It is therefore most clearly separated from the next older formation by its constitution. But occasionally its constitution closely approaches that of the Beacon Hill formation, and where its topographic relations are at the same time indecisive, its differentiation is uncertain.

From the Pensauken, on the other hand, it is most clearly separated on topographic grounds, especially in the western part of the State. Here the Bridgeton beds lie at a level distinctly above that of the Pensauken beds, the latter being restricted to the low area west of the Miocene escarpment. The topographic relation of the formations indicates a long interval of erosion between their deposition.*

This is the formation which on the whole has most resemblance to

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*See Annual Report for 1896, pages 11, 12.

the Lafayette formation further south. In earlier reports it was believed to be one with the Pensauken. In that for 1896 its distinction from the Pensauken was affirmed, and its affinity with the Beacon Hill suggested. Some idea of the former extent of the Bridgeton beds may be gained if all existing remnants of it be conceived to be extended until they merge into one another, bridging the areas intervening between the existing remnants. It is believed that the formation extended much less far north than that which preceded, though the original limits are probably not determinable.

It is altogether possible that some of the areas mapped as Bridgeton, west of the New Jersey Southern railway, may prove to be Beacon Hill instead, and that some of the areas east of that line may prove to be Pensauken. The distinction in the latter area is based almost wholly on topographic grounds.

THE PENSAUKEN AREA.

Unlike the preceding formations, the Pensauken, as will be seen from the map, is found at the surface in two principal belts, instead of one. One of these runs across the State in a northeast-southwest direction from the head of Raritan bay nearly to Salem; the other runs along the east side of the State from the vicinity of Asbury Park to Bridgeton. The former belt is narrow and clearly defined, and within it the formation occurs in a series of closely-associated patches, some of which are large and some small; the latter belt is wider and less well defined, the patches of the formation being more widely separated.

Aside from these two main belts, there are isolated remnants of the formation lying farther north. North of the Raritan river there are remnants in the vicinity of Somerville, Raritan, Metuchen, Plainfield and Merchantville (near White House). It is possible that there is a single remnant still farther north, but its correlation is uncertain. South of the Raritan there are also remnants near Neshanic and Millstone.

It will be seen that in the first of the preceding belts, the Pensauken lies chiefly along the northeast border of the Cretaceous beds, and to a lesser extent on the Brunswick shales of the Newark system. Where it lies on the Cretaceous, it is where the surface of the latter formation has but a slight altitude. Where it lies on the

Trias, it is likewise where that formation is low, namely, along its southeastern portion. Thus it will be seen that the formation is distributed along the central trough of the State already referred to as running from Raritan bay to Bordentown, and thence southwest along the Delaware to Salem. North of the axis of this trough rises the slope of the Trias, on which there are remnants of the Pensauken; south of it rises the slope made up of the higher beds of the Cretaceous, on which likewise there are remnants of the same formation. In both directions from the axis, the Pensauken seems to be limited by increasing altitude.

Within the low belt where the remnants of the Pensauken are abundant, the formation usually caps the crests of such minor elevations as the slight relief of the region affords. It is found on the low hills and ridges, and covers the broader areas where the surface is flat, and distinctly above the valleys; that is, the areas which have not been dissected by erosion since the Pensauken beds were deposited. This distribution of the Pensauken clearly points to the fact that the formation was laid down before the present relief was established, and the general absence of the formation along the lines of the present valleys shows that it has there been cut out by erosion since its deposition. An approximate idea of the original distribution of the formation along this belt may be obtained by conceiving the whole area within which the remnants occur to have been uninterruptedly covered by it. The formation probably extended considerably north of New Brunswick, covering the wide, low Triassic plain south of First mountain. It did not cover Rocky hill or Sourland mountain, or any of the higher Triassic areas in that part of the State. It probably extended a considerable distance north of the Raritan in the eastern part of the State, but its original limits in this direction are not now determinable. It also extended east over parts of Staten and Long Islands.

In the vicinity of Trenton it appears never to have risen above the levels which are now 130 feet above tide; in the vicinity of Somerville its upper limit appears to have been nearly the 180 foot contour. On the southeast side of the trough, its maximum altitude is somewhat greater, showing greater uplift since its deposition.

As the map shows, the formation extended across the Delaware into Pennsylvania, and has a wide distribution in the vicinity of Philadelphia. It is well exposed about Germantown Junction, and constitutes what was known by Lewis as the "Red Gravel" of Philadelphia.* Its upper limit southwest of Trenton, and in the vicinity of Philadelphia, is at an elevation of 120 to 130 feet. The formation was deposited beneath the water, and the foregoing figures concerning its altitude simply indicate the height to which the shores of the waters of the Pensauken period have since been brought in this locality.

Along the southeast margin of the northwesterly belt of Pensauken remnants the formation probably never extended much beyond (southeast of) the outlying remnants as now seen. When the formation was deposited, there was therefore a long island running through southern New Jersey, from Monmouth county on the northeast, nearly to the mouth of the Delaware west of Bridgeton. On the eastern (southeastern) side of this island, the sea water seems to have been shallow; but the sea extended in from the coast approximately to the line of the New Jersey Southern railway. Over much of the area east of this line, the formation has since been removed by erosion. In all the area of its original distribution in this part of the State, it probably covered the Bridgeton, or such part of it as erosion had not removed before the deposition of the younger formation. It will be remembered that it is in this area, southeast of the railroad indicated, that the Pensauken and Bridgeton are distinguishable only with difficulty, and that for this area the chief criterion for discrimination is topographic. The remnants of the formation which now exists were doubtless once continuous with one another.

The Pensauken formation, as indicated by its constitution, was probably contemporaneous with an early glacial epoch (Kansan or Albertan).† The extent to which it has been removed by erosion and the rather complete dissection of the areas where it has not been completely carried away, tell more conclusively than description can, of the amount of erosion which has taken place since this early glacial epoch, and therefore of the length of time which has elapsed. It is to be borne in mind in this connection that the areas where this extensive erosion has taken place are not areas of great altitude, but areas where the elevation is, for the most part, less than 150 feet, and where, as a result, erosion cannot have been especially rapid.

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* Proc. Acad. Nat. Sci. of Philadelphia, 1880.

† Chamberlin, Journal of Geology, Vol. III., page 270.

EXTRA-MORAINIC GLACIAL DRIFT AREA.

There are a few small areas of the extra-morainic glacial drift which were perhaps contemporaneous in origin with the Pensauken formation in the southern part of the State. These remnants are chiefly small, and like the remnants of other surface formations, their present size and relations are the result of erosion subsequent to the deposition of the more extensive formations of which they give evidence. These areas are represented on the map by the brown (8 and 9) color. The area within which they occur lies south of the moraine of the last glacial epoch, and north of a line running from Raritan to Riegelsville on the Delaware. The nature and relations of this drift have been discussed in earlier reports.* It is probable that when the ice of this early epoch reached the vicinity of Somerville and Raritan, it reached the shores of the Pensauken sea (or sound),† and that its edge was limited by the water. Discharging here, the ice and the drainage from it brought in the debris which constitutes a considerable part of the Pensauken formation.

THE AREA OF THE LATE GLACIAL DRIFT.

The Pensauken formation and the old glacial drift had been long subjected to erosion when the ice from the north, invading the borders of New Jersey for the last time, reached the limit marked by color number 10 on the map. When the last ice sheet retreated, it left over the area which it had covered a mantle of glacial drift ‡ of variable thickness, ranging from zero to more than 100 feet. The relations, characteristics and classification of this drift have been the subject of earlier reports, and will not be described in this place. §

The area covered by the ice is covered in part by stratified drift and in part by unstratified. The drift is disposed in various ways, depending partly upon topography, and partly upon the relations of ice to drainage during the final melting of the great glacier.

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* Annual Report of the State Geologist of N. J. for 1892, pages 60--72. Ibid., 1893, pages 73--104.

† Physical Geography of New Jersey, page 129.

‡ This corresponds to the glacial formation known as the "Wisconsin drift." Chamberlin, Journal of Geology, Vol. III., page 270.

§ Annual Reports of the State Geologist of N. J., from 1891 to 1894, especially that for 1894.

At the same time that the ice was doing its work in the north, the streams flowing out from it made deposits of sand and gravel farther south. These are indicated by color number 11 on the map.*

AREA OF THE CAPE MAY FORMATION.

Along the borders of the Coastal plain, from Raritan bay to the mouth of the Delaware and up the Delaware as far as Trenton, there is a low-lying belt of flat country, often somewhat terraciform, having an elevation of 30 to 50 feet. The substructure of this terrace is usually some one of the preceding formations, but it is generally covered by a thin body of loam, sand and gravel of lesser age than any of the preceding formations, except possibly the drift of the last glacial epoch. Occasionally this young formation has a considerable thickness, extending from the surface down to and even below sea level.

The disposition of this formation seems to indicate that when it was deposited, the Coastal plain (of New Jersey) was depressed something like 35 to 45 or 50 feet below its present level, the amount varying slightly in different localities. At the same time the drainage of the Coastal plain was sluggish, and deposits contemporaneous with those along the shore were made by the streams in their valleys. Starting with the debouchures of the streams, the alluvial deposits extended up the valleys, sometimes well toward their sources, and to elevations much above 50 feet. The disposition of this formation is shown on the map, where it is represented by color number 12. It will be seen that it makes a wide, though very irregular border from Keyport to Ocean City, and from Trenton to the mouth of Maurice river. Besides this, it not only covers the whole of Cape May county, but within this county it makes up nearly all the mass of the land which is above the sea. The strict contemporaneity of this formation with the drift of the last glacial epoch is not established, but it is probably at least partly contemporaneous with it, though its later portions may be slightly younger. The approximate contemporaneity of the two is inferred from their topographic relations, especially in the lower part of the Delaware valley, down which

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*For description of this extra-morainic drift of last glacial age, see Annual Report of the State Geologist of N. J. for 1892, pages 102–122.

glacial drainage coursed, making deposits which are topographically continuous with those of this formation.

Since it has its best development in Cape May county, the name of that county is an appropriate one for the formation. The name is here used to cover those deposits of late glacial and early post-glacial time, which were made beyond the region directly affected by the ice or its drainage. It includes much of the loam which has heretofore been referred to under the name of the "low level Jamesburg."*

HIGH LEVEL LOAM (NOT MAPPED).

At many points at various high levels in different parts of the State there is a loam, the origin and explanation of which have occasioned much study, but for which no satisfactory explanation has been found. It is not confined to the Coastal plain, though it is there most widespread. It occurs at various elevations up to 200 feet and more, and from this altitude ranges down to the low-lying formations which has just been described. Outside the Coastal plain it lies on the Triassic shale at various points. In its clayey phases, it is used for brick clay. Thus the brick clay south of Pennington, 50 feet or more above the upper limit of the Pensauken formation represents it. Farther south, and at slightly lower levels, it overlies the Pensauken formation, covering it as a mantle three or four feet in thickness. In the vicinity of Trenton Junction, the clay loam mantle has been extensively used for brick, and it might be so used at numerous other points. Loam in such similar positions and relations as to lead to belief in its community of origin, is found up to the elevation of 181 feet in the vicinity of Marlton, 160 feet at Fountain Green, and 200 feet or more in the vicinity of Cream Ridge.

Its physical character varies from point to point, but in the southern part of the State it often contains a goodly amount of marl, even when the immediately underlying formation does not, seeming to make it necessary to suppose that the marl formations were well exposed when it was deposited. Furthermore its position is such as to show that it is younger than the body of the Pensauken formation, representing either its last phase or something subsequent to it.

In the vicinity of Philadelphia, the brick clay overlying the Pen-

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* Annual Report of the State Geologist of N. J. for 1894.

sauken gravel and running to still higher levels, seems to connect itself with the clay loam on the low river terraces which are correlated with the youngest (Cape May) of the preceding formations. If the connection of the high-level loam with that on the low terraces is correct, the former, like the latter, must be much younger than the Pensauken.

Farther north, between Raritan and Pluckamin, there is at some points a surface clay which is highly calcareous. It is a deposit from standing water and seems to have been connected with the glacial waters of the last ice epoch. Clays which may be supposed to have a contemporaneous origin overlie the last glacial gravels and sands at the Plainfield brick yards. These and other facts which will not be here detailed have raised the strong suspicion that there was a deep, but very brief submergence of the State to a much more considerable extent than has been commonly recognized at, or soon after, the close of the last glacial epoch.

The high-level loam here referred to is found at many points in the Coastal plain. In general it is so discontinuous, so thin when it is present, and often so indecisive in character, that it cannot always, and perhaps not generally, be distinguished with certainty from the weathered products of the formations which underlie it; but occasionally it is so distinct as to leave no doubt of its separateness. This is true, for example, where the loam is marly, while the underlying beds are altogether free from marl; it is also true where it overlies the red shale, and where its character is such that it cannot be supposed to have originated from the decay of that formation. This high-level loam is what was designated the "high level Jamesburg loam" in some of the earlier reports.

The formation is too meagre, too equivocal at most points, and the borders of even its best developed areas too ill-defined, to render its mapping practicable or profitable.

THE AREAS OF RECENT FORMATIONS. MARSHES, DUNES AND BEACHES.

The youngest formations of the State which cover areas represented on the map, are the marshes, beaches and dunes about the coast. The tide marsh belt has a considerable width from Point Pleasant to Cape May, and thence to Salem. The formation of the marshes, which is still in progress, consists of the fine sediment washed and blown from the land, but chiefly of the remains of the vegetation (peat) growing in the undrained areas. The peat has accumulated until its depth is in many places considerable. The marshes are being gradually filled up both by the sediment and the vegetation, and unless the land be slowly sinking, they will ultimately be converted into dry land.

Outside the tide marsh belt is the so-called *beach*, or series of beaches. The northern extremity of these beaches is Sandy Hook. This beach is essentially continuous to Long Branch, but is wanting from that point to Mount Pleasant. From Mount Pleasant it is nearly continuous to Cape May, and has a much lesser development, not shown on the map, on the bay side of the Cape. The beach and dune sand are represented together on the map by the black lines (13). The substructure for the beaches was made by waves and shore currents in very recent time; that is, they were originally beach ridges in the proper sense of the term. So soon as the waves had piled up the sand above the surface of the water, the wind commenced its work upon it, and fashioned it in its own way. The continued activity of the waves and currents has furnished new supplies of sand for the wind to work upon, thus giving rise to the well-known dune hills and ridges, rising many feet above the level of the beaches proper, along the larger part of the coast.

Over other parts of the State there is much wind-blown sand, but it is rarely aggregated in such considerable quantities as to constitute dunes which can be shown on a map of the scale of that here used. Dune sand is very prevalent in the vicinity of Old Bridge, especially southeast of the railroad, and along the east side of the Delaware river, especially below Trenton, where it has been blown up out of the valley since the deposition of the last glacial and Cape May formations. Wind-blown sand is also to be found to the depth of a few to several feet in scores, probably hundreds of places in the pine forests. In general, however, the areas of wind-blown sand are too small for representation on the accompanying map.

PART II.

The Newark System

OR

Red Sandstone Belt.

BY

HENRY B. KÜMMEL.

THE NEWARK SYSTEM OF NEW JERSEY.

BY HENRY B. KÜMMEL, PH.D.

OUTLINE.

Introduction.

Chapter I. The Sedimentary Rocks.

- Area.
- Stockton series.
  - Constitution.
  - Distribution.
    - Trenton-Wilburtha area.
    - Hopewell area.
    - Stockton area.
    - Area north of Flemington.
    - Along the Hudson.
      - Localities.
- Lockatong series.
  - Constitution.
  - Distribution.
  - Soil.
  - Modification of the Lockatong beds.
  - Absence of the Lockatong beds in the northern area.
- Brunswick beds.
  - Constitution.
  - Distribution.
    - In the western part of the State.
    - In the northeastern part of the State.
      - Elizabeth and west.
      - Newark and northward.
      - Hackensack to Paterson.
      - Bergen county.
      - Between First and Second Mountain.
      - Above Second Mountain.
- Border conglomerates.
  - Quartzite conglomerates.
  - Calcareous conglomerates.
  - Gneissic conglomerate.
    - Relations of these conglomerates to the older rocks.
    - Relations of these conglomerates to the shales.

Chapter II. The Trap Rocks.

- Origin of the trap rocks.
- Origin of the ridges.

Chapter VI. Economic Resources.

INTRODUCTION.

During the summer of 1897, the work on the Newark system was carried forward as rapidly as possible. The time at the writer's disposal (June 25th to September 15th) was sufficient to permit the completion of the areal work in the northern part of the Newark belt. The entire area of Newark rocks in New Jersey has now been examined in detail. The same general methods of work were employed during this season as previously, *i. e.*, all the roads, railroad cuts, quarries, and so many of the stream beds as was advisable, were examined and the dip and strike of practically all outcrops were recorded. Descriptive written notes supplemented the graphic notes wherever necessary.

The results obtained, however, have been meager compared with those of the previous year. This has been due to two causes. The second year's work must naturally be but the continuation of the earlier work, the carrying forward of the conclusions already reached. But for another reason the area examined has been comparatively barren of results. Almost the whole of it lies within the terminal moraine, and over large areas the rock is so deeply buried beneath glacial and lacustrine deposits that often the deepest wells do not reach it. It was possible, therefore, to trace only in a very general way the various belts of rock comprising the Newark system.

In the following pages I have incorporated much from my report of 1896. It seems advisable to do this in view of the fact that many who receive this report, may not have the earlier report at hand, and it is quite essential to have in mind the more important of last year's conclusions. To the advanced student of geology there may be much unnecessary explanation and repetition, which, however, is not out of place in a report meant for persons who are not specialists.

Although the whole area of the Newark system within New Jersey has been carefully examined and the fieldwork completed, this report is not intended to be final. Certain problems can best be discussed after a wider view of the formation than that afforded by the limits of a single State. It is hoped that there may be opportunity in the future for such broader study.

CHAPTER I.—THE SEDIMENTARY ROCKS.

AREA.

The Newark system of rocks extends across the northern part of New Jersey, forming a belt varying in width from thirty-two miles along the Delaware river, to fifteen miles at the New York State line. On the Delaware it extends from Trenton to within two miles of Riegelsville, and at the northern boundary of the State from the Hudson river to Suffern, N. Y. and Ramapo mountain. It lies between the Piedmont Highlands on the northwest and the Coastal plain on the southeast. Topographically it forms the Piedmont plain. The northwestern boundary passes near Pattenburg, Jutland, Clinton, Allerville, Lebanon, Apgar's Corner, Pottersville, Peapack and Bedminster, whence it extends in a nearly straight line to Suffern, N. Y., passing near Bernardsville, Morristown, Boonton and Pompton. Along this border the rocks are all much older than the Newark sandstones, and for much of the distance rise abruptly several hundred feet above the sandstone lowland. Faulting has probably taken place along at least a part of this border.

The southeastern boundary is extremely irregular. From Trenton to near Woodbridge, it is formed for the most part by the overlapping clays and marls of the Cretaceous, or by still later gravel deposits. From Woodbridge, northward, the waters of the Kill von Kull, New York bay and the Hudson river generally limit it. That part of this area lying southwest of a line drawn through Plainfield to Peapack was discussed in the Annual Report for 1896. The area to the northeast was examined during the field season of 1897. It lies chiefly in the counties of Union, Morris, Essex, Hudson, Bergen and Passaic.

The Newark system comprises both sedimentary and igneous rocks. The latter, commonly called trap, is much harder and more resistant than most of the sedimentary rocks, and, therefore, the areas underlain by it generally form hills and ridges considerably above the general level. The relations of the trap and sedimentary rocks have always been matters of interest to geologists, and much has been written concerning them.

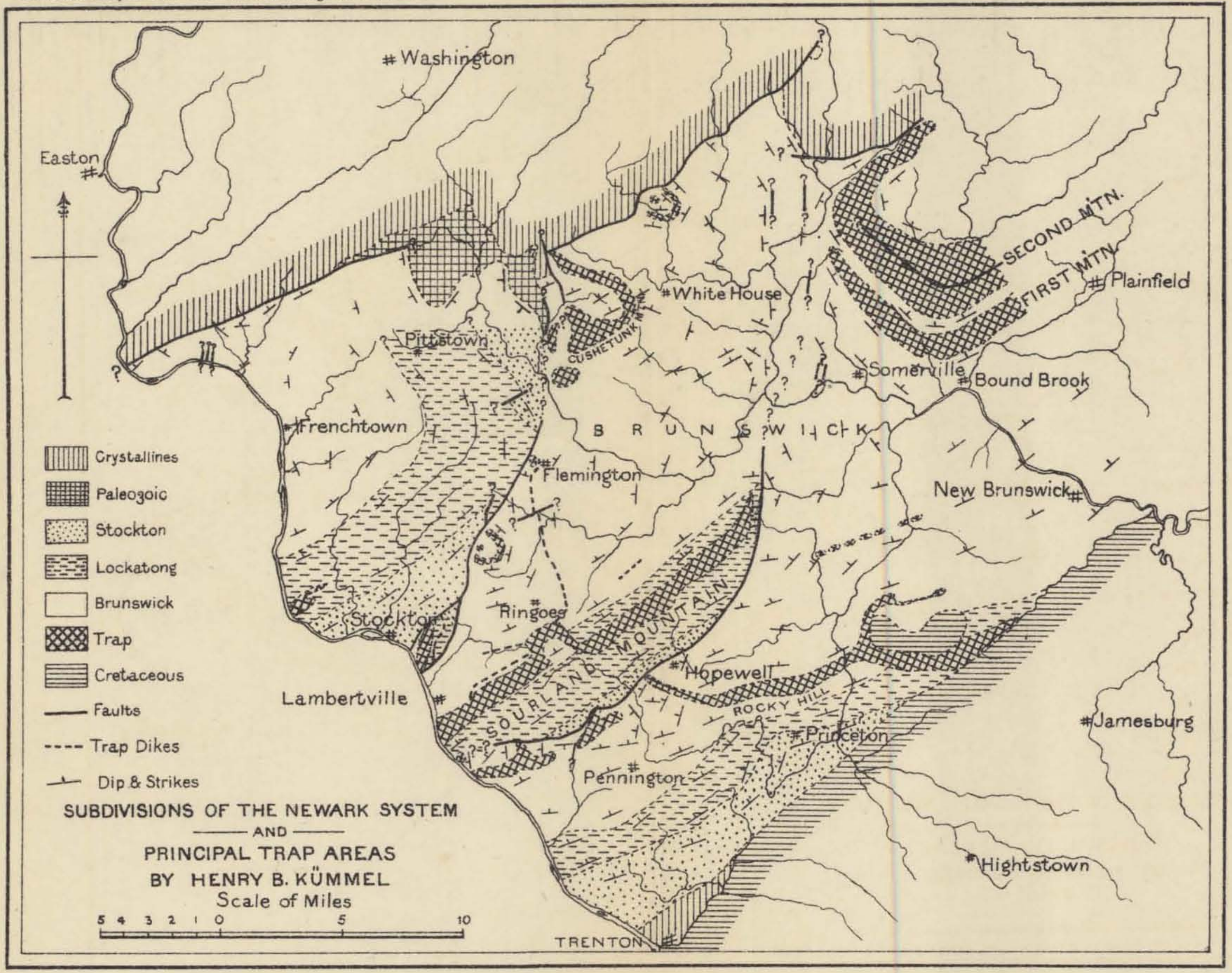
In my report for 1896, the sedimentary rocks of the Newark series in western New Jersey were divided into three series. These divisions were not based upon fossil evidence, but upon lithological differences, which were so marked and so characteristic as to be readily recognizable within limited areas. The characteristics of each division were found to vary in different localities, and in some places to lose their distinctiveness, but by constant examination it was quite possible to note these changes and take account of them.

STOCKTON SERIES.

Constitution.—The basal beds of the system are found at Trenton, where they rest upon the older crystalline rocks—the Philadelphia-Trenton gneiss belt. They consist of (*a*) coarse, more or less disintegrated arkose conglomerates; (*b*) yellow micaceous, feldspathic sandstone; (*c*) brown-red sandstones, and (*d*) soft-red argillaceous shales. These are interbedded and many times repeated. The characteristic beds are the arkose conglomerates and sandstones, the latter of which afford valuable building stones.

This series of beds is best shown in the quarries near Wilburtha, five miles northwest of Trenton; in all the quarries near Stockton, and along the base of the Palisades, from Weehawken northward, the rapid alternation of beds from shales to freestones and to arkose conglomerate is shown. Not infrequently a well-marked bed thins out rapidly within the limits of a quarry, or even disappears entirely, its place being taken by a layer of a different texture. In other cases the bed, although retaining its identity as a distinct layer, yet changes so in texture or color along its plane that it would not be recognized as the same bed were it not visible continuously. The

PLATE II.



SUBDIVISIONS OF THE NEWARK SYSTEM

AND

PRINCIPAL TRAP AREAS

BY HENRY B. KÜMMEL

individual layers have the shape of very broad, thin lenses, which overlap at their edges where they thin out.

The cross-bedded structure, often observed in the sandstones, the ripple-marks, mud-cracks and impressions of raindrops found in the shaly layers, all indicate that these beds were accumulated in shallow water in close proximity to the shore, after the manner of seashore deposits of the present day. The direction and velocity of the currents were constantly changing, thus permitting the deposition of fine sand or mud directly upon layers of gravel. At times the mud flats were exposed to the air, and became dried and cracked under the sun's rays, or violent rainstorms beat down upon them, leaving the impressions of the raindrops upon the surface. With the return of high water another layer of silt was deposited, and in some cases at least the impressions were preserved. The bulk of the material of which they are composed was derived from the crystalline rocks on the south and southeast.

Distribution.—As shown by the map (Plate II) the Stockton series occurs in four separate areas in the western part of the Newark belt. This is due to the folding and faulting which the rocks have undergone. A brief statement of these various areas may be convenient here.

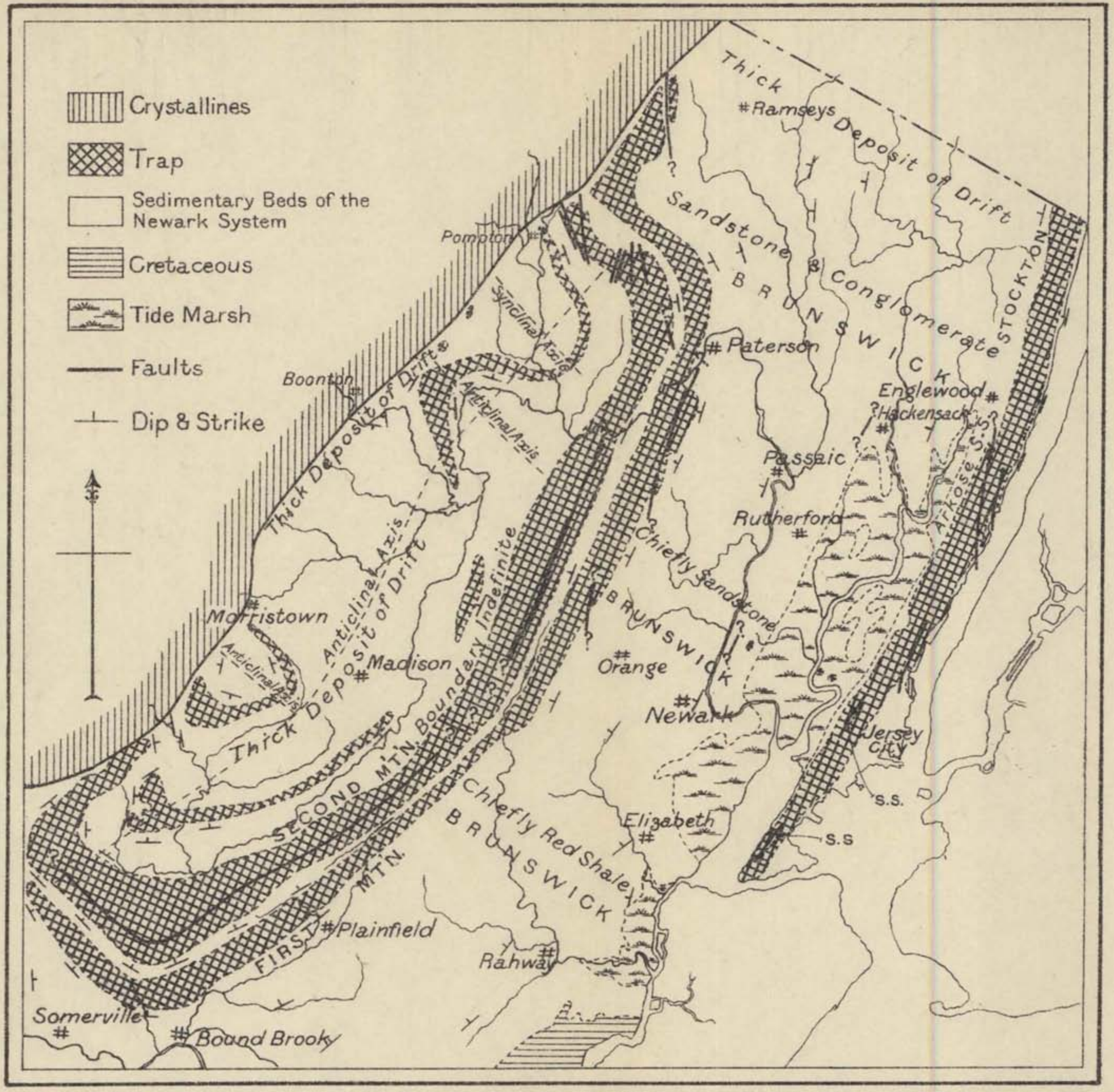
Trenton-Wilburtha Area.—Along the Delaware river this area extends from Trenton to a point three-fourths of a mile above Wilburtha. Traced along their strike these beds extend northeast through Ewingville, Lawrence and Princeton, their upper limit crossing the college campus. The upper part of the series is well exposed in the southernmost quarries along the canal southeast of Princeton. Along the Princeton-Lawrenceville pike the uppermost beds are also well shown on the long hill west of Stony brook. East of the Millstone river the strike soon carries all the beds of this series beneath the Pensauken deposits and further east beneath the Cretaceous beds.

Hopewell Area.—Near Hopewell the Stockton series form a narrow belt, three-fourths of a mile in width, along the southeastern face of the Sourland plateau, extending from Harbourton to a point near Skillman, a distance of nearly ten miles. They form that part of the plateau which one sees from the railroad near Hopewell and northeast. These beds are the upper members of the series, here brought to the surface by a great fault which extends along the foot of the escarpment.

Stockton Area.—Owing to a second great fault the same beds again appear at the surface seven miles to the northwest. This belt extends along the Delaware from Brookville (a mile below Stockton) to a little beyond Raven Rock, with a maximum width of three miles. The area in New Jersey is roughly triangular in shape, the base being on the Delaware, the upper limit extending along the crest of the Hunterdon plateau escarpment, and the lower limit following the fault, which has a more northerly course than the strike of the beds. The apex of the triangle is midway between Sand Brook village and Flemington, at the point where the fault intersects the upper boundary. The quarries near Stockton afford unexcelled opportunities for studying the composition, texture and succession of the beds. The rocks are chiefly free-splitting sandstones of various tints of grey, yellow and red-brown, very similar to those at Wilburtha. Beds of red shale and also conglomerate alternate with the sandstones. In the bluff between Stockton and Brookville, thick beds of very coarse conglomerate occur, the lower beds in this locality being much more consolidated than those near Trenton. On the Pennsylvania side of the river, opposite Brookville, the Stockton beds rest upon Paleozoic limestones which have been brought to the surface in the midst of the Newark beds by the same fault which we find in New Jersey. But in our own State the amount of dislocation, or as it is called, "the throw" of the fault, was not sufficient to bring to the surface the floor on which the Newark beds rest.

North of Flemington.—A mile and a quarter north of Flemington the same beds are again brought to the surface by the fault, as a result of a gradual change of strike from N. 65 E. to N. and then to N. 20 W. From the point of first appearance the beds extend northward to the limits of the formation near Clinton, in a gradually widening area, which attains a maximum breadth of three miles in the latitude of Lansdowne.

Within this area a significant change in the texture and composition of the beds was observed where they approach the northwestern boundary. Near Flemington they consist of coarse arkose sandstones and soft shales. Northward, nearer the boundary the typical arkose beds diminish in number and thickness. Their place is taken by beds of red shale, and sandstone and conglomerate of a different type. The material from the neighboring formations (Paleozoic shales, grits, limestones and quartzites, besides older gneiss) has entered



EASTERN PART OF THE NEWARK SYSTEM & PRINCIPAL TRAP AREAS.
BY HENRY B. KÜMMEL.

Scale of Miles
5 4 3 2 1 0 5 10

largely into the composition of the overlying beds and determined their character. In place of the free-splitting brown and grey sandstones, there occur coarser beds, made up largely of thin bits of Hudson river shale and small quartzite pebbles. With increasing coarseness of material, there are conglomerates of white, grey and reddish quartzite, whereas pebbles of the typical Stockton conglomerate are chiefly quartz and feldspar. Although in this vicinity the Stockton series rests in part upon limestones and gneiss, these two rocks occur but rarely in them.

Along the Hudson.—As was noted above, the strike of the Stockton beds in the Trenton area carries them beneath the Pensauken and Cretaceous formations a short distance east of the Millstone river. The lowest beds exposed along the Raritan river below New Brunswick are much higher in the series. But owing to a slight change of strike the Stockton beds come to the surface again on both sides of the Palisades from Hoboken northward. (Plate III.) They are exposed in many places along the foot of the Palisades near the water's edge, and in a few localities where the glacial drift is thin, the typical arkose sandstone has been found on the west side of the Palisades. These rocks are correlated with those of the Trenton area for the following reasons: Lithologically, they are almost exactly identical. In both, there are coarse arkose sandstones locally conglomeratic; in both, red shales and reddish-brown free-stones, and in both, these layers are several times repeated. Second, both occupy the same position stratigraphically. Near Trenton they are found resting upon the older crystalline rocks. In Jersey City wells bored near the water front strike gneiss and schist. At Stevens Point, Hoboken, the crystalline rocks outcrop, and, as is well known, they underlie the whole of Manhattan Island, just across the river. A little over half a mile back from the water front, in Jersey City and Hoboken, wells, which penetrate the glacial drift, reach sandstone and shale, some beds of the former being unmistakably coarse arkose. Third, minute crustaceans (Estheria ovata) have been found * in the shale beds at Weehawken and Shady Side, and again in similar relations in the quarries at Wilburtha. This, taken with the other evidence

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* Nason. Annual Report of the State Geologist of New Jersey, 1888, pages 29--33. I am not able to give assent to all of the correlations proposed by Nason, *i. e.*, the beds at Washington's Crossing are, in my opinion, certainly not a repetition of those of Wilburtha.

already given, is sufficient to establish beyond a reasonable doubt, the stratigrapical identity of the beds along the Hudson with those found in the area between Trenton, Wilburtha and Princeton. This being the case, we have here the basal beds of the Newark system, their contact with the older crystalline rocks being concealed, for the most part, in the bed of the river.

In one respect these beds do not at first sight seem to belong to the Stockton series. In the typical locality, black and dark green slates are almost never present, but both above and below the Palisades, hard greenish and black slates are found in considerable thickness. By nearly all observers these have been considered to be "baked" shales, their hardness and color being due to changes induced when the trap was intruded in a molten condition between the shales. My examination of these beds has shown me no reason for dissenting from the commonly-accepted view. Both above and below the trap the adjoining beds have been indurated and changed in color. The finer beds have been the most affected, whereas the coarser arkose sandstone is but little changed. The latter, however, where very close to the trap, has been somewhat metamorphosed, so that it resembles a quartzite. Near the trap, and for a distance of 100 feet from it the shales between the sandstones are black, with a greenish or purplish tinge, very hard and brittle. In some cases secondary minerals, chiefly tourmaline, have been developed. More often a more or less complete segregation has occurred, forming ill-defined greenish nodules and layers. At greater distances from the trap, the shales are purple and pink, having tints which resemble exactly those often taken by kiln-burnt stones. This resemblance is so strong that often the unskilled observer of the neighborhood does not hesitate to call them "baked" rocks. These changes caused by contact metamorphism will be considered more in detail later.

Localities.—From Hoboken northward, outcrops of the arkose sandstones and of the metamorphosed shale are common along the foot of the Palisades. Good exposures are found near the Hunter steps, Paterson street, Hoboken; at the head of West Nineteenth street, Weehawken; at King's Point, near the Delaware and Hudson railroad coal pockets; and thence northward, to the West Shore railroad tunnel. At Guttenberg, beneath the cliff, there are frequent exposures both of the sandstone and of the black slate, particularly a short distance south of Lane and Son's quarry. At Shady Side, also, there are fine exposures of the metamorphosed shale, in which Nason has found numerous specimens of Estheria. At the eastern entrance of the New York, Susquehanna and Western tunnel, between Shady Side and Edgewater, the same rocks are again well exposed. This is also the case a mile and a half further north, near the power-house of the Bergen County Traction Company. Here there are thick exposures of the arkose sandstone and shales which make a fine display of the "burnt" tints. As this locality is within a hundred yards of the new Fort Lee and One hundred and Twenty-fifth street ferry, it is easy of access from New York.

From this point northward, outcrops along the water's edge are quite common, but generally not easy of access, since for much of the distance north from Fort Lee, there is not even a foot-path beneath the cliff. But at Sneden's Landing, Alpine, Huyler's Landing and east of Englewood, roads zigzag down the cliff to the water's edge, and the zealous searcher can there find good exposures. As these localities are all at least 200 feet below the trap, the highly-metamorphosed black slate is absent, but purplish and ashy "burnt" tints are not wanting, and often a hard scramble up the steep talus slope, along the line of some little stream bed, will reveal the jaspery slates or hornfels, and perhaps a contact.

On the west side of the Palisades exposures of the Stockton beds are by no means so common. The altered beds are shown in deep cuts at the west end of the West Shore tunnel, and also of the New York, Susquehanna and Western tunnel. The arkose sandstone is found in the railroad cuts half a mile north of Granton and again at the quarry in the eastern part of Ridgefield. There are obscure exposures along some newly-opened streets at Palisades Park and along the brook near Leonia. In the northern outskirts of Englewood a grey sandstone is found, which is somewhat indurated, possibly marking the upper limit of alteration. Traces of the sandstone were noted east and northeast of Tenafly, but in general the glacial drift buries deeply the rock. A mile and a half east of Closter, however, there are two quarries in the arkose sandstone, at which there is good opportunity to examine these beds.

Extent.—West of the southern part of the Palisade ridge there is a wide expanse of salt marsh, the Hackensack meadows. The upper limit of the Stockton series, were it to be drawn, would cross this belt which, of course, is without outcrops. Further north the drift is so thick along the probable boundary line that outcrops are very few. The typical Stockton beds were not observed west of the line of the Northern Railroad of New Jersey, although it is not impossible that were the drift stripped off they would be found further west. The indefiniteness of their upper limit is not, however, due entirely to the lack of exposures. As will be shown below, the conditions attending the deposition of the Newark beds in this area were quite unlike those of the region further south and west, so that the lithological subdivisions established last year for the western part of the State do not hold here.

LOCKATONG SERIES.

Constitution.—It was found in the western part of the State, that the Stockton beds were overlain by a series of hard, dark-colored shales and flagstones, to which the term Lockatong was applied, the name being taken from the creek along which they are best exposed. They consist (*a*) of carbonaceous shales, which split readily along the bedding planes into thin laminæ, but which have no true slaty cleavage; (*b*) hard, massive, black and bluish-purple argillites, which break sharply in any direction with a marked conchoidal fracture, but never split into thin layers along the bedding planes; (*c*) dark grey and green flagstones, some layers of which afford slabs nine or ten feet in diameter and three or four inches thick; (*d*) dark red shales, approaching a flagstone; (*e*) and occasional thin layers of very impure black and drab limestone, or rather highly calcareous shales. Gradations between these types are common.

Although many writers have called these beds "baked" shales, and have ascribed their color and hardness to alterations due to proximity of trap masses, they are in general quite different from the altered beds found near the trap. They often occur several miles from any known igneous mass, and are just as hard and black at this distance as where near the trap. Moreover, comparatively soft, thin layers of highly carbonaceous shales occur between beds of hardest argillite, and if the latter are the result of local metamorphism, it is difficult to understand why the interbedded carbonaceous shales were not also altered. Furthermore, the texture and stratification of the Lockatong series is such that it does not seem possible they could have been formed from the red shales by any process of metamorphism. The dark-colored argillites, shales and flagstones form a distinct member

Mud-cracks on a weathered surface of Lockatong Argillite, Sourland Plateau.

of the system, and must not be confounded with the black and ashy-blue metamorphosed shale locally developed near several of the trap sheets. Microscopic examination by A. Andrae and A. Osann has shown that the latter are very different mineralogically from the former.

Both ripple-marks and mud-cracks occur at all horizons in the Lockatong beds, showing that shallow-water conditions prevailed, although the materials deposited were exceedingly fine. (Plate IV.)

Distribution.—As was shown in the Annual Report for 1897 (pages 42–46), these beds occur in three separate areas, in each case overlying the Stockton sandstones. The first of these is the Ewingville-Princeton area, which has an average width of two miles. At several points along the Delaware river, above Wilburtha, there are good exposures of these rocks, and again at the quarries at Princeton and those south of Kingston, on the Millstone river. East of the Millstone the beds are more or less obscured by more recent deposits (Pensauken, chiefly) and exposures are rare. The upper limit, so near as could be determined, extends from an outcrop of argillite on the Brunswick turnpike, southeast of Franklin Park, eastward to Lawrence brook, near the mouth of Beaver Dam brook, and thence, northeast along Lawrence brook, crossing the Raritan river below their junction. Outcrops of greenish-black and drab shale at Milltown are the last beds seen which can be put with certainty in this series. The isolated hill of red shale rising from beneath the Cretaceous clays about midway between Woodbridge and Perth Amboy, locates the Lockatong beds in that vicinity still further south. Data from well borings, however, indicate that the belt extends for several miles northeast from Perth Amboy.

The same beds outcrop again along the southeastern side of the Sourland plateau, where they rest upon the narrow strip of Stockton sandstones, which forms the escarpment of this upland. This belt has a width of one and three-quarter miles, the dip of the beds being from fifteen to twenty degrees to the northwest. Northeast of the village of New Market the Lockatong beds occur on both sides of the trap-sheet which forms the backbone of the plateau. This is due to the fact that the trap makes several sharp bends and descends to a lower horizon. About a mile south of Flagtown village the belt is terminated by a great fault which cuts obliquely across the strike.

Between the Delaware river and Dilt's Corner there is a small area of Lockatong beds, bounded by two faults. They grade downwards into the arkose sandstones of the Stockton series.

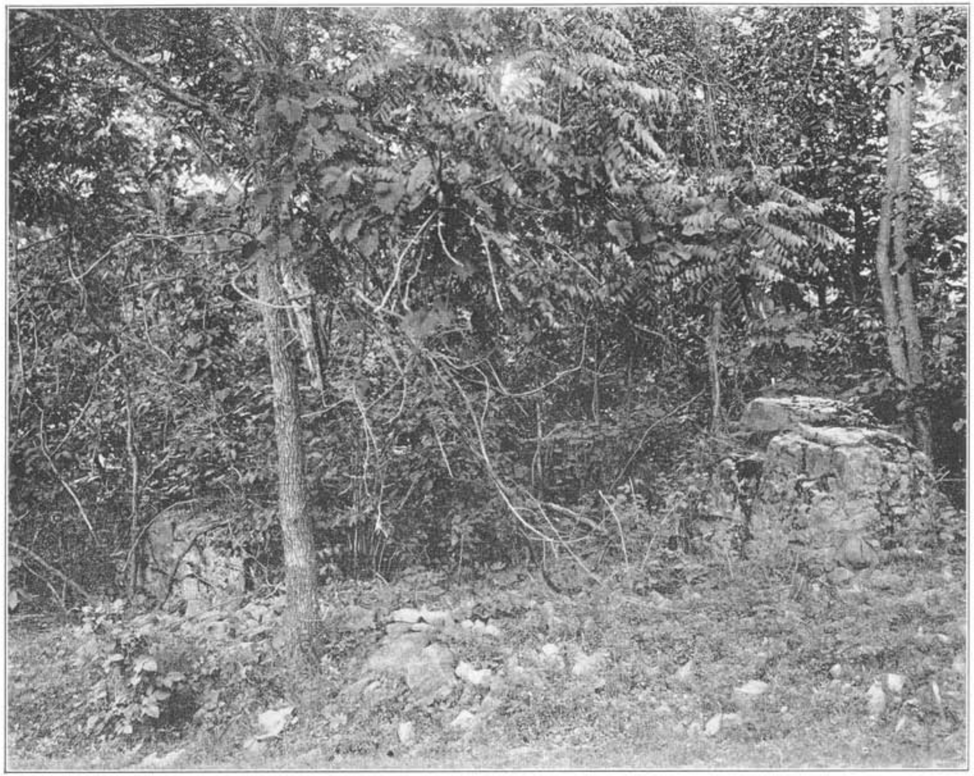
The most extended outcrop of the Lockatong beds occurs in Hunterdon county in the high area of country which in my earlier report I called the Hunterdon plateau and which is locally known as "the swamp." The slates and argillites here rest upon the Stockton beds which are quarried so extensively at Stockton and Prallsville. Between Sand Brook and Flemington, however, the sandstones are cut out by the great Flemington fault, and the hard argillites have been brought in contact with the soft red shales. To this fact is due the height and steepness of the escarpment between Sand Brook and Flemington.

The upper limit of this belt passes north of Kingwood village, along Mud run in a northeasterly direction; thence, curving gradually to the northward, it passes half a mile east of Oak Grove, and continues in a north by west direction towards Littleton. In this vicinity its location is largely an arbitrary matter, since, as will be shown below, there is here practically no difference between these beds and those higher in the formation.

The width of the belt increases gradually from about three miles along the Delaware to nearly four and a quarter west of Flemington, beyond which it slowly dimishes. The dip of the rocks averages only ten to thirteen degrees in this area as against fifteen to twenty degrees in the Sourland plateau area, so that with the same thickness of rocks, the outcrop would be much wider.

This belt forms a regular curve, parallel to the strike of the beds, which changes from N. 65 E. along the Delaware to N. 10 E. midway between Croton and Flemington, to N. 45 W. near Klinesville, and N. 30 W. near Pittstown. The height of the Hunterdon plateau is due to the wide outcrop, curving strike and hardness of these rocks, and the upper layers of the Stockton series, which have retarded greatly the forces of denudation, so that whereas the adjoining softer rocks have been reduced to an average elevation of under 200 feet, this belt has an elevation of from 500 to 700 feet.

Soil.—The Lockatong beds give rise to a rather heavy, clay soil. The surface is quite thickly strewn with slabs of the argillite and flagstone and on the slopes outcrops are generally abundant. Except in places favorable to the accumulation of the soil from higher slopes, its depth is generally less than five or six feet. On the Hunterdon



Bowlders of Lockatong Argillite, Sourland Plateau.

plateau it is more than usually wet and heavy. This is due in great part to the poor drainage of the region and the comparative impenetrability of the underlying rock. By tiling, the quality of the soil has been greatly improved. Abundant supplies of surface-water can generally be obtained from wells ten to fifteen feet deep, but it is not of the best quality.

Modification of the Lockatong Beds.—Midway between Croton and Quakertown these beds begin to lose their typical character. The change is mainly one of texture, but as a result of their increased coarseness, there is also a change in the color, the manner of weathering and the soil formed by their decomposition. The hard black, dark green and red shales and argillites grade into drab, red-brown, green and yellow shaly sandstones. Some beds become slightly arkose, resembling closely some members of the Stockton series. This change occurs *along the strike* and increases in amount as the northwestern boundary of the formation is approached. The change is first noted in the upper beds of the series, and gradually extends to the lower beds as one approaches the border. That is to say, the conditions which favored the deposition of the black shales and argillites extended in the earlier part of the period nearer to the present boundary of the formation than they did during the latter part. Along Cakepoulin creek there are good exposures of thick red and grey sandstones with occasional pebble-bearing layers, which strongly resemble the Stockton series, but are often somewhat harder. Yet these same sandstones, when traced along the strike, are found to grade into the flags, argillites and carbonaceous black shales which underlie "the swamp." Pebble-bearing layers, which were first noted along the section between Littleton and Sidney, increase rapidly in thickness and number to the northwest, and within a mile or a mile and a half the series is composed chiefly of massive beds of heavy quartzite conglomerates, which continue to the crystalline border. The conglomerates lying north and northwest of Pittstown are contemporaneous with the fine-grained, dense shales and argillites, and can be traced into them foot by foot through all the intermediate stages.

Absence of the Lockatong Beds in the Northern Area.—In the Report for 1896, page 42, it was noted that north of Princeton the beds which could be referred without any doubt to the Lockatong series, formed a belt less than a mile in width, whereas the average width to the westward was two miles. Since the inclination of the beds is slightly less than further west, the diminished width of outcrop cannot be due to the change of dip, because a gentler dip would give rise to a wider belt. Several explanations were suggested: (*a*) that the rate of deposition was slower in this vicinity during the time represented by the Lockatong beds elsewhere, and therefore the series here is thinner; (*b*) that deposition went on at nearly the same rate here as elsewhere, but that the conditions favoring the deposition of black argillite and shale did not last so long to the northeast of Princeton as they did nearer the Delaware; in this case the beds must change lithologically along the strike; (*c*) that the upper part of the Lockatong series has been cut out by a fault. Between these three hypotheses, it was not possible to choose. A few cases of crushed and contorted beds and slickensides lent a little plausibility to the last supposition.

When the region west of the Palisade ridge was examined no trace of the typical Lockatong beds could be found. As already indicated, the black slate along the Palisade ridge is the result of local metamorphism, and does not belong to the Lockatong series. West of the outcrops lie the broad Newark and Hackensack meadows—salt marshes beneath whose beds of clay and peat all traces of rock are lost. The Lockatong series, if present in this part of the State, should occupy the area of the meadow. When it is remembered that in the western part of the State these rocks are always ridge-makers, rising distinctly above the level of the rocks on either side, the impossibility of typical Lockatong beds underlying the salt meadows is at once appreciated. In Hunterdon county they are the mainstay of the plateau which rises from 350 to 500 feet above the red-shale lowland about Flemington. They, together with a trap-sheet a mile wide in outcrop, form Sourland plateau, which rises from 200 to 400 feet above the red shale plain northeast of Hopewell. Along the Ewingville-Princeton belt, they rise about 80 feet higher than the arkose sandstone country. In view of these facts there can be no hesitation in asserting that the argillites and flagstones cannot underlie the salt marshes.

Moreover, along the ridge to the north which at Little Ferry rises above the meadow, outcrops of soft red shale occur so frequently as to preclude the idea that the argillites form the mass of this ridge beneath the drift. West of the meadows and underlying Elizabeth, Newark, Rutherford and Hackensack, soft red shale and sandstone are found, which undoubtedly belongs to the third division of the system—the Brunswick beds.

In spite, therefore, of wide areas over which no exposures can be found, the conclusion seems fully warranted that the typical Lockatong beds do not exist within the northern half of the Newark area. The narrowing of the outcrop near Princeton fits in, therefore, with what has been observed further north. It is hardly probable that sedimentation ceased entirely in this northern area while the argillites were being deposited to the southwest, since there is no evidence of oscillations of sea-level or of unconformity. The hypothesis that the beds thin out from lack of deposition seems, therefore, improbable.

It would seem, also, that the hypotheses of faulting had best be laid aside, since there is no positive evidence in favor of it, and all the large faults known in the New Jersey-Newark system, cause a repetition of the beds, not their suppression. The most probable explanation for the absence of these beds is, therefore, that the conditions favoring their formation did not prevail in the northern part of the basin; that here the red shales and sandstones were deposited contemporaneously with the argillites and flagstones to the southwest, and that could we trace the latter from the point near Princeton, where they begin to disappear beneath the Pensauken and Cretaceous deposits, we would find all the steps in their transition to the soft red shales. It follows from this that the term Lockatong, when used apart from the particular rocks to which it was first applied, represents certain *conditions of sedimentation*, which resulted in the deposition of hard shales, flags and argillites, and not a definite *time-period.*

BRUNSWICK BEDS.

Constitution.—It was shown in the Report for 1896, pages 47–50, that above the Lockatong beds in the western part of the State, there is a great thickness of soft shales with a few sandstone layers. They are predominantly red in color, although a few purple, green, yellow and black layers occur. In general the series consists of a monotonous succession of very soft argillaceous red shales, which crumble readily into minute fragments or split into thin flakes, particularly when the beds are strongly micaceous. Although the bulk of this series is soft red shale, there are some black layers and occasional beds of fine-grained sandstones, some of which afford valuable building material. In the northern part of the Newark area, these beds are on the whole much coarser than in the central and southwestern part, sandstone and conglomerate layers being quite abundant. Massive conglomerate beds also occur at several points along the northwest border of the formation, a part of which are correlatives of the Brunswick shales.

Evidence that these beds were deposited in shallow water is abundant. Ripple-marks, mud-cracks and raindrop impressions occur at many horizons. In some quarries impressions of leaves, and of stems of trees, or the stems themselves, are not infrequently found. Occasionally slabs are found bearing the foot-prints of reptiles and other vertebrates which wandered over the soft mud flats while these beds were in process of accumulation.

Distribution.—The Brunswick shales occupy all the area, save that occupied by the belts of the other two series and the trap-rocks. They underlie by far the greater part of the whole area, partly because they are much thicker than the other subdivisions and partly because they form broad, gentle folds.

Along the Delaware river they are first found a mile and a quarter below Washington's Crossing, whence they extend to near Moore's. Below Washington's Crossing there is an almost continuous exposure for over a mile, in which at least 1,700 feet of beds are shown. These rocks extend northeast and underlie the rolling country from Hopewell to New Brunswick and beyond.

A second belt begins on the Delaware, just below Lambertville, where the shales next the trap have been much altered. Its upper limit is at the southern extremity of the small trap hill, Mount Gilboa, a mile above Lambertville, and it extends north by east past Flemington, following the fault-line which has brought to the surface the Stockton and Lockatong beds of the Hunterdon plateau. The lower beds of this belt form the northwestern slope of Sourland plateau, at the northeastern end of which, where it is known as Neshanic mountain, the two belts of red shale on either side unite to form one broad, gently-rolling lowland, the valley of the Raritan.

Owing to the curving fault-lines and the gentle folds of the strata, the Brunswick shales are the only beds * found along a section across

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* The conglomerates near Pottersville are the shore equivalents of the red shale and belong in the Brunswick beds.

the Newark formation, as here exposed, from New Brunswick to Pottersville, a distance of twenty-five miles. Along this line the Lockatong and Stockton series on the south are buried by the Cretaceous beds, and have not been brought to the surface by the faults which have so greatly increased the width of the Brunswick outcrop. The best exposures are found along the Raritan above and below New Brunswick, and along the Delaware below Washington's Crossing. Good exposures also occur along the Millstone, the South Branch and the Neshanic rivers, and along many of the smaller brooks which drain this region, particularly the short and steep tributaries of the Delaware.

The Brunswick shales are found also above the Lockatong series in the northern and lower part of the Hunterdon plateau. They are exposed in high bluffs along the Delaware from near Tumble station to the crystalline rocks near Holland station, and along the numerous creeks emptying into the Delaware between these points. Black and green shale layers occur somewhat frequently in the lower beds, and are rare, though not entirely absent, in the upper layers.

It was found that the shales of this area, when traced along their strike towards the margin of the formation, became rapidly coarser, passing, along some horizons, into massive conglomerates. It will be remembered that similar changes were found to take place in the Lockatong beds, so that within two or three miles of the margin the distinctions between the three subdivisions are largely obliterated.

Brunswick Series in Union, Morris, Essex and Bergen Counties.—What has already been said of the Brunswick beds applies particularly to the area surveyed in 1896, and to a less extent to the northern half of the Newark area. Within the area examined this past season (1897) certain significant changes were observed in the texture and structure of the beds. These require somewhat careful consideration. In the main they are an increasing coarseness in the deposits as one goes northward, so that the Brunswick shales gradually change to sandstones and even to conglomerates. This change is more gradual than the rapid transition noted last year as occurring in Hunterdon county along the northwestern boundary. The character of this change will best be understood by a somewhat careful statement of the following details.

Elizabeth and Westward.—For several miles east of Metuchen and Plainfield rock exposures are very rare owing to the morainal accumulations. The few observed are of the typical soft red shale. In the northern and eastern part of Elizabeth the drift is thirty to forty feet in thickness,* but in the western part of the city a few exposures of sandy shale were noted. At Irvington Mills a small quarry was found where the shales are decidedly arenaceous, even deserving the name of sandstones. The same beds outcrop along the road in the western part of Irvington, a mile north.

Newark and Northward.—In Newark a ledge of red shale outcrops at the corner of Sussex avenue and Summit street, and the same or similar beds undoubtedly underlie the hill along High street, where in laying sewers rock was found within six feet or less of the surface. The quarries on Bloomfield avenue, which once yielded annually from fifty to sixty thousand feet of stone, worth one dollar a foot, are no longer worked. Both sandstone and shale beds occur, the former being a brownish-red feldspathic freestone easily worked. The same beds outcrop again in several abandoned quarries along Second river, below Soho and Woodside Park.

West of Newark no exposures were found through the Orange towns, until the steep slope of First mountain was reached. West of South Orange sandy red shale outcrops a short distance below the trap. Similar beds were noted two miles further north by east, west of Orange valley. Northward from here the beds become coarser and have been quarried for sandstone a mile northwest of McClellan, beneath the famous basaltic columns in O'Rourke's quarry. Good exposures of similar sandstone and shale beds were noted along the brook in Llewellyn Park, where the sandstone layers are from two to three feet in thickness, separated by six-inch layers of shale. Along the strike half a mile northward there is an outcrop of conglomerate along the road to Eagle Rock. The pebbles are quartz, and small. The exposure is significant in that it is the first indication of the conglomerate layers which are so conspicuous at this horizon a few miles further north.

In the brook near the Brighton avenue station on the Erie railroad, at a much lower horizon, there are good exposures of sandstone and shale. It is highly feldspathic and resembles closely the red-brown sandstones of the Stockton series, but its stratigraphical position shows that it is the equivalent of the red shale further south.

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*I am indebted to the City Surveyor for these figures.

Along the brook at Glen Ridge, also, there are fine exposures, both of sandstone and of shale.

Along a section through Kingsland, Avondale, Brookdale and Upper Montclair to the trap of First mountain, the beds, so far as exposed, are predominantly sandstones and sandy shales. The best exposures are at the famous Avondale quarries where the light-colored brownish-grey sandstone has been worked for many years. The sandstone layers are twenty to thirty feet in thickness, in courses commonly two or three feet thick. Interbedded with the sandstones are layers of argillaceous shale. The same layers may vary in texture from one quarry to the next, or even within the limits of a single quarry. Thin beds of a fine-grained conglomerate rarely occur, the pebbles being chiefly quartz and limestone. In the sandstones quartz and feldspar are the chief constituents, but the layers are mostly all calcareous. In fact, hand specimens from these quarries could be distinguished with difficulty, if at all, from specimens of the finer-grained sandstones from the Stockton or Wilburtha quarries. So far as lithological character goes these rocks ought to be put in the Stockton series. But their stratigraphical position in the Newark system seems to be far above the Stockton beds. The facts on which this conclusion is based are as follows: The trap-sheet forming First mountain is extrusive in origin. That is, it is an overflow sheet, and, therefore, its base is conformable to the bedding of the sandstones, and represents a constant horizon. This being the case, it gives us a reliable datum line. The position of the sandstones of Avondale in reference to the trap agrees with that of the Brunswick shales further south, and not with that of the Stockton series. Second, they are too far removed from the base of the system, which follows the Hudson river, to be classed with the Stockton beds. Thirdly, when traced southward along the strike as closely as possible, considering the limited number of outcrops, they appear to grade into soft argillaceous shales.

Although great weight is attached to these arguments, and this correlation is believed to be correct, it must be admitted that they are not conclusive. It is within the bounds of possibility that owing to a system of faults, of which I have found no traces, these sandstones belong in the Stockton series. But all of the known facts save that of lithological likeness support the other conclusion.

I have already shown that the Lockatong beds do not exist in this part of the Newark area, their time equivalents being represented by red shales and sandstones. The resemblance of the Avondale sandstones to many of the beds of the Stockton series shows that the subdivisions made in the southwestern part of the State do not hold for this area. It will be found convenient, however, to use the terms Stockton and Brunswick to denote relative position, although here the two are not sharply separated from each other, and it was impossible to differentiate the equivalents of the black argillites (Lockatong series).

At Passaic good exposures of thin-bedded shaly sandstones were noted near the high school and the Continental Match Company's factory. Cross-bedded sandstones and shales outcrop at many points west of the town. Feldspathic sandstone also occurs in an abandoned quarry near Athenia station on the Erie railroad, and in the railroad cuts half a mile northward conglomerate layers are found interbedded with the shale and sandstone.

Hackensack to Paterson.—Along a section from Hackensack to Paterson the beds are on the average coarser than further south. In the western part of Hackensack soft argillaceous shales occur, the best exposure being in the railroad cut near Prospect avenue station. At the western end of the cut a fault has brought heavy sandstone beds against the shales. On the next ridge west, on which Maywood is situated, the beds are chiefly sandstones, with a few pebble-bearing layers and some shales. The pebbles are chiefly quartz, feldspar and limestone. Somewhat similar beds occur near Rochelle Park. Thence there are practically no exposures until Paterson is reached. Here, however, in the southern part of the city, and in the numerous quarries under Garret rock and below the falls there is a fine opportunity to examine carefully the composition and the structure of these beds. Sandstone, quartzite, quartz, limestone, shale and feldspar pebbles, up to five inches in diameter, occur in the conglomeratic layers. Not a single gneissic nor granitic pebble was found. Considering the fact that along the nearest border of the Newark beds only the latter rocks occur and no quartzites, sandstones or limestones are known, the constitution of these beds is significant. The quartz and feldspar were undoubtedly derived from gneissic or granitic rocks, but the absence of all granitic pebbles indicates that these rocks were thoroughly disintegrated into their constituent minerals. Some of the sandstones and quartzite pebbles are lithologically identical with the members of the Green Pond mountain group, and their presence here seems to imply the former greater extension of those rocks. The smaller limestone and feldspar pebbles are usually much disintegrated, being often not more than bits of clay. The sandstones accompanying the conglomeratic layers seem to be composed chiefly of quartz and feldspar.

Bergen County.—Similar coarse-grained sandstones and conglomerates occur further north to the State line. The topography of this part of the Newark area reflects the difference in texture. Where the Brunswick beds are soft red shales, the surface is a gently-rolling lowland, having an average elevation of from 100 to 200 feet above tide. With the appearance of the coarser and more resistant beds the general elevation becomes greater, and in place of the gently-rolling lowland, we find a series of ridges and valleys following very closely the trend of the beds. Toward the New York State line the higher of these sandstone ridges attain elevations of 450 to 625 feet above tide, the local relief being 200 or 300 feet.

Practically the only exposures of rock are found along the ridges, since the valley bottoms are deeply filled with glacial deposits. The rock of all the ridges is much alike. It is a coarse sandstone with some pebble-bearing beds and occasional shale layers. Nason * ascribed the repetition of the ridges and the similarity of the beds to faults along the valleys parallel to the strike. The question of faults will be discussed below, so that the matter may be dismissed here with the statement that no positive evidence of faulting could be found, and that the topography finds ready explanation on the assumption of alternating hard and soft beds through a great thickness of strata.

The areas where the rock outcrops frequently will be briefly mentioned. Along the crest of the ridge north by east of Arcola, the conglomeratic sandstone comes near the surface. At the northern end, near the Home of the Incurables, it has been recently quarried to obtain stone for a new building. Here, as at Paterson, the constituent pebbles are sandstone, quartzite, quartz, limestone, slate and feldspar, while there is an entire absence of granite, gneiss or schist. Occasionally pebbles five inches in diameter occur. The stone rough-dresses easily, and the smaller pebbles do not detract from its beauty.

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* Nason. Annual Report of the State Geologist of New Jersey, 1888, page 25, *et seq.*

Doubtless, quarries of considerable value might be developed here as the drift is thin. From New Milford northward to the State line, exposures are wanting over a belt several miles in width. But northward from Paramus, between the Pascack and Saddle rivers, the rock is exposed in many places, particularly on the eastern slopes: (*a*) at Storm's mills, (*b*) along the hillside one-third of a mile to the west, (*c*) on the hillside west of Woodcliff (formerly Pascack), (*d*) along Bear brook, and (*e*) on the road along the crest of the hill half a mile west, there are good exposures of this same coarse sandstone with conglomêrate layers. At several places, also, on the slopes and crests of the hills east and southeast of Saddle River village, there are outcropping ledges.

West of Saddle river to the limits of the formation along the base of Ramapo mountain and north of the latitude of Hohokus, there are almost no exposures, the drift being everywhere so thick as to effectually bury all the ledges. From the constitution of the drift and the similarity in topography, however, it is concluded that the beds are not different from those further east.

At Hohokus there are good exposures along the creek and the railroad, and again at Midland Park numerous cuts are found. Here again my notes indicate that granitic and gneissic pebbles are entirely absent, although quartz, feldspar, shale, limestone, quartzite and sandstones are common. At both places the creeks chose courses on the drift across thinly-buried ledges of rock. They soon eroded their channels through the unconsolidated beds and were forced to cut downward in the sandstone. Above and below these rock gorges the streams are flowing in channels cut entirely in drift, the sandstone there lying deeper and not yet having been reached. Such cases of local superimposition are common in all drift-covered regions, so that these streams have had an experience common to thousands of others in the northern part of the United States and Canada. Ledges also occur along the small creek north of Van Winkle.

Brunswick Beds between First and Second Mountains.—In the valley separating these two trap-sheets, beds of shale and sandstone occur which are higher in the series than any yet mentioned. South of the moraine and its associated gravel deposits, exposures are frequent, whereas to the north there are but few places where anything more than mere traces of the rock can be seen. A line of quarries located at Pluckamin, Martinsville, Washingtonville, Pleasantdale, Little Falls and Haledon afford good opportunities for studying the strata. The beds along Mine brook southwest of Bernardsville and adjoining the crystalline rocks, belong to the same horizon as those in the Martinsville-Pleasantdale valley. This is due to a gentle synclinal fold or trough in the beds, which is shown most clearly by the crescent shape of the trap ridges.

They are composed of soft red argillaceous and micaceous shales, some green and black shales, and grey, greenish, yellow and red-brown sandstones. At Smith's quarry, Warrenville, the original color of the sandstone was steel-blue or darker, and it has been weathered to a yellowish grey. Small cores of the unaltered stone occur in the center of the larger blocks. The weathered zones are parallel to the joint planes, and slabs, if broken at right angles to the jointing, often show a concentric zonal or banded structure. In small specimens these might be mistaken for stratification laminæ of different colors, but in the quarry they are seen to be independent of the dip and strike and are clearly due to weathering.

The composition of the sandstone all along the valley is much the same. Macroscopically, quartz and mica predominate with a less amount of feldspar. The "rust brown" specks so conspicuous in most of the Wilburtha and Stockton stone do not occur.

The evidence is strong that the sandstone beds are local lenses, not infrequently thinning considerably within the limits of a single quarry, so that although they occupy the same general horizon, individual layers are not continuous throughout the entire valley.

At Feltville (Glenside Park) the following section is exposed in the bluff just below the row of cottages:

(1)	At top. Soft red shales	Several feet.
(2)	Red-brown sandstone, slightly shaly	1 foot.
(3)	Soft argillaceous red shale	9 feet.
(4)	Grey semi-crystalline limestones	⅓ foot.
(5)	Soft argillaceous shales, red	1 "
(6)	Calcareous black shale, locally almost a limestone	1 "
(7)	Black limestone	¼ "
(8)	Dark grey shale	⅙ "
(9)	Drab and black limestone in beds from one to three inches thick	1 "
(10)	Red sandy shale, very calcareous	¼ "
(11)	Soft red shales and shaly sandstones	1¼ feet.
(12)	Reedy red-brown sandstone	Base not shown.

The above section illustrates the constant change in texture characteristic of many of the Newark beds. Nowhere else along the valley were beds of limestone found, but that is not surprising when the thinness of these beds and the lack of exposures in many places is considered.

Brunswick Beds above (west of) Second Mountain.—Between Second mountain and Long hill outcrops are common west of New Providence. East and northeast of that place the glacial deposits obscure the rock save for an occasional outcrop high on the flanks of Long hill. The beds are soft red shales, with a few greenish layers. No sandstone was found and it is not probable that any considerable beds occur. The best exposures are in the railroad cuts near Stirling and in the gorge at Millington. At Stanley and Chatham the same beds are exposed.

North of Chatham, and within the drift-covered area, beds at the same horizon can be found on the east side of Mine Hill, west of Livingston, where red argillaceous shales are found a few feet below the trap. Thirteen miles northeast, near Upper Preakness, wells near the Union hotel and Point House hotel, on the Hamburg turnpike, reach red shale, of perhaps of little coarser texture, at depths of thirty feet. Still further north, and at the same horizon, outcrops of shale and red-brown sandstone occur about a mile south by east of Pompton lake.

Along the road at the south end of Pompton lake, there is a good exposure of greenish conglomerate which apparently dips beneath the trap-sheet a few feet to the west. The actual contact is not shown. This trap-sheet occupies the same position relative to Second mountain as does the Long hill sheet, and they have been assumed by various observers to be parts of the same overflow. This being so, the conglomerates correspond stratigraphically with the soft red shales underlying the Long hill sheet, since, as has been shown by Darton and others, these sheets are overflows on uneroded beds, and their bases afford reliable stratigraphic horizons. These conglomerates are but slightly above the shales and sandstones which occur at point a mile south by east of the lake.

Much of the conglomerate is so poorly consolidated as to be readily worked for road gravel, although this may be due to recent disintegration. The pebbles, which range up to ten inches in diameter, are of hard green sandstone, limestone, black slate, purple quartzite, the members of the Green Pond mountain group, and their presence here seems to imply the former greater extension of those rocks. The smaller limestone and feldspar pebbles are usually much disintegrated, being often not more than bits of clay. The sandstones accompanying the conglomeratic layers seem to be composed chiefly of quartz and feldspar.

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There are fine exposures of interbedded red and green shale, sandstone and massive conglomerate along the brook, three-eighths of a mile east of the above-described conglomerate. In the latter, limestone cobbles over a foot in diameter are not uncommon. Directly beneath one conglomerate mass, a fine-grained, thin-bedded, black shale occurs, in which are occasional fossil leaves. Similar coarse and fine beds occur at a few other points in this vicinity.

The position of these conglomerates interbedded with shales and undoubtedly grading into other shales at a short distance from the border of the formation, accords perfectly with what has already been noted as occurring at many other points along the northwestern border. The conglomerates do not form a definite horizon of themselves, but are strictly local accumulations which occur at all horizons.

The red shale which outcrops at various points between Millington and Basking Ridge is still higher in the series than any I have heretofore mentioned, overlying as it does the trap of Long hill, the third of the concentric trap-sheets. Lithologically it does not differ from beds at lower horizons.

Northeast of Basking Ridge there are exposures of red and green shale, with some black carbonaceous layers. The latter have given rise to the belief that beds of coal occur in that vicinity. Similar red and green shales are found within the crescent-shaped trap ridge near New Vernon. Here the beds form an anticline, the axis of which dips southeastward, and the beds along the outer flanks are higher in the series than those nearer the center. Near the two ends of the trap ridge are hills of conglomerate, the pebbles of which are green and purple sandstones, conglomerate, quartz, quartzite and shale. Here, again, the gneiss and granite are very rarely or never present, although the crystalline rocks bordering the formations are almost within stone's throw.

Rock exposures are almost entirely wanting within that part of the Passaic basin from Basking Ridge to Boonton and Little Falls. Within this area are the thick alluvial deposits of the Great swamp, Black meadows, Lee meadows, Troy meadows, Hatfield swamp, Great Piece meadows, Bog and Vly meadows, as well as glacial deposits of more than ordinary thickness. This area all lies within the basin of the glacial Lake Passaic, and no small part of these deposits owe their origin to this circumstance.

A series of outcrops, however, was found close along the northwestern boundary from Boonton northeastward. Red and black shales occur along the Rockaway river below Boonton, in some layers of which finely-preserved fossil fish were found many years ago. With the shales are interbedded sandstones and conglomerates, the the latter composed of gneissic pebbles chiefly, with some quartz and quartzite. They are poorly rounded, and in some cases six inches in diameter. The fossil-bearing black shales occur in close proximity to the sandstone and conglomerate beds. These beds outcrop at intervals along the river for over a mile, and are about half a mile from the crystalline rocks. Their strike (trend) is N. 30–40 W., that is, at right angles to the border.

BORDER CONGLOMERATES.

In my earlier report * I described at some length conglomerates which occur at a number of points along the northwest boundary of the formation. In order to render this report the more complete, the important points concerning them are here repeated.

Quartzite Conglomerates.—At a number of points there are thick accumulations of massive conglomerates, composed chiefly of quartzite and hard sandstone. Pebbles of limestone, gneiss and shale occur sparingly in some layers. All the constituent materials are well rounded, a fact which in the case of the hard quartzite indicates a long period of attrition.

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* Annual Report of the State Geologist, 1896, pages 50-54.

These conglomerates, interbedded with sandstones and shales, are best exposed in the "pebble bluffs" along the Delaware river above Milford. The conglomerates form lenticular beds which thin out in the distance of a few rods to be replaced by beds of a different texture. The alternation of beds betokens shore conditions. The heaviest accumulations of this conglomerate underlie the high region stretching northwest from Pittstown and south of Pattenburg. This region is known as "the Barrens" from the nature of the soil—an exceedingly stony clay, resulting from the disintegration of the conglomerate. Less massive accumulations occur, also, at other points, chiefly south of Clinton, and again four miles north of Peapack, where there is an outlier called Mount Paul. The conglomerate hills near New Vernon, and also those near Pompton lake, mentioned on page 50, fall into this category.

Calcareous Conglomerates.—Conglomerates composed almost entirely of limestone fragments frequently occur. This rock is in appearance almost the exact counterpart of the famous "Potomac marble" quarried at Point of Rocks, Maryland. The limestone pebbles are usually bluish or grey, sometimes reddish, set in a red mud matrix, so that the rock has a variegated appearance. The average diameter of the larger constituents is six or eight inches, but bowlders five feet in diameter have been seen, and at a quarry two and a half miles northeast of Suffern, N. Y., bowlders twelve feet in diameter are reported to occur. The larger fragments are generally rounded, but the majority of the smaller are sharp-cornered or at most subangular. Compared with the pebbles in the quartzite conglomerate, the limestone pebbles are but little worn, a fact of some significance in connection with the origin and source of the materials, since with equal transportation the softer limestones must have been most worn. In many localities this conglomerate is so pure a limestone that it is quarried and burnt for lime for local use.

Gneissic Conglomerates.—Locally a few gneissic and granitic pebbles occur in the quartzite and limestone conglomerates, but they form a very insignificant part of the whole. Not uncommonly the most careful search failed to reveal a single pebble of this character. There is, however, one area where these pebbles constitute by far the major part of the formation. This area was not described in the earlier report, as were the others, and so may be given more space here.

It begins near Montville and extends for two to three miles northeastward along the border of the formation. The rock occurs mostly in low hills bordering the loftier crystalline highlands. Between the rock knolls, and locally more or less completely covering them, there are flat-topped hills of sand and gravel, some of them being glacial deltas marking the shore-line of Lake Passaic.*

At Montville there is one exposure along the road, three-eighths of a mile south of the village; another ledge just below the mill-d am near the canal, and a third in the railroad cut half a mile east of the village. At all exposures the rock is a coarse conglomerate with cobbles not uncommonly a foot in diameter. The bulk of the material is granitic and gneissic, five or six different types of crystalline rocks being present. Quartzite, sandstone and limestone pebbles are common in the exposure alone the railroad, but were not noted at the other points. Amygdaloidal trap pebbles form a significant, although small part of the constituents, both at the mill-dam exposure and along the railroad. The most conspicuous rock is a coarse-grained granite, with large pinkish feldspar crystals, which is abundant both in these beds and in those exposed to the northeast. The matrix is composed of the disintegrated and smaller fragments of the same rock as the pebbles. Outcrops occur at frequent intervals to the northeast, particularly near the Jacksonville school-house, along the road leading from Whitehall to Pompton Plains. The proportion of trap, quartzite and limestone pebbles varies slightly at different localities, but traces of each can usually be found.

Rising slightly above the level of these rocks are two small areas of trap. One of these lies three-fourths of a mile north by west of Whitehall, the other two miles north by east of the same place. At both localities the rock is vesicular, and the ropy structure is shown. Coils of dense, firm trap are involved with vesicular and scoriaceous beds, as if a partially cooled mass of lava had rolled over and over. Locally this structure may, in a small exposure, resemble a massive trap conglomerate and readily be mistaken for it. This seems to have been true in the case of the area two miles from Whitehall, which was so described by Nason.†

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* Annual Report of the State Geologist for 1894, pages 279–283.

† Annual Report of the State Geologist for 1888, page 41.

The origin of the trap pebbles found in the gneissic conglomerate of this vicinity is not beyond question. Nason* has held that they were derived from dikes in the neighboring crystalline highlands. This does not necessarily follow. The pebbles are vesicular trap, and, so far as their external appearance goes, they may have been derived from Hook mountain or from either of the two Watchung ridges. According to my observations the trap dikes of New Jersey are never vesicular. It will be shown later that Hook mountain and the Watchung ridges are overflow trap sheets. They occupy a lower horizon than do the conglomerates under discussion, and, therefore, the outflows of lava antedate the formation of the conglomerates. Since the Hook mountain sheet is the nearest stratigraphically, it is more probable that the pebbles were derived from it, than from the Watchung sheets. If so, the former sheet must have been exposed to the action of the weather and waves while the uppermost Newark beds were forming.

Relations of these Conglomerates to the Older Rocks.—The relations of these conglomerates to the older rocks along the border are significant. In some cases the calcareous conglomerates adjoin small areas of Paleozoic limestone, from which the materials may have been and probably were derived. In other cases, and *this is true of the largest areas,* the calcareous conglomerates abut against the gneissic rocks, and for much of the distance it is certain that no limestone occurs between the gneiss and conglomerate, at least not at the surface horizon. Crystalline pebbles, however, are comparatively rare in the conglomerate. Substantially the same conditions prevail in the case of the quartzite conglomerate. For the most part it adjoins the gneiss, but gneissic pebbles in it are rare. The known areas of quartzite along the border are small and in general not near the massive conglomerate beds. Lithologically, moreover, they are unlike the bulk of the quartzite pebbles.

A numerical statement of the case makes the contrast greater. Between the Delaware river and Pompton, the northwestern boundary measures sixty-five miles and a half. The older rocks are distributed as follows:

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* Annual Report of the State Geologist for 1889, pages 68–70.

Gneisses and granites	49¾	miles.
Limestone	6½	“
Shale and slate	8½	“
Quartzite	¾	mile.

The various rocks of the Newark system are distributed along the border as follows:

Quartzite conglomerate	19½	miles.
Limestone conglomerate	9¾	“
Gneissic conglomerate	4	“
Red shale	15¾	“
Trap	2½	”
Rock unknown (buried by drift)	14	“

That part of the boundary northeast of Pompton (ten miles) is not included in this estimate, since on both sides of the contact the rocks are almost completely hidden by the deposits of the Ramapo river. A contorted slate, seen at two points along the river, indicates that the Newark beds do not abut, at least not continuously, against the crystalline rocks of Ramapo mountain.

From these tables it is seen that whereas the gneisses and granites form the boundary for nearly fifty miles, gneiss conglomerates occur only along four miles. Even should all the unknown rocks (fourteen miles) be gneiss conglomerates—a thing altogether improbable—these conglomerates would be less in amount than the quartzite conglomerates. On the other hand, whereas the quartzite conglomerates are found for nearly twenty miles, the known areas of quartzite along the boundary measure less than a mile. The contrast in amount between the quartzite and gneiss conglomerates would be much greater were the width of outcrop also taken into account in the foregoing tables. It will also be noted that the belt of limestone conglomerate is fifty per cent. longer than the exposed limestone areas. In view of these facts, it is evident that along the greater part of this border the beds of the Newark system were not derived from the older rocks which now immediately adjoin them. The waves of the sea in which the Newark beds were deposited did not beat against the rocks which now border this area. The most probable explanation of these facts is found in the hypothesis of faulting along the border—an hypothesis which I shall develop more fully below.

Relation of the Conglomerates to the Shales.—The relation of the conglomerates to the shales is also an interesting and significant one. When traced along the strike the shales and argillites are found to grade into coarser beds which, at some horizons, become the massive conglomerates near the border. That this is the case has been established beyond a shadow of a doubt by numerous observations. Time and again thin pebbly layers were seen to appear in the shales and to increase in thickness and numbers until they became massive conglomerates. This is true both of the calcareous and of the quartzite conglomerates, and could doubtless be seen also in the case of the gneiss conglomerates were the exposures more abundant.

These conglomerates do not, therefore, form a separate horizon but range through the whole formation. In the bluffs on the Delaware river, above Milford, they belong with the Brunswick shale. So also do the beds of a part of "the Barrens" southeast of Pattenburg. The rocks of "the Barrens," north and northwest of Pittstown, pass into the Lockatong beds, and are therefore slightly older than the conglomerates nearer the Delaware. The pebbly layers south of Clinton belong to the Stockton series. Both the calcareous and the quartzite conglomerates near Pottersville and Peapack belong with the Brunswick beds. In the same subdivision must be placed the quartzite conglomerates near New Vernon and south of Morristown, the gneiss conglomerates near Montville, and the quartzite conglomerates south of Pompton lake.

I have already pointed out in considerable detail (pp. 47, 48), that in Bergen county, the Brunswick beds are as a whole comparatively coarse and contain many conglomerate beds with both limestone and quartzite pebbles. These are well shown in the quarries in Paterson. They are not basal beds brought up by a fault, as has been suggested by Darton.* On the contrary, toward the north, the whole mass of the Brunswick beds, so far as exposed, becomes coarser and even conglomeratic at many horizons. In these particular layers at Paterson, the pebbles were carried further to the southwest by the currents than in the immediately underlying or overlying beds.

It must also be understood that what has been said concerning the three types of conglomerates does not apply to the conglomerate layers interbedded with shales and sandstones, which occur either along the southeastern part of the formation, or near Hopewell, or

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*U. S. Geological Survey, Bulletin 67, pages 17, 18.

near Stockton. These latter are comparatively thin beds of little importance from a topographical standpoint and belong to the Stockton series. They present no features of particular interest.

CHAPTER II.—TRAP ROCKS.

In many of the earlier reports * of the survey, the trap rocks of the Newark system have been more or less completely described and their location shown upon the Geological map. Darton † has published an elaborate and valuable account of the principal trap masses and their relationship to the adjoining sedimentary rocks. Russell, Davis and many others have added to our knowledge of certain localities. In spite, however, of all that has been written by many observers, there is still much uncertainty, even among persons of the State who take no small interest in such things, concerning the origin of the trap rocks, their relations to the shales and their effects upon the sedimentary beds. In view of this I shall discuss somewhat fully these rocks and repeat some things which have been well known to all geologists for many years.

ORIGIN OF THE TRAP ROCKS.

The traps belong to that class of rocks called by geologists igneous, from the fact that they were formerly in a molten condition. While in this state they were forced up through the overlying solidified strata to the geological horizon at which they now occur. The nature of the force by which this was accomplished is not well understood, but the fact remains. The trap rock, which, by its composition and structure, is known to have once been molten is now included in beds of shale and sandstone. These are known by their structure and texture to have been accumulated under water from the fragments of older rocks. Manifestly the only explanation is that the trap was forced up from the highly-heated interior of the earth into the sedimentary layers, where it cooled at or near the surface.

The Newark trap rocks of New Jersey occur in three different ways. Some occur as sheets or layers perfectly parallel to the layers of shale or sandstone with which they are interbedded. The relation-

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* Geology of New Jersey, 1868. Annual Reports 1879, 1881, 1883, 1884, 1886, 888, 1896.

† Darton. U. S. Geological Survey, Bulletin 67.

PLATE VI.

Trap Bowlders in a stream bed on the side of Sourland Plateau, near Skillman.

ship is exactly what one would find in a case where first a layer of sandstone was formed, then a layer of molten trap overflowed the sandstone, and lastly other layers of shale or sandstone formed on top of the trap. Such a sheet would be called "extrusive" or an "overflow," since the lava was poured out over the surface of the sandstone layer. The Watchung mountains (both First and Second mountains), Long hill, the New Vernon sheet, Riker hill, Hook or Towakhow mountain, the New Germantown sheet and the Sand brook sheet are of this character.

A second type is found in the narrow almost vertical sheets or *dikes* which cut sharply across the shales at various angles. As seen in cross-section they frequently make angles approaching ninety degrees with beds of shale. Their occurrence is that of a molten or pasty mass of lava which has risen through a crack in the overlying beds, widening and filling it. At Blackwell's mills west of New Brunswick, and on the Croton road just west of Flemington, there are fine exposures of such dikes.

The third type stands between the two already mentioned. The rock is in sheets not infrequently several hundred feet thick, which lie nearly but not entirely parallel to the beds of the inclosing shales. They follow the bedding planes for a greater or less distance and are then parallel to the shales, but sooner or later they break across the strata to another horizon. In these cases the molten or pasty lava ascended through dikes or vents to a certain horizon, where it spread out between the layers, bulging up the overlying beds and occasionally passing from one bedding plane to another. These sheets are said to be *intrusive*, since they are forced into the beds. Manifestly, there can be all gradations between the dike which cuts the inclosing beds at right angles, and an intruded sheet which is nearly or quite parallel to the bedding. In the latter case it may be a matter of much difficulty to distinguish between an intrusive and an extrusive sheet. Rocky hill, the Palisades, Sourland mountain, Cushetunk mountain, Round mountain, and the other trap masses in the western part of the State are intrusive sheets or masses, which are more or less parallel to the bedding, although in every case they cut across it at one or more points.

There is usually no difficulty in separating the nearly vertical dike from the other two types, but the extrusive and intrusive sheets are often much alike. In spite of this likeness, however, there are many criteria * by which they may be differentiated. These differences are the result of the different conditions of origin. The extrusive sheet must be conformable to the surface on which it lies; the intrusive sheet may break across the beds. The one may show evidence of having cooled rapidly and not under pressure, by a vesicular, scoriaceous, glassy or ropy upper surface; whereas the other, having cooled more slowly beneath the surface and under pressure, will be coarser-grained, non-vesicular (save in rare cases), and may have metamorphosed the overlying beds. The extrusive sheet may contribute material to form the overlying sedimentary beds, and so be covered by a trap conglomerate or sandstone, or it may be associated with beds of volcanic ash and lava bombs, or the overlying sediment may work down into the inequalities of its upper surface, thus filling the vesicles and spaces between the clinkers. The intrusive sheet, on the contrary, may send off spikes and streamers of trap into the overlying beds, or may surround and inclose masses of the overlying rock which it has broken off as it forced its way along between the beds. There are other differences, but these are the most important.

ORIGIN OF THE RIDGES.

With the exception of a few of the narrowest dikes, all the trap masses are sharply marked topographically. The thicker sheets form hills or ridges rising several hundred feet above the general lowland. The extrusive sheets and those intrusive sheets which are nearly parallel to the bedding, have steep easterly faces, locally surmounted by cliffs and long, gentle westerly slopes corresponding to the dip of the overlying sedimentary beds. The popular view that these ridges owe their height to the upheaval of the molten lava to its present altitude above the shales is of course erroneous. Molten or pasty lava raised to the surface could not assume the present position and height of these hills above the shales, but must manifestly have flowed as a thin, nearly horizontal sheet over the surface. Moreover, the evidence is conclusive that some of the masses solidified between the shales at considerable distances beneath the surface of that time. Other sheets after extrusion were buried beneath many hundreds if not thousands of feet of sediments. From this it follows that all these masses of trap owe their present position as hills above the general level to the wearing away of the overlying beds. Since they are much more resistant to the attack of the agents

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* Davis. Bulletin of the Museum of Comparative Zoology 1889, pages 100-103.

PLATE VII.

The Raritan Valley Lowland from Sourland Plateau. The plain is underlain by the Soft Brunswick Shale. Compare with Plate VIII.

of disintegration and denudation than the shales and sandstones, they have been eroded less rapidly, and now rise above the softer rocks. This fact must be clearly grasped in order to comprehend at all the history of these rocks. Not only has a thickness of shales equivalent to the present height of the trap ridges been eroded from the lowland surrounding them, but many hundred feet of sedimentary rocks have been worn off their crests. They form hills and ridges, not because they have been pushed up higher than the shales, but because the latter have been worn down the faster.*

The Palisades.—The Palisades sheet is by far the most widely known of all the trap masses of New Jersey. No traveler along the Hudson river either by boat or by train can fail to notice its rugged, stern and almost forbidding cliffs. Fort Lee, erected during Revolutionary days, on one of its projecting points, connects it with the struggle for independence. The tragic death of Hamilton, on the fatal dueling ground at its foot, links it with the early history of the nation. In these latter days widespread attention has been directed to it by the efforts to induce the government to protect it from the attacks of the quarrymen.

On Staten Island the trap is quarried for so-called "granite" paving blocks. It outcrops at sea-level at Bergen Point, but the elevation gradually increases northward, being 250 feet above tide at West Hoboken, 333 feet at Fort Lee, 433 feet east of Englewood, until its maximum height in New Jersey of 547 feet is reached one and three-fourths miles south of the State line. Just north of the State line there is a broad, low sag, with an average elevation of about 200 feet, which at Sparkill is cut through by a narrow valley almost to sea-level. Within a mile northward, however, it rises to a height of 680 feet. Its maximum height of 832 feet is found at High Tor, just south of Haverstraw, where it curves westward away from the river, decreasing in elevation until it disappears beneath the glacial deposits along the western boundary of the Newark beds.

From Hoboken northward the sedimentary rocks outcrop frequently beneath the trap, and many localities are known where the igneous and sedimentary rocks can be seen in contact. South of Hoboken the contact of the trap and shale is below sea-level, but northward it rises to a height of about 180 feet east of Englewood,

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*A complete discussion of the topography of the trap ridges and its development is given in vol. IV., Final Report of the State Geologist, pages 27-40 and page 99 *et seq*.

of 240 feet at Alpine, and falls again to 100 feet* at Sneden's Landing.

On the west side of the ridge neither shale nor sandstone is found from Bergen Point northward almost to Schuetzen Park, the contact of the trap with the overlying shales probably being beneath sea-level. North of Schuetzen Park, however, the western flank of the ridge is formed of shales and sandstones, which north of Ridgefield attain considerable width. The upper contact is not so frequently exposed as the basal, but a number of localities are known to geologists where it can be seen.

Thickness.—Estimates of the thickness of the Palisades vary greatly. This is due in part to the probable great variation in its actual thickness, and to the difficulty of making accurate estimates in the case of a sheet, cut by many faults, more or less unconformable to the inclosing sedimentary layers, and deeply eroded. Darton† has estimated its thickness at Bergen Hill to be about 300 feet, near Weehawken about 400 feet, near the State line 700 feet, and at High Tor at not less than 850 feet. I believe these figures to be too small. A well recently drilled at Jersey City Heights‡ penetrated the trap to a depth of 364 feet, where sandstone was reached. But it is not probable that this boring represents the entire thickness of the sheet, since the upper part has been removed by erosion. My own estimates of the thickness near Weehawken vary from 700 to 875 feet, according to the varying angle of dip.

At Fort Lee the thickness is 950 feet, estimated on the basis of a dip of twelve degrees. Two large faults are here known to traverse the sheet, but allowance was made for them. That the thickness is more than the figures given by Darton is shown by the fact that a well at Fort Lee penetrated trap rock to a depth of 875 feet, where the metamorphosed slate was struck. The position of the well is such as to render it probable that the thickness of the sheet is slightly greater than this.

Under Contacts. 1. *Hoboken.*—A hundred yards north of the head of Paterson street, Hoboken, the trap occurs in contact with a hard arkose sandstone. The contact is extremely irregular, the underlying

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*These figures are taken from the topographical map, not from any levelings of my own.

† Darton. Loc. cit., page 44.

‡ Data supplied by P. H. & J. Conlan, Newark. The well was drilled for J. Mehl & Co.

rock being penetrated by several tongues of trap, and a large mass of the sandstone is inclosed in it.

2. For a mile and a half north of the above locality, the contact is beneath the level of the salt marsh deposits or is concealed by talus. When next exposed, the trap is seen resting upon black and purple shale (hornfels). About fifty feet below the trap and under the shale are beds of sandstone similar to those seen next to the trap at the head of Paterson street.*

3. *Weehawken.*—At the head of West Nineteenth street, Weehawken, the trap escarpment makes an abrupt turn to the east for 300 yards or more, and then resumes its northeasterly trend. The bend is caused by the sheet breaking across underlying strata and not by a fault. In a distance of about sixty yards, the trap can be seen to cut downward to the east across beds ninety feet thick. The actual contact is visible for only a small part of this distance, but the trap outcrops at constantly lower horizons. Angular fragments of the slate are found in the trap near the contact, and where it reaches the level of the street it is seen to rest upon heavy-bedded arkose. The trap descends somewhat more than a hundred feet at this point.

4. A few yards west of the corner of West Nineteenth street and Hackensack avenue, a mass of arkose sandstone was noted between two layers of trap. It is traceable for thirty-five feet with a maximum thickness of six feet, but owing to the talus its exact relationship is not certainly known. From its irregular shape it is probably a mass of sandstone broken off and inclosed in the trap, lying about ten feet above the base.

5. A short distance north of this corner the trap cuts obliquely across the heavy arkose beds in such a manner that as one goes northward it is found to rest on higher beds.

6. Near the entrance to Highland Park, Weehawken, the trap rests unconformably on heavy-bedded and slightly-indurated arkose sandstones.

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*Many of the facts hereafter enumerated, both for the Palisades and the other trap areas, have been described by earlier investigators. Cook, Russell, Davis and Darton have contributed largely to our information of the trap sheets and their relationships. In the following pages I shall describe more or less briefly all the localities noted by me, whether or not previously reported. The facts given are the result of my own observations even at localities previously described. To avoid the repeated use of foot-notes I wish to acknowledge here my indebtedness to previous writers, particularly to the above-mentioned geologists, for many suggestions gleaned from their writings and for aid in locating important points.

7. At King's Point the trap escarpment makes another sudden offset to the east. That this was due to faulting was suggested by Davis and demonstrated by Darton. (See below, chapter on faults). On the east side of the point along the railroad tracks is one of the best known of all the unconformable contacts.* The main mass of the trap ascends across the shale by successive steps, yet a stratum three and half feet thick extends between beds of highly-altered shale for about 100 yards until the trend of the beds carries it below the surface. The junction of the thin layer with the main mass is very obscurely shown, but the former is undoubtedly an offshoot from the latter.

8. Half a mile further north and directly below El Dorado tower, Weehawken, the trap again ascends obliquely across the shales for twelve feet, within a horizontal distance of forty-eight feet. Here, too, a long tongue of trap five feet thick extends from the main mass into the shale (Fig. 1, also Fig. 13, *A*). Locally the shale is much brecciated near the contact.

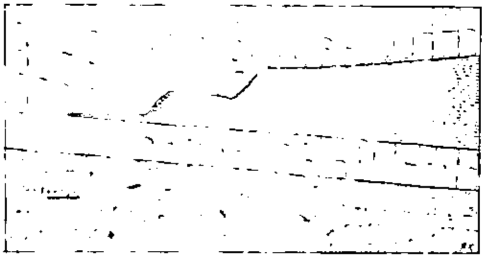

Fig. 1.

Diagrammatic sketch of the trap and shale at Weehawken, beneath the El Dorado tower. The shale beneath the tongue of trap is mostly concealed by debris.

9. At the eastern entrance to the West Shore tunnel, Weehawken, the trap rests conformably upon hard black slate, the contact being exposed for a distance of thirty-five feet, but just before it disappears beneath the talus, it breaks across the shales for a distance of three inches.

10. At intervals for several hundred yards north of the tunnel, the black altered shale outcrops from ten to thirty feet beneath the trap. Still further north a coarse heavy-bedded arkose sandstone is found within fifteen feet of the contact. The base of the trap sheet has changed its horizon once more, although the unconformity is not exposed.

At Guttenberg a trap dike four and a half feet wide is visible in the arkose beds thirty feet beneath the main mass. It is probably an offshoot from above, but this cannot be demonstrated.

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* Described by Russell, 1880; Cook, 1882; Davis, 1883; Darton, 1890.

11. At the south end of Lane & Son's quarry, south of Bull's Ferry, the trap rests conformably upon the somewhat indurated arkose sandstone. The exposure is not a long one.

12. Half a mile further north, in the southern part of Shady Side, it rests unconformably upon shale and sandstone, ascending northward about eight feet in fifty. Four or five feet below the main sheet there is a mass of trap within the shales, probably the cross-section of an offshoot from the overlying sheet. Although partially obscured by talus, no hesitation is felt in asserting that it is not a bowlder. It is clearly intruded into the shale.

13. At the eastern entrance to the New York, Susquehanna and Western tunnel the contact is conformable. The same relationship is shown along the road just north of the tunnel entrance. Hand specimens showing the two rocks welded together can be obtained without difficulty. At this locality, also, there are interesting cases of faulting which will be referred to later.

14. Just north of the power-house of the Bergen County Traction Company, Undercliff, there is a fine exposure of indurated arkose sandstone and red shale. The latter is the more altered of the two, various tints of purple and red being present. The rock has the peculiar shades often seen on kiln-burnt stones. During the building of the electric railway the contact was exposed near here. The trap cuts vertically across six or eight feet of shales, above which it extends conformably to the bedding. A thin tongue of trap extends from the main mass for a distance of ten feet between two beds of slate. Highly-indurated shale immediately underlies the trap and is succeeded downward by alternating beds of metamorphosed shale and arkose.

15. Near the water's edge at Fort Lee good exposures of altered rock are found. It is arkose sandstone, containing thin lenticular layers of vari-colored shale, which is so indurated as to closely resemble jasper. In color it presents the various shades of red and purple common to a kiln of fired brick. The whole aspect of the rock is indicative of a former high temperature. Nowhere has this aspect been observed in the Newark rocks except in the case of beds near certain trap sheets, particularly along the base of the Palisades. An obscure exposure along the public road just west of the Bluff Point Hotel shows the trap breaking across the edges

of the shale and arkose. The exact relations are not clear, but the fact that the two are not conformable is beyond all dispute.

16. For a mile above Fort Lee the talus hides the contact, but a short distance above Carpenter Bros.' quarry, under the cliff at Linwood, there is a fine exposure. The relations are best brought out by the accompanying diagram, (Fig. 2). The contact is an extremely irregular one, breaking across the beds in a most complex manner. Narrow tongues of trap extend into the seams between the beds of shale. A mass of shale and sandstone sixty feet long and ten feet wide is entirely inclosed in the trap, as is also a small piece of sandstone near it. Frequently along the contact the sedimentary beds are shattered and the laminæ much contorted. Elsewhere the black, highly-altered shale (hornfels) is welded to the trap so closely that only the most painstaking examination can separate the two. The sketch fails to bring out the minute complications where the trap breaks across the beds, the rocks frequently being so intricately interlocked that exact reproduction on a small scale is impossible. Beneath the trap the altered sediments are exposed continuously where a stream has washed away the talus for twenty-five or thirty feet further. Apart from a preponderance of secondary minerals and a mottled-green segregation (kalk-silicate hornfels) in the beds near the trap, there is no marked difference in the amount of metamorphism of any bed exposed. A rough climb along a poor path through the thick bushes and over the talus blocks is necessary to reach this exposure, but when found it is one of the most significant along the entire length of the Palisades.

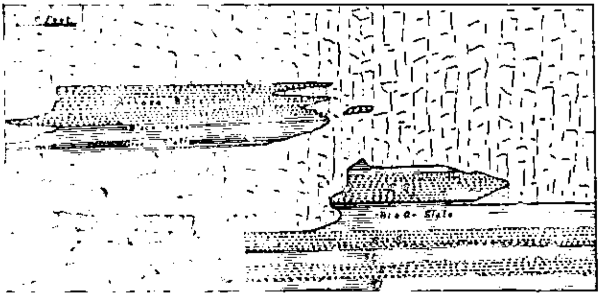

Fig. 2.
Diagrammatic sketch of the contact of the trap and underlying shale at the base of the cliff at Linwood, on the Palisades.

17. Southeast of Englewood a road winds its way down the face of the cliff. Along this road just south of a stone school-house the contact is exposed. Here the trap rests on arkose sandstone and cuts obliquely across the beds, ascending four feet in a distance northward of twelve feet. Bedding planes in the sandstone terminate abruptly against the trap, (Fig. 3).

18. Just back of the school-house the contact is conformable.

19. At Brown & Fleming's quarry, a mile further north, the blasting has exposed the base of the trap for a distance of fifty yards. The contact is difficult of access owing to the steepness of the slope below. Although following the beds pretty closely the trap apparently descends ten feet northward within the distance seen. The metamorphosed beds beneath present a great variety of types, including jaspery black slate more or less mottled, greenish-black slate (hornfels and kalk-silicate hornfels), quartzite and arkose sandstone, which in appearance closely resembles granite, some secondary fibrous green hornblende being present.

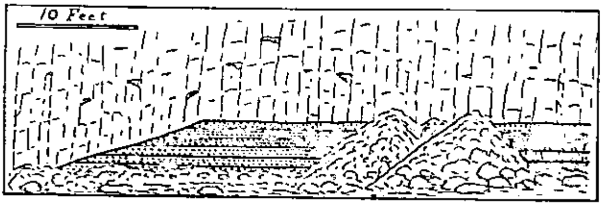

Fig. 3.
Under contact of the trap and arkose sandstone, east of Englewood.

The contact is not exposed near Huyler's Landing nor at Alpine, although at the latter place, arkose sandstone altered to a quartzite and indurated black shale are visible just below the trap. Both north and south of Alpine the talus extends above the base of the trap and is thickly grown with brush and trees, so that the opportunities for observing the contacts are wanting. The trap sheet has not been examined north of the State line.

Summary.—Nineteen localities have been cited where the under contact is visible. At fifteen of these the trap certainly crosses the beds from one horizon to another at some part of the exposure, although it may follow a bedding plane for a part of the distance. At three localities the trap is to all appearances perfectly conformable with the shales; but at only one of these three is the exposure more than a few feet in length. At one locality (Brown & Fleming's quarry) the trap seems to cross the sedimentary beds, but owing to the steep approach, which prevents careful examination, the question may be regarded as an open one. At every contact the shale is highly metamorphosed, not only next to the trap, but often at a distance of over a hundred feet vertically from it. The arkose sandstone layers are less affected, but they have not escaped induration. In by far the greater number of cases the trap ascends to higher horizons northward, so that its position at the State line is much above its horizon at Bergen Point.

The irregularities of the under surface of the trap, its constant shifting from one horizon to another, the tongues or offshoots from the main mass, the angular masses of the shale broken off by the trap and included in its basal portion, and the intense and far-reaching metamorphism which has everywhere affected the underlying beds to depths of over a hundred feet, all can be readily explained on the hypothesis that the trap was forced into its present position between the sedimentary rocks in a molten condition, and that it did not come to the surface and overflow. The vast erosion which has taken place during the millions of years since the intrusion, has removed the overlying shales and sandstones, thus bringing the surface down to the level of the solidified lava sheet. Not only do all the phenomena observed along the base of the sheet support this hypothesis and none oppose it, but the facts observed along the western or upper side are in harmony with it, and the texture of the trap itself is explained by it. These will now be considered.

Upper Contacts.—1. Between Bergen Point and Schuetzen Park (Homestead station) the trap is frequently exposed at tidal level, but the overlying shales do not appear. A few hundred yards south of Homestead station there is an old quarry in which highly-metamorphosed overlying shales are seen at intervals in contact with the trap for fifty feet. The position of the shales is abnormal, strike N. 30° W., dip 65° S. W., and the contact is approximately parallel to the strike, but there are local irregularities. In places thin offshoots of the trap two inches or less in diameter are intruded for short distances into the overlying shale. Locally the contact zone is twelve to eighteen inches wide. There is not the slightest suggestion of amygdaloidal or scoriaceous structure in the trap near the contact nor any trace of waterworn particles of trap in the overlying shale, such as might occur on the back of an overflow sheet.

A few rods to the north the boundary makes an abrupt turn to the east for half a mile, and arkose sandstone is found outcropping near the trap along the road high up on the side of the hill; thence northward to the West Shore tunnel the boundary is parallel to the trend of the shale and of the ridge. This abrupt eastward bend indicates either a descent to a lower horizon or a fault with down-throw on the east. There is nothing in the topography to favor the latter hypothesis. It is more probable that the trap breaks across the beds to a lower horizon to correspond to the sharp descent noted on the under-surface at the "observatory," Weehawken. (See 3, p. 63).

2. At the West Shore tunnel, however, the trap turns westward again and rises to a higher horizon. Just west of the entrance it is shown in contact with arkose sandstone, which has a strike of N. 40° to 45° E., and a dip 16° N. W. The trap crosses both the strike and dip of the sandstone very obliquely, the plane of contact striking N. 25° W. and dip 65° S. W. The accompanying diagram (Fig. 4) indicates the relations as viewed from above. Near the contact both the trap and sandstone are much decomposed. Darton, however, reports finding a welded contact here, which is proof that it is not due to faulting.

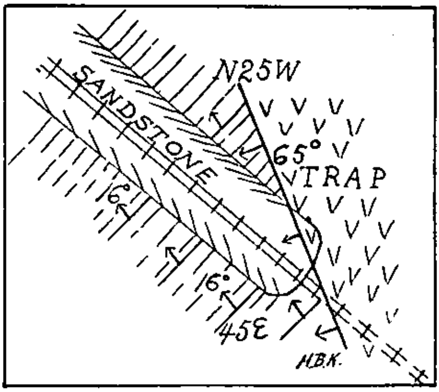

Fig. 4.

Map of the trap and overlying sandstone at the west end of the West Shore tunnel, Weehawken.

3. The contact is again exposed just within the western entrance of the New York, Susquehanna and Western tunnel. Here the indurated sandstone dips 9° westward, whereas the upper surface of the trap dips 18° westward. The contact is clearly shown in the side of the tunnel and there is no possibility of error in the observation. On the north side of the tunnel wall, near the level of the track, and about fifty feet from the entrance, two narrow dikes of trap, one six inches, the other varying from four to ten inches in thickness, penetrate the overlying sandstone for two and four feet, respectively. They extend nearly parallel to the upper surface of the sheet and

within two feet of it. Their contact with the sandstone is a welded one, and hand specimens can readily be secured, showing the two rocks in contact. Microscopic study has made clear the nature of the rock beyond doubt. Both dikes can be traced to within a few inches of the main sheet, so that there is no doubt as to their connection with it. The importance of these offshoots into the overlying beds in their bearing on the origin of the trap sheet is manifest. Clearly in an overflow sheet there could be no dikes extending into the overlying beds, since the latter would not exist at the time of the overflow. About ninety feet of interbedded shales and sandstones are exposed above the trap in this cut, the topmost beds being to all appearances as thoroughly metamorphosed as those next to the trap, and the total thickness of the altered beds is even greater than this.

4. In the woods half a mile northeast of Ridgefield the metamorphosed shales are exposed in the bed of a small brook. A few rods distant there is a broad exposure of the smooth upper surface of the trap, the dip and strike of which agree exactly with those of the shale. The trap to all appearances passes conformably beneath the metamorphosed shale.

5. Along Riley avenue, Leonia (Fig. 15, *A*), thin patches of intensely metamorphosed shale are found resting upon the trap, which is apparently nearly conformable to the bedding. Microscopic examination of a slide cut at right angles to the contact shows that the latter is in general a sharply-marked, straight or gently-undulatory line. At one point, however, a mass of the altered shale projects downward into the trap. Near this projection a small bit of the shale is included in the trap. For a distance of at least three-fourths of an inch the ground-mass of the trap is very fine grained and incloses phenocrysts of feldspar and augite. Next to the contact the ground-mass and the phenocrysts have been somewhat altered. At a distance of one and a half inches the trap is distinctly holocrystalline.

6. The top of the trap and the metamorphosed shale are exposed within twelve feet of each other, in the bed of a brook half a mile northwest of Linwood (Fig. 15, *B*). The dip of each is the same, ten to twelve degrees westerly; the slope of the hill is nearly the same. The impression gained by sighting along the trap is that it cannot pass beneath the shale without an increase of dip, and in this event it must be unconformable. This question is, however, an open one.

7. The altered shale and sandstone are again exposed near the trap along the brook half a mile or more east of Nordhoff (Fig. 15, *C*). Here, also, the trap surface has the same dip as the shales and apparently passes beneath them. There are fine exposures of the metamorphosed shales along this brook.

8. Along still another stream a little northeast of the above (Fig. 15, *D*) the trap surface is exposed, but here it does not present the smooth, gently-dipping character noted at the localities just cited. It is much broken by vertical joints which trend N. 30° E. The shale is not exposed near the trap, but it is buried by bowlders in the stream bed. It is questionable whether the shale could rise regularly along the dip and overlap conformably the trap where they would come in contact. It is quite possible that the abrupt termination of the trap and its jointed condition may be due to a sudden steepening of the dip at this place.

9. Three-fourths of a mile southeast of Tenafly the green jaspery shale is exposed along the bed of a brook, within thirty feet of the trap. The trap surface apparently passes conformably beneath it at an angle of 14°. At no points further north did I find the shale in contact with the trap.

Summary.—The actual contact of the overlying shale and trap has been observed at four places (1, 2, 3, 5). At two of these (1, 3) small dikes were found extending into the shale for distances up to four feet. At two localities (2, 3) the contact as a whole was not parallel to the shales, but crossed the beds. A microscopic study of slides from one locality (5) showed a bit of the sandstone included in the trap near the contact. At two localities (1, 5) the trap and shale were not markedly unconformable. In addition to these, five other places were visited where the shale and trap were observed close to each other, but not actually in contact. At four of these the weight of evidence favored the view that the contacts are conformable; at one it is apparently unconformable. In every instance the beds near the trap are much metamorphosed, to a thickness, in one case at least, far exceeding ninety feet. In addition to the nine localities just summarized the general outline of the trap north of Schuetzen Park indicates an abrupt change to a lower horizon. In no single instance were any of the phenomena observed which are typical of an overflow sheet. Nowhere, from Bergen Point to the State line, is the trap known to be vesicular, or scoriaceous, or amygdaloidal, or to have a ropy surface. In view of all these facts, many of which have been noted by earlier observers, the intrusive origin of this trap sheet can scarcely be called in question, certainly not by anyone familiar with the facts of the case.

Darton has stated that the trap ascended to its present horizon in the shales through a steeply-inclined dike which follows at or near the western edge of the ridge. The steep dip of the trap at the west end of the West Shore tunnel, Weehawken, is supposed to be due to the dike. At several points the topography of the western side of the ridge is suggestive of such a relationship. The evidence in New Jersey is not, however, as conclusive of this hypothesie as one might wish.

Texture and Composition.—On the whole the trap is coarse grained. Near the contact it is fine grained or occasionally slightly glassy, but the crystals rapidly increase in size within a few feet of the shale. Where coarsest, thin tabular crystals of feldspar, two or three-eighths of an inch in length, occur. Usually they are smaller. Compared with the trap of sheets which are known to be overflows, the texture is much the coarser throughout. These facts accord with the condition of origin indicated by the structural relations. The coarseness of grain indicates a slower rate of cooling than would have prevailed in an overflow sheet.

At a number of points at intervals of many miles a marked zone of deeply-weathered rock was observed between the dense and firm trap. It occurs in the cliff at Alpine, southeast of Englewood, at several points north of Fort Lee, opposite the public school at Weehawken and at several other points as far south as the Delaware, Lackawanna and Western railroad. This zone is from fifteen to twenty feet wide and occurs from forty to sixty feet above the base of the sheet, being apparently everywhere at about the same horizon. In all probability it occurs at many points where it was not observed.

The rock is probably of different mineralogical or chemical composition along this zone, but the exact differences are as yet unknown.

Andreae and Osann have made extensive microscopic studies of the trap. Both in its mineralogical composition and structure it is a quartz-bearing hypersthene diabase, composed essentially of plagioclase, monoclinic pyroxene (augite) and hypersthene, while a dark, reddish-brown mica, quartz and opaque minerals occur in very subordinate quantities. Ophitic structure is typically developed, but sometimes gives way to a porphyritic structure.

Within a distance of one or two centimeters of the under contact the structure is completely porphyritic, a few larger pyroxene and feldspar phenocrysts appearing in sharp relief from the very dense ground-mass. The amount of biotite is greater, and instead of the hypersthene, olivine occurs which is often altered to serpentine.*

The faults by which the Palisade ridge has been traversed will be considered later.

Granton Trap.—North of Granton station there is a small trap hill which presents some interesting features. The rock is exposed at the northern end in two quarries. At the one nearer the highway (eastern) the following section is exposed, beginning at the top:

1. Trap, 20 feet or more.
2. Arkose sandstone, 6 to 7 feet.
3. Trap, 10 to 12 feet.
4. Indurated green and black shale, 30 feet.

The contact of the upper trap and the arkose sandstone is obscured, but the two are apparently not quite conformable. The under trap is not quite conformable either to the arkose sandstone above or the metamorphosed shale below.

At the other quarry only one mass of trap is seen. The dike by which it ascended vertically across the beds was exposed at the time of my visit, as was also the place where it spread out as a sheet along one layer. A small fault, with throw of about twenty feet, apparently separates the rock in the two quarries.

Along the western margin of the area the trap plunges steeply below the swamp level, apparently descending at a steeper angle than the dip of the shales. Near the southern end of the railroad cut a small patch of overlying shales very much metamorphosed was found. Its length is not more than thirty feet and its maximum thickness is five feet. The contact is unconformable to the bedding of the shale. At F. J. Marley's quarry, a few rods further south, the under contact is shown. Locally the trap breaks abruptly across the shales for two or three feet at a time and extends parallel to the bedding for forty or fifty feet. Till obscures much of the eastern face of the trap mass. The sheet or sheets are clearly intrusive in origin. At the south end the maximum thickness is hardly more than seventy-five feet. This trap is so close to the Palisade sheet that it is probably an offshoot from it.

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* Andreae and Osann: Tiefencontacte an den intrusiven Diabasen von New Jersey. Separat-Abdruck aus den Verhandlungen des Naturhist.-Med. Vereins. zu Heidelberg. N. F. V. Bd. 1. Heft.

Snake Hills.—Two rocky hills rise above the level of the meadows between Hoboken and the Hackensack river. The smaller is entirely of trap, and its structural relations are unknown. The larger is mainly of trap flanked with shale and drift. Its maximum height is 203 feet. Quarries in the north, west and south sides give good exposures. Metamorphosed shale and sandstone outcrop at the northern end of the Penitentiary quarry. In the main part of the quarry a nearly vertical face of trap is seen, against which the shale formerly abutted. Traces of what seems to be a fault breccia together with slickensides occur along this face, but Darton, who studied the locality before the shale was so completely cleared away, makes no mention of faulting here.

In the quarry at the southwest corner of the hill, there is strong evidence of a small fault which has separated a low knob of trap from the main mass. In the old railroad cut at the south end of the hill metamorphosed shales are found underlying the trap. The latter appears to have ascended vertically at the dike on the west side and then spread for a short distance between the shales. That it is intrusive is indicated by its texture, which is coarse and not vesicular, and by the metamorphism of the shale. Earlier observers have assumed that both the trap masses are offshoots from the Palisade sheet. There is no direct evidence either for or against this supposition.

Rocky Hill Trap.—Reasons for considering this sheet intrusive were given in the Annual Report for 1896 (p. 62). The sheet crosses the shales obliquely from a horizon well above the base of the Brunswick beds down into the Lockatong series. The shale near it is everywhere considerably metamorphosed, so as to resemble closely the altered shales near the Palisades. There are some reasons for believing that these two sheets are one and the same, the connecting part being buried beneath Cretaceous beds. If this is the case, the Palisade-Rocky hill sheet ranges through all three members of the sedimentary series. Near Hopewell it is high in the Brunswick shales; east of Princeton it passes down into the Lockatong beds, and from Hoboken northward it ascends slowly through various layers of the Stockton series.

Sourland Mountain.—Conclusive proof of the intrusive origin of this sheet was cited by me last year. Three large dikes penetrate the overlying shales for distances up to seven miles, as measured on the surface. Moreover, metamorphosed shales are found near the trap, which was proven to cross the strata from the Brunswick beds into the Lockatong series.

The top of Sourland Plateau. Bowlders of trap rock covering the surface.

Bald Pate Mountain and Pennington Mountain.—These two trap masses lie between the Delaware river and the end of Rocky hill, near Hopewell. No conclusive evidence was found here, but they are believed to be intrusive for the following reasons: (*a*) Their irregular shape does not favor the supposition that they are conformable to the shales. (*b*) Although in places the shales appear conformable, yet many other outcrops were found where the strike of the shales was clearly unconformable to the trap. Unfortunately the outcrops were not so near the trap as to settle this point conclusively. (*c*) The shales near the trap are altered in color, texture, and in the development of secondary minerals. Similar shales occur near those sheets which have been proved to be intrusive. (*d*) The neighboring shales are in some cases contorted and crushed as would naturally be the case where they had been crowded aside by the intrusion of the molten rock. (*e*) The texture of the trap is coarse, resembling that of the intrusive sheets, and never scoriaceous or amygdaloidal, as is often the case with extrusive sheets. In view of these considerations I entertain no doubt as to the intrusive origin of these traps.

Belle mountain, between Bald Pate and Sourland mountain, and Mt. Gilboa, north of Lambertville, are in all probability intrusive, for reasons similar to those urged above. Several trap dikes were found in the vicinity of Gilboa, although in no case was it possible to make out their direct connection with it.

Point Pleasant.—The trap mass at Point Pleasant is intrusive. About 500 feet south of Byram station the contact of the argillite with the trap is well exposed. The shales dip 12° northward, whereas the contact dips 40° south. Near the trap the shales are somewhat crushed, sheared and slightly reversed in dip, but they are absolutely and completely unconformable, and there can be no doubt but that this unconformity has been caused by the irregular intrusion of the trap. The accompanying diagrammatic sketch (Fig. 5) illustrates the relationship.

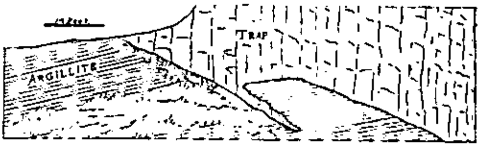

Fig. 5.

Diagrammatic section of the contact of trap and argillite at Byram, N. J. (Point Pleasant).

Cushetunk Mountain.—The crescent or horseshoe form of this mountain, between whose curving flanks lies the picturesque Round valley, is certainly striking. The facts indicate quite clearly that this trap mass is intrusive in origin, and that the curving outline is not due, primarily, at least, to an anticlinal or synclinal fold in the shales, but to the curving fracture through which the trap has come. The outline of the trap, as given on all maps heretofore published, has been incorrect. Instead of the broad area of trap on the southwest limb of the crescent, a belt of hard, black and purplish shale from half to three-quarters of a mile in width extends north from Stanton to Prescott brook. To the west of this shale there is a strip of trap a quarter of a mile wide and a mile and a half long, separated by it from the main mass of the trap.

I am at present by no means certain whether this hard, black shale is the red shale metamorphosed by its proximity to the two trap masses, as may well be the case, or whether it is a part of the Lockatong series brought into this position by some complication of the structure. The latter is obscure in this vicinity and outcrops are too few and far between to permit any positive assertions on this point. The former view, on the whole, seems more probable from the character of the rock itself.

No doubt, however, is held as to the intrusive origin of the trap sheets. (*a*) The trap masses, when examined both in detail and in their general relationships, are found to be unconformable to the shales. (*b*) Apart from the doubtful shales just mentioned, there are others, which have been unmistakably altered in color, hardness and in the production of new minerals. The extent to which the alteration has taken place is roughly proportional to the width of the trap. (*c*) The trap, so far as seen, is always coarse, even very near the contacts. Nowhere was scoriaceous or vesicular rock found. The evidence strongly favors the supposition that it cooled slowly at considerable depths, and never reached the surface. A small dike was found near the end of the southern arm of the curve, but its connection with the main mass could not be established.

The rock of Round mountain, just south of Cushetunk, is similar to that of the former, and the surrounding shales, so far as they could be seen, were somewhat altered. The intrusive origin of this sheet is probable, but not conclusively demonstrable.

Watchung Mountains.—The trap ridges extending from Bedminster and Somerville to Oakland and Darlington are known as the Watchung or Orange mountains. They are sometimes called First, Second and Third mountain, beginning with the outermost or eastern one. They extend in long crescentic curves in a general southwest-northeast direction. They uniformly have a steep, locally-precipitous slope toward the outer side of the curve, *i. e.*, to the southeast and east, and a longer gentle slope in the opposite direction. The most cursory examination serves to show that this is due to the inclination of the trap sheets, the hard outcropping edges of which form the steep slopes.

At first sight they appear to resemble somewhat closely the Palisade trap ridge, but closer examination of the structural relations shows a marked difference. These sheets are to all appearances strictly conformable, both to the underlying and to the overlying shales. Nowhere is there any indication that the trap breaks across the sandstone or shale layers. Wherever the basal contact is exposed, and exposures several hundred feet in extent are known, the trap is seen to follow exactly the bedding plane of the shales.

Moreover, the extensive metamorphism of the associated sedimentary beds, so marked a feature in the case of all the sheets enumerated above, is entirely absent. Locally, the shale is slightly altered for a few inches beneath the trap, but this is not always the case. So far as observed, the underlying shales are never metamorphosed to a depth exceeding four feet. When this is compared with the intense alteration which has affected the shales beneath the Palisades for a distance of over 100 feet, the difference between the sheets is emphasized.

Upper contacts have not been observed in many cases, but the upper surface of these sheets is frequently vesicular, amygdaloidal and scoriaceous. Locally, a thin layer of waterworn trap particles, intermixed with red mud occurs between the vesicular trap and the unaltered typical red shales. The overlying shales conform to the slightly irregular, ropy surface of the trap. In frequent exposures the rolling-flow structure named by the Hawaiian Islanders *Pa-hoe-hoe* is visible. Nowhere have any tongues of lava been found extending from the main sheet into the neighboring shales.

In texture there is a marked difference between the sheets. Not only is the trap vesicular and even scoriaceous at many points on the upper surface, but it is uniformly of much finer grain than that of the Palisades and similar ridges. Microscopic examination of fragments from the upper surface shows that volcanic glass occurs in considerable quantities. The conclusions drawn from the texture are that these masses cooled much more rapidly than did the Palisades trap. Locally, vesicular and scoriaceous layers occur next to the under shales, beneath dense fine-grained trap. Generally in such localities the rolling-flow structure is clearly marked. The inference from these facts is that as the lava flowed along the partially-cooled vesicular upper surface was rolled over to the under side of the flow. Nothing of this sort was observed in any of the sheets considered intrusive.

In view of all these facts, thus briefly summarized, these three masses are regarded as overflow, or extrusive sheets. The fact that sheets so diverse as the Palisades and the Watchung ridges occur in the same district gives excellent opportunity for comparison, and the contrasts themselves furnish the strongest argument for the intrusive origin of some and the extrusive origin of the others.

Since these trap sheets are conformable to the sedimentary beds, it follows that the crescentic curves, so marked a feature in the case of these ridges, is due to gentle flexures or folds in the shales. The most marked of these is a broad, shallow, basin-shaped syncline, whose major axis extends northeast from a point between Somerville and Pluckamin. The western side of the basin has been cut off by a fault along the crystalline border. Since the traps are conformable members of the series, they are valuable guides in interpreting the structure of the region, the details of which will be considered below.

The general relations of these sheets having been indicated, the various localities where the significant phenomena are shown may now be described.

First Mountain.—This ridge extends from Pluckamin to Darlington, a distance of nearly fifty miles, as measured along the ridge. At two points, Millburn and Paterson, it is cut by wide, deep gaps. Well-borings show that at Millburn the bottom of the gap in the rock is below sea-level, but it is now partially filled with 150 to 250 feet of glacial drift. At Paterson the gap is nearly two miles in width. Through this opening the Passaic escapes from the back country, having an elevation of 110 feet at the head of falls, where it plunges over the hard trap ledge. The general floor of the gap, however, has an elevation (170 feet) somewhat greater than that of the river.

At other points the ridge is cut by depressions of varying width and depth, the largest of which is at Crystal lake, but none equal the two just mentioned. Apart from these gaps which cut the ridge sharply and have steep sides, the crest line is remarkably even. Its average elevation southwest of the Millburn gap is 480 to 500 feet, with extremes of 388 and 589 feet. Between Millburn and Paterson, its average elevation is nearly 600 feet, with a maximum of 665 feet, northwest of Montclair. North of Paterson the range is greater, from 429 feet to 752 feet, the maximum height being reached a mile and a half south of its northern terminus.

With the exception of a short distance between Upper Montclair and Paterson, and also near its northern end, the ridge has a single well-defined crest. At the intervals noted the crest is double, a fact due in the former case certainly to faulting.

Under Contacts.—At the American Copper Mining Company's shaft, about three miles north of Somerville, a drift has been opened along the contact for over 800 feet. The under surface of the trap is gently wavy, but is strictly conformable to the shales which dip twelve to fifteen degrees northeastward. Beneath the trap the shale is somewhat altered for a depth of two feet, but this alteration is not in the nature of induration or baking. It is more or less impregnated with copper ores, the red oxide and carbonate being the most common.

The shale is normally a dark reddish brown, grading upward near the trap into a rather soft, porous, vesicular, purple shale. The changes are probably due to chemical reaction set up by water percolating along the contact of the two rocks, one consequence of which has been the deposition of the copper ores. The trap near the shale is generally firm, fine-grained and dense. The ropy structure is sometimes seen. A small fault trending about northeast, *i. e.*, at right angles to the dip, was noted at one point in the mine. The upthrow, which was on the south, was between four and six feet.

2. At Haelig's quarry, directly opposite Chimney Rock, Bound Brook, an obscure exposure of the contact was found in 1895. Above the contact the trap shows concentric weathering, and the lower foot or two is slightly amygdaloidal. Next to the trap the shale is slightly indurated and a greyish purple. Four feet below the trap soft argillaceous red shale occurs entirely unaltered. No effects of the trap upon the shale can be discerned at a greater distance than about three feet.

3. At Smalley Bros.' quarry, Plainfield, the trap rests upon a sandy shale, which is purple in color to a depth of a foot from the contact.

Next to the shale the trap is vesicular, scoriaceous and ropy. The contact line is slightly sinuous, the red shale extending up between the rolls of trap. Evidently as the trap rolled along, its weight forced the soft mud up into the inequalities of the under surface.

4. At Wahl & Hatfield's quarry, Scotch Plains, the actual contact was not exposed at the time of my visit, but the unaltered sandy shale was found a few feet below the trap. Future excavations may lay bare the contact plane. From this point northward to Upper Montclair there are no localities where the contact can be studied or where the trap and shale occur within a few feet of each other.

5. At the Osborne & Marsellis quarry, Upper Montclair, the under contact is beautifully shown. The trap follows the undulating surface of the shale, which is usually not altered at all, even at the very contact. Locally, it is somewhat indurated, but not changed in color. For twelve to eighteen feet above the base the trap is vesicular and deeply decomposed, the most scoriaceous bed being in part next to the sandstone and in part several feet above the contact. The lower trap presents clear evidence of flowage in the more or less ropy structure. In an old quarry, a few rods to the south, this same disintegrated vesicular trap underlying firm, dense rock is well shown, but the actual contact with the sandstone is not now exposed.

The best exposures are those found in the various quarries at Paterson, where the contact is shown for a total distance of several hundred yards.

6. At Devlin's quarry, on the east face of Garrett Rock, the contact is exposed for between 100 and 200 yards. It is inaccessible and so cannot be examined in detail, but so far as seen from below it is absolutely conformable to the sandstone. The trap next to the contact is somewhat disintegrated, whereas the underlying shale is not altered at all, certainly not for more than a few inches.

7. At Pope's quarry, a few rods north, conformable contact is again shown, the trap resting upon soft red shale, which is but slightly altered to a depth of a few inches. The contact is not readily accessible.

8. Around the end of Garrett Rock, to the west, the dip of the shales brings the contact to the level of the railroad tracks, where it can be carefully examined, (Fig. 16). It is absolutely conformable to the shales, which are unaltered save for two inches or less immediately adjoining the trap. Just above the contact the latter is filled with

calcite amygdules for a distance of eight inches. For a thickness of one and a half feet the trap weathers into botryoidal masses, above which the columnar structure is well marked. An interesting case of faulting occurs here, which will be described later.

9. At McKiernan & Bergin's quarry, Paterson, constant quarrying keeps the contact freshly exposed. The trap is conformable to the underlying sandstone, which is unaltered, save for a slight induration and change of color immediately at the junction. Above the sandstone the trap forms massive layers for a distance of twelve or fifteen feet, above which the basaltic columnar structure is developed. The bedded structure is due to joint planes parallel to the under surface of the trap, not to successive flows, of which there is no indication. The same "bedded" trap is well exposed in the high bluff on the west bank of the river, under the soldiers' monument. Locally, it is vesicular for a few inches next to the sandstone.

10. At the Ryle avenue quarry and along the left bank of the river for several hundred yards the trap can be seen to rest conformably upon the slightly-undulating beds of sandstone. Here also amygdaloidal rock occurs for a foot or so above the contact, and is succeeded by fine-grained dense layers, in which the large columnar structure is locally well developed. Below the contact the sandstone is friable and unindurated, although its color is somewhat darker at the immediate junction.

North of Paterson the sandstone is nowhere exposed near the trap. No facts, however, were noted which would indicate contact phenomena other than those just described.

Upper Surface.—Upper contacts are not frequent, although the overlying shale was found at a number of places not far removed from the trap. Nowhere along the whole length of the sheet were there found the slightest traces of metamorphism in the shale. The upper surface of the trap is frequently vesicular and amygdaloidal, very different from the upper surface of the intrusive sheets.

At the Field copper mine, near Warrenville, the shaft was sunk through the shales upon the trap. On the dump-pile are fragments of green, grey and black carbonaceous shale, but no traces of metamophosed beds. Scoriaceous and amygdaloidal trap occurs, so full of vesicles as to be fairly honeycombed with them. Flattened stems of trees were noted here in the black shale, and good specimens of fossil fish have been found here.

At Feltville (Glenside Park) is the well-known upper contact, described by Russell,* Davis † and Darton. ‡

The contact occurs along a small brook a few hundred yards northeast of the row of cottages on the bluff. At the entrance to the ravine green and brown micaceous shales occur. A few yards further up the stream (lower geologically) the ropy scoriaceous trap is first seen in the bed of the brook and then upon the bank with soft red shales just above it. The actual contact, however, is obscured by rubbish. The trap is deeply disintegrated and has something of a stratified appearance, due probably to the weathering. Continuing up the stream the shale is again found at the water's edge on the north side of the brook, but trap is seen on the south. The descent of the contact line is in part apparent, due to the course of the stream, but in part really due to the uneven, rolling surface of the trap. A few rods further there is a small excavation in the bank, an abandoned mine adit. Here there is a trap and shale conglomerate of very irregular thickness overlying the trap and extending downward into the spaces between the rolls or bosses of its surfaces. In one case a narrow tongue of the conglomerate extends downward two feet between rolls of trap. In general, the trap fragments in the conglomerate are much decomposed, but there can be no doubt as to the origin of the larger pebbles. The largest fragments seen measured eight inches in diameter. Microscopic examination of the conglomerate shows that much of the trap is glassy. Traces of the conglomerate were noted in the bed of the brook above the adit.

The surface of the trap is ropy, scoriaceous and undulates in low domes, themselves irregular by reason of the coils and folds of vesicular lava. The conglomerate fits itself to these inequalities of surface, and is, therefore, of varying thickness. The greater irregularities of the trap surface account for the varying dip of the immediately overlying shales. Nowhere is there the slightest trace of metamorphism in the overlying shales, but on the other hand the evidence is most convincing that we have here the upper surface of an overflow sheet on which there was first accumulated a true basal conglomerate of fragments derived from the sheet itself, and afterwards soft clayey and sandy shales.

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* I. C. Russell. Am Jour. of Sci., 3d series, vol. 15, pages 277–280.

† W. M. Davis. Museum of Comp. Zoöl. Bull., vol. 7, 1880–1884, pages 274–5.

‡ N. H. Darton. U. S. Geol. Surv. Bull. No. 67, page 26.

A small patch of the overlying shale is still preserved on the back of the trap along the road from Feltville south over the mountain. No new features are presented here.

In a small ravine a few rods southwest of Feltville, the trap and shale are shown in close proximity, but not in actual contact. The conglomerate was not found here, but the upper surface of the trap is ropy, vesicular and undulatory as at the above locality. The shales are sandy and unaltered.

For many miles north of Feltville the valley between First and Second mountains is encumbered with glacial deposits, and there are no exposures of the shale near the trap. In the vicinity of Paterson the upper surface is frequently vesicular and ropy, but no contacts were found. Near the High Point Hotel, three and a half miles north of Paterson, the shales are exposed not far above the trap, but careful search along a brook did not result in finding the contact.

For many miles north of High Point the back of the trap is so thickly buried by glacial deposits that the boundary can be determined only approximately, and the shale is not known to outcrop anywhere near the trap. That the Newark beds occur along the Ramapo river above the trap and beneath the glacial accumulations, is well substantiated by borings, but nowhere do they appear on the surface between Oakland and the State line.

Texture.—In general, the trap is bluish black, very fine-grained and dense. Where the upper surface has not been deeply eroded it is frequently vesicular and amygdaloidal. A thin layer of amygdaloidal trap also occurs at many places on the under surface. The ropy flow structure is quite common, particularly on the upper surface, but sometimes also near the base.

Along the gorge of the Passaic, below the falls at Paterson, the trap is distinctly bedded in planes approximately parallel to the underlying shales. There is, however, no evidence of successive flows, the bedding apparently being due entirely to the joints.

Columnar structure is frequently well shown. The best examples of this are seen in the quarries west of Orange, notably at O'Rourke's,* near Llewellyn Park, where the columns are of varying sizes up to four feet in diameter, and display both a vertical and a radiate arrange-

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*Described and pictured in the Annual Report of the State Geologist for 1884, pages 23-38. Also, J. P. Iddings, Am. Jour. Sci., third series, vol. 31, pages 321-331, pl. 9.

ment. Similar structures are shown at the quarry southwest of Eagle Rock. Columns of varying sizes are displayed at many points in the vicinity of Paterson, notably at Garrett Rock and below the Passaic falls.

The columnar structure is caused by the shrinkage of the rock after it had solidified from its molten condition. It still retained a great amount of heat, and as it cooled further it contracted until it cracked along the many lines separating the columns. The direction of the columns is perpendicular to the plane of cooling. For a thorough discussion of the mechanics of cooling and the functions of the columnar structures, the reader is referred to Prof. Iddings' paper cited above.

Second Mountain.—This ridge is more markedly crescent-shaped than First mountain. At its northern end, at Pompton lake, it rises quite abruptly from the valley of the Ramapo river, on the opposite side of which rise the high crystalline hills, here bordering the Newark beds. It trends, first, southeast, toward Haledon, then west of south and southwest to Martinsville, whence it curves northwest to Pluckamin, and then northeast to Bernardsville, beyond which it apparently terminates in a small knob, on the surface somewhat separated from the main mass by heavy accumulations of drift. The length of Second mountain is a little over forty-five miles. At its northern and southwestern ends it borders the crystalline rocks, from which it is separated, as will be shown later, by a fault.

In many respects it closely resembles First mountain. The outer slope is usually much steeper than the inner, but cliffs are by no means so common. The average height is a little greater, its crest generally being twenty-five to fifty feet higher, but locally it is lower. Its maximum elevation, 879 feet, is at High mountain, between three and four miles north of Paterson. Its continuity is broken by a wide gap at Little Falls, through which the Passaic river flows in a trench sunk from twenty to fifty feet below the level floor of the gap. Borings show that there is another deep and wide gap at Short Hills, which has been filled by the moraine nearly to the level of the ridge on either side.

In one respect, however, this ridge differs conspicuously from First mountain. For many miles of its course the crest is double, with a distinct and continuous depression between the ridges, the outer one of which is usually slightly higher than the inner. The double crest is first noticeable in the latitude of Pluckamin, just south of where the ridge recurves to the northeast towards Bernardsville. It is conspicuous for several miles northeast of Mount Horeb, but less so near Murray Hill, where the inner crest is hardly more than a bench on the flank of the higher ridge. It is distinctly traceable, however, as far as Summit, whence for several miles northward it is obscured by the morainal deposits. West of the Orange reservoir, it again becomes discernible and continuous more or less definitely to the gap at Little Falls, beyond which it is not conspicuous, although locally there are traces of two summits. The depression between the crests, although in the main continuous, does not form a single valley drained its whole length by any one stream. Brooks follow its course for a mile or two at most, and then escape by transverse gorges to the low ground on the east or west.

The cause of the depression is not far to seek. Earlier investigators have found at various places traces of red shale thrown out from excavations and the past summer the shale was found in place in the valley. The depression is due, therefore, to the more rapid erosion along the line of soft shales as compared to that of the hard trap on either side. Several interesting questions at once arise as to the stratigraphical relations of these beds. Are they interbedded shales between two layers of trap, or are they due to a fault which conforms to a remarkable degree with the curves of the trap? The answer to these queries may best be considered in connection with the whole question of faults in the formation, and therefore will be deferred for the present.

Under Contacts.—Along Mine brook, southwest of Bernardsville, the shale is frequently exposed not far from the trap and always trending conformably to the ridge. The base of the trap, where seen, is slightly vesicular or amygdaloidal. Fine exposures of rock filled with calcite amygdules the size of coarse shot are found along the road leading southeast from Far Hills station, and the scoriaceous base of the trap is well exposed below the falls in the ravine of the neighboring stream.

Pluckamin.—At Compton's quarry, near Pluckamin, the under contact is exposed for a space of ten or twelve feet. Both trap and sandstone are much disintegrated and jointed near the contact, but the evidence is clear that here at least the trap is perfectly conformable. The lowest trap is somewhat vesicular, but it speedily becomes firm and dense. The sandstones have been somewhat altered in color for a distance of three feet, but are not noticeably indurated. "Burnt" tints occur very close to the trap. The changes of color and signs of metamorphism are here somewhat greater than usually present at the under contact of the extrusive trap sheets, although they are insignificant compared with that beneath the Palisades.

Little Falls.—At the Little Falls sandstone quarry the contact is exposed for nearly a hundred yards. It is slightly undulatory, the layers of shale bending down and rising in a perfectly conformable manner with the under surface of the trap. Much of the latter possesses the ropy-flow structure, its thickness varying from almost nothing to more than thirty-five feet. Locally, the dense columnar rock is seen resting upon the ropy trap. The coils or ropes of lava vary in diameter from one to five feet. They are dense and fine-grained in the center, but more or less vesicular towards the circumference, and the spaces between them are filled with what appear to be volcanic ash. Spike amygdules of calcite frequently occur with long diameters generally at right angles to the peripheries of the coils.

The shale is often slightly depressed below the solid masses of the rolls, whereas between them it rises slightly and locally extends upward a short distance between the coils. The facts find a ready explanation on the assumption that a rather viscous lava rolled slowly over and over in successive coils, exerting enormous pressure upon the soft mud of the estuary bottom, which was forced up between the rolls for short distances. The shale immediately beneath the trap is slightly indurated for a few inches, but otherwise entirely unaltered.

Similar phenomena are shown on the line of old quarries extending along the left bank of the river for half a mile northward. Heavy columnar trap rests upon ropy, vesicular rock along an irregular and somewhat indefinite contact line. The ropy trap in turn rests conformably upon the unaltered shales and sandstones. Locally the trap down to the contact is columnar and not ropy. There is no sharp line of demarkation between the two, and in one place, at least, the ropy, scoriaceous trap rests upon fifteen feet of columnar rock which overlies the shale. Owing to the inaccessibility of most of these outcrops (since the quarries are filled with water) it was impossible to examine them closely enough to determine whether the material was tuff and scoriæ, overflowed and penetrated by a later lava sheet, as supposed by Darton, or whether the material presents only various phases of a

PLATE VIII. A.

East Jersey Water Co. Quarry, Little Falls. The conformable contact of the trap of Second Mountain with the underlying sandstone is clearly exposed. The trap shows both the columnar and the spheroidal structure, the latter being due, in part at least, to concentric weathering.

single flow. In either case the phenomena are such as can only be explained on the hypothesis of an overflow sheet.

Haledon.—At Haledon are two quarries, in both of which the contact is well shown. Here, as at Little Falls, the shales beneath are almost entirely unaltered, the contact is slightly wavy, following exactly the bedding planes, and the trap shows both the ropy, vesicular and the columnar structure. The two are more or less closely intermingled, due to the rolling motion of the flowing trap, huge masses of dense fine-grained rock being surrounded and separated from each other by the amygdaloidal layers. North of Haledon the glacial drift and talus conceal the contact entirely.

Upper Contacts.—At no point along the entire length of Second mountain is it possible to find the trap and overlying shale in contact. In the upper Passaic and Dead river valleys the shale has generally been eroded below the level of the alluvial deposits of those streams. North of Summit the glacial accumulations rise high on the slope of the ridge and effectually conceal the contact, often making it extremely difficult to determine even approximately the limits of the trap. Although the contact is not visible, the shales at a little distance above the slope are known to trend in perfect conformity with the curves of the ridge. The upper surface of the trap is frequently vesicular or amygdaloidal, but not so generally as the back of First mountain, and the ropy structure is occasionally found.

Texture.—The rock is very similar to that of First mountain. The greater part is fine-grained and dense, blue black in color; sometimes slightly greyish. It is, locally at least, scoriaceous and amygdaloidal at its base and probably more generally so at its upper surface. The columnar structure, although generally not so well displayed as in First mountain, occurs, being probably best seen at Little Falls and at a small quarry about two miles south of there. Very frequently the rock is broken into small wedge-shaped fragments by innumerable joint planes, three inches to a foot apart.

The conformability of this trap sheet with the sandstones, the absence of contact metamorphism, so far as contacts have been seen, the vesicular and scoriaceous character of both the upper and under surface and the ropy-flow structure, all indicate its extrusive character. This conclusion is opposed to that held by some earlier workers * on the survey, but is in accord with the views of other investigators.†

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* Cook, Nason. † Davis, Darton.

Third Mountain.—Above the trap sheet forming Second mountain, and separated from it by a considerable thickness of shale, there are several masses, which are probably all parts of a single sheet, although this cannot be demonstrated. The outcropping edge of the largest forms Long hill, extending from Chatham to Basking Ridge. Riker's hill, west of Livingston, Towakhow or Hook mountain, extending from Pine Brook to Mountain View, and Packanack mountain, from Mountain View to Pompton, are the others. The third sheet is considerably thinner than either of the others, and consequently the ridges are less conspicuous topographically. The eastern slopes are generally much steeper than the western, but cliffs and ledges are in the main wanting, or are low and inconspicuous. The underlying shale usually extends high up the eastern face, often nearly to the crest of the ridges, but the contact is generally obscured by talus or glacial drift. Their average elevation is about 450 feet above tide, and from 200 to 300 feet above their surroundings. So far as can be determined, the trap is conformable to the shales both above and below. The latter have not been metamorphosed. The upper surface of the trap is frequently vesicular, and it is fine-grained and dense in texture. Physically it resembles the rock of the other sheets. Although the evidence is not so complete as in the case of First mountain, no doubt is held as to the extrusive origin of these ridges.

Long Hill.—The northward turn of the trap, between Liberty Corner and Basking Ridge, is due to a flexure in the shales, the same synclinal fold which causes the bends in the outer ridges. At only one point was the trap found in contact with the underlying shale. At Millington, 400 yards west of the station, a conformable contact is obscurely shown for a distance of fifty feet. The shale is unaltered save to a thickness of a foot and a half, in which the color has been changed to a purple blue. Above the contact the trap is much disintegrated for a distance of two feet, above which it becomes more or less columnar. The decomposed trap is apparently in layers, and at first sight resembles a sedimentary rock, but minute tabular crystals of feldspar are readily discernible with a hand lens, and there is a marked difference between this rock and the shale beneath.

At other points along the ridge the normal red shale was seen within a few feet of the trap, in all cases dipping beneath it conformably. Nowhere are there indications of contact metamorphism for more than a foot or two.

The overlying shales are seen in close proximity to the trap along the road a few rods west of the bridge north of Millington. The trap is extremely vesicular and much disintegrated. A few inches above it there is a thin layer of yellow shale, above which are the normal argillaceous red shales. Macroscopically, the yellowish shale appears to be composed in part of fragments of trap. The scoriaceous trap is exposed for several rods along the road, amygdules being abundant to a depth of ten to fifteen feet.

Thickness.—Since these two contact points are at nearly the same level, and on directly opposite sides of the sheet, they afford the most reliable means of determining the thickness. On the basis of a dip of twelve degrees, *i. e.*, the average for the underlying beds, the thickness is 375 feet. The overlying shale dips only six degrees. On this basis the thickness would be only 189 feet. The actual thickness is probably midway between these estimates.

Riker's Hill.—This ridge rises somewhat gradually at the southern end near West Livingston, and terminates somewhat abruptly three miles and a quarter to the north. Its maximum elevation, 473 feet, is about 250 feet above the country on the west, and 200 above that on the east. At the south the trap descends gradually below the level of the drift-covered country, and certainly continues some distance southward of the last surface outcrop. On the east the sandstone reaches almost to the crest of the ridge, and along the road leading west of Livingston the unaltered shale outcrops a short distance beneath the trap and apparently dips conformably with it. On the back of the ridge vesicular rock occurs with traces of the ropy-flow structure.

Towakhow or Hook Mountain.—This ridge differs from the others in its sharply-curved outline, making as it does a sharp right-angled bend at Whitehall. Its length is about eight miles and its maximum height is 458 feet, 290 feet above the Great Piece meadows on the east and south. The inner face of the curve, *i. e.*, the eastern and southern, is much steeper than the outer, due to the dip of the trap, which is in accord with that of the shales. These form an anticlinal fold whose axis plunges northwestward. The apparently abnormal width of Second mountain in the vicinity of Caldwell is doubtless due to the same fold, which, however, at that point has nearly disappeared.

No contacts are known to exist along this ridge, but the shale which extends well up the eastern and southern slopes is always perfectly conformable in strike with the trend of the ridge. A few outcrops of the overlying beds showed the same conformability. The upper surface of the sheet is vesicular or scoriaceous. Vesicular outcrops occur just south of White Hall station and along the towpath of the canal near Plane 10 East. The sheet is undoubtedly extrusive.

Less than a mile north by west of White Hall are several detached outcrops of vesicular trap, which locally has a ropy structure. About two miles north by east of the same locality there is another area half a mile in length and 200 to 300 yards in width. At the southern end the trap is vesicular, ropy and is spherically weathered. At other outcrops it is fine-grained and bluish black in color. At both localities the rock is similar lithologically to the trap of Hook mountain. Whether they are connected with it or are separate flows is uncertain. The glacial deposits so conceal the underlying rock that the structure is not well known.

Packanack Mountain.—At Mountain View there is a gap occupied by the Pompton river, separating Towakhow from Packanack mountain. The trap sheet is apparently thinner here than elsewhere and may be wanting entirely. No trace of it is obtainable along the river bed. It appears again, however, in the bank of the canal-feeder and forms a curving ridge, trending first northeast, then north and finally northwestward, terminating somewhat abruptly at the west of Pompton lake. This ridge, with the eastern half of Towakhow mountain, is the outcropping edge of a synclinal fold, whose axis plunges northwestward. Its length from Mountain View to Pompton lake is about seven miles, and its average elevation between 450 and 500 feet—200 to 300 feet above its surroundings.

Shale and sandstone extend nearly to the top of the ridge on the east, the edge of the trap generally being marked by a low escarpment or cliff, but the shale is nowhere exposed near the contact, save near the dam at the south end of Pompton lake, where conglomerate beds dip conformably beneath the trap fifteen to twenty feet distant. The inner or western slope is entirely trappean, only one outcrop of shale being found along the western side, and that some little distance above the contact. The strike of the shale in all cases, however, agrees with the trend of the ridges. Vesicular rock occurs at various points along the upper surface. A well drilled at the Norton House, Pompton Furnace, where the upper surface disappears beneath the glacial drift, penetrated, according to report, seventy feet of trap and then reached sandstone. If the facts were correctly reported, we have here a fairly accurate measure of its thickness. Beautiful glacial grooving occurs along the Hamburg turnpike, at Cedar Grove farm, Pompton.

New Vernon Ridges.—In the vicinity of New Vernon there is a crescentic-shaped ridge of trap, which may be a continuation of the Long hill sheet or an independent flow. In support of the former view, it may be urged that the intervening shales have a synclinal structure by which the Long hill sheet may be brought to the surface.

The curving form of the ridge is due to an anticlinal fold, the axis of which pitches east by south. The ridge is continuous, save where deeply trenched by two water gaps, across which, however, the trap undoubtedly extends, although it is not continuously exposed. The average width of the outcrop is half a mile, its length eight miles and its average height between 400 and 450 feet—150 to 200 feet above its surroundings. Nowhere are the trap and shales seen in juxtaposition, but within the curve the underlying shales frequently outcrop and agree closely in strike with the trend of the ridge nearest them. The rock is fine-grained, blue black in color and notably vesicular and scoriaceous in places. The thickness of this sheet at the water gap back of Green Village is estimated to be about 250 feet. No hesitation is felt in classing this sheet as extrusive in origin.

New Germantown Traps.—Near New Germantown there is a small horseshoe-shaped trap ridge inclosing between its ends two small isolated masses. The entire length of the ridge is about two and a half miles, its width a little more than a quarter of a mile, and its height hardly more than 100 feet above its surroundings. The trap is fine-grained, dense and black, quite unlike the coarse-grained trap of Cushetunk mountain. Locally it is slightly vesicular and the ropy structure is discernible. No contacts could be found, but the dip of the associated shales indicates that the ridge is formed by the outcropping edge of a synclinal sheet, the axis of the syncline pitching northwestward. The dips of the beds within the crescent are very steep, ranging from thirty-four to sixty degrees. Taking the least of these for a basis, I compute the thickness of the trap to be about 400 feet. Dips as high as fifty degrees were noted in the underlying shale close to the trap. Darton estimates the maximum thickness at 250 feet, but with dips as steep as those noted above, the greater thickness must be accepted. No signs of contact metamorphism were found. The trap is undoubtedly extrusive. The relationships of the two small masses could not be determined.

Sand Brook Trap.—In the annual report for 1896 (pages 68, 69) I called attention to a small crescentic ridge and isolated mass of trap, of almost identical shape with the New Germantown sheet, which lies near Sand Brook village, Hunterdon county. It was of interest chiefly because it had not before been reported upon. Reasons were given for considering it an extrusive sheet. The trap and shales are conformable and have an average dip of thirty-five degrees. Its upper surface is everywhere vesicular and only the lower portion is dense and fine-grained. In shales only a foot above the trap there was no sign of induration, change of color or alteration of any kind which could be ascribed to the trap. At two localities the trap vesicles were found to be filled with fine red mud, and at one locality vesicular trap is overlaid by a thin layer of finely-comminuted trap and red mud. Thickness is estimated to be not less than 450 feet.

Trap-dikes.—In addition to the intrusive and extrusive trap sheets, enumerated in the foregoing pages, a number of localities are known where narrow dikes traverse the shales for varying distances. Many of these have been reported upon by earlier investigators. Some were noted during the recent survey of the surface formations, under the direction of Prof. R. D. Salisbury, and a few had not before been located, so far as I can learn. For the sake of completeness I will enumerate them all very briefly.

Along the Palisades narrow offshoots from the main mass were noted at several points. These have already been described (pp. 63–65, 68, 69), and in some cases pictured.

The three dikes which radiate from the upper part of the Sourland mountain sheet were fully described in the annual report for 1896 (pp. 64, 65), and have already been referred to in this paper (p. 74). They are the largest and longest dikes, and the most important, from a scientific point of view, since they prove conclusively the intrusive origin of the Sourland mountain sheet.

Prospect hill, west of Flemington, is a small mass of trap which may be connected with the longest of the three Sourland mountain dikes, but such connection is not shown on the surface. A quarter of a mile east of the Flemington cemetery, a trap-dike, probably the northern continuation of the longer of the Sourland mountain dikes, crosses the road. Its width is from fifteen to eighteen feet; it dips steeply eastward, and the inclosing shales, which are altered to a purple and yellow color for between two and four feet from the contact, dip 30° westward. It is traceable both northward and southward. Near its northern end, in the outskirts of Flemington, two similar dikes appear in the road, offset slightly to the west. Whether these are all the same dike, separated by faults or are separate intrusions, cannot be determined.

Baptistown.—Two miles east of Baptistown a narrow strip of yellow trap earth and disintegrated fragments indicates the presence of a dike. Little can be determined of its length, width or angle of slope. It is not marked topographically, and the trap residuary is somewhat widely spread out. It appears to be over half a mile in length.

Stanton Station.—A small trap-dike crosses the Flemington-Clinton road, nearly due west from Stanton station. Owing to the wash of debris from the higher slopes the dike is visible only at the roadside.

Three Bridges.—Half a mile northeast of Three Bridges a narrow dike crosses the Centerville road. Its position is indicated by the soil and the weathered fragments. Its width is probably not more than six to ten feet. It is impossible to trace its course more than a few rods on either side of the road.

South Branch.—A narrow line of trap detritus is traceable for nearly a mile, parallel to the road leading southwest from South Branch and from one to two miles from that village. The rock itself is not exposed.

Just south of South Branch village a trap-dike six or eight inches thick cuts the shale at about right angles. The trap is much decomposed, but is recognizable. The dike cannot be traced across the fields.

Neshanic Station.—A trap-dike, three feet wide, is exposed in a cut on the Lehigh Valley railroad, about a mile west of Neshanic station. It dips 30° southwest. The shales on either side are altered for a distance of three feet. North of the railroad it apparently increases in width, and can be traced for a third of a mile in a northeasterly direction.

Half a mile northwest of this locality another dike crosses the road in a northeast-southwest direction. It is marked mainly by the scattered debris, which forms a belt with a maximum width of 120 feet. The dike is probably somewhat narrower. It is traceable about half a mile.

Peapack.—A small dike is seen in the railroad cut, a few rods south of Peapack station. The adjoining sandstones and shale appear somewhat altered, more so than would be expected for so small a dike. Nothing is known of its extent beyond what is seen in the cut.

Blackwell's Mills.—On the east bank of the Millstone, half a mile north of Blackwell's Mills, there is a fine exposure of a trap-dike, ten or twelve feet in width, which intersects the shales at a high angle. Near the contact the trap itself is somewhat shattered and slickensided surfaces occur, and the adjoining shale is altered in color for distances varying from six feet on one side to one and a half feet on the other. A good example of spheroidal weathering is shown. An altered mass of shale, five feet long and from one to two feet thick is inclosed in the midst of the trap. On the Geological map this dike is represented as outcropping, at frequent intervals, as far as the Raritan river. I was unable, however, to find any trace of it, save for a short distance from the Millstone river, although the opportunities for observation were good, and careful search was made along the roads and through the fields. West of the river, however, it can be traced without difficulty for three miles by means of the line of debris and a low swell of ground. Its maximum width is probably 100 feet, but usually it is not much more than half that. It gradually thins out a mile southwest of Hillsborough.

New Brunswick.—Near Martin's dock, on the left bank of the Raritan river below New Brunswick, two thin sheets of trap are exposed interbedded with shale, which, both above and below the trap, are strongly altered. The sheets are about two feet and fifteen feet thick respectively, separated by a few inches of black, highly-indurated slate, which seems to thin out at one end of the exposure, so that the two trap sheets join. Cook,* Davis † and Darton ‡ have all described this locality, and all are agreed that the sheets, although essentially conformable to the shales, are intrusions.

Two miles southwest of New Brunswick a disintegrated trap-dike

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* Cook. Report of the State Geologist for 1882.

† Davis. Bulletin of the Museum of Comparative Zoology, vol. VII., page 276.

‡ Darton. Bulletin of the United States Geological Survey, No. 67, page 65.

is exposed in the cut on the Pennsylvania railroad. On the north side of the cut the debris measures forty-two feet in width, on the side 100 feet. There may be two dikes here separated by shale, since only the debris could be seen. A sparse scattering of residuary fragments enables one to trace the dike, with some interruption, for half a mile on either side of the railroad. A small isolated knoll was also found near a stream a mile east by north of the exposure in the cut.

Franklin Park.—A mile northeast of Franklin Park a narrow dike can be traced both by the surface debris and by a slight ridge for a mile and a half. It is twice interrupted, and each time slightly offset as if faulted, but no other evidence of a fault could be found. Near its northeastern end, where it crosses the road leading northwest from Franklin Park station, its width is less than twenty feet. Three-fourths of a mile west by south, where it crosses a small stream, the fine-grained, dense and hard blue-black trap is exposed. West of here, in the timber, the ridge is quite distinct, and the width of the dike is probably nearly 150 feet. Nearer Franklin Park its limits are quite indefinite. Its position suggests that it is an eastward continuation of the prong of the Rocky hill sheet, which curves north and then east past Griggstown, almost to Franklin Park.*

Griggstown.—Three-fourths of a mile south of Griggstown there are three somewhat widely separated trap masses. Indurated shale is found near the largest. All three are near the prong of the Rocky hill sheet and are probably offshoots from it.

Still another mass occurs a mile and a half east of Griggstown. The trap is medium-grained, and has altered the adjoining shales slightly. It lies almost entirely within a small piece of timber, the limits of the trap and of the woods being almost coincident. This fact illustrates in a striking manner and on a small scale the relation between geology and agriculture. The area of trap rock is so stony as to be useless for agricultural purposes, and so has been left to timber, whereas the shale area has been cleared.

Wertsville.—Just south of Wertsville school-house a narrow sheet of trap can be seen at the roadside. Its thickness is about two feet and it is parallel or nearly so to the dip of the shales. I was informed by Dr. Larison, of Ringoes, that another narrow dike crossed the road a few yards to the south, and scattered trap fragments corroborate his statement, but the dike could not be located exactly.

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*Thanks are due Mr. G. N. Knapp, of the survey staff, for information concerning these last-mentioned dikes.

The trap is very fine-grained, blue black in color and very hard and tough. A mile northeast at the next road a few scattered trap fragments indicate the approximate portion of the dike. In the intervening space outcrops were found in two small gullies, where the trap layer one foot thick dips conformably with the shales. Scattered fragments occur on the fields between these localities, and another outcrop is found in a ravine a third of a mile northeast of the road. Here the trap is hardly more than ten inches thick.

Southwest of Wertsville the dike is thicker and can be traced more readily by the debris, and locally by a slight rise of ground. It crosses the road a few hundred yards south of Van Liew's Corner. A mile southeast, it is clearly shown where it crosses the road near the house of A. C. Bellis, and in the bank of the brook northeast of his house its width is thirty-five feet. Southwest of the road it can be traced to another brook, where it is well exposed and has a width of eighteen feet. It here cuts the shales vertically, altering them slightly for one to three feet. The length of this dike is over three miles. Its general course is N. 55° to 60° E., parallel to the strike of the beds, and to the trend of the Sourland mountain trap, a mile and a half distant. As already noted, at one end (its thicker part) it cuts the shales vertically, and where much thinner it is interbedded with them.

Dilts' Corner.—From Dilts' Corner a wide trap-dike extends northward for nearly half a mile. It forms a slight elevation and the ground is strewn with residuary fragments. The rock is fine-grained. Judging solely from surface indications its maximum width is about 200 feet. A small area was found a few rods west of the corners, and a narrow dike is exposed in the bed of a stream a third of a mile east of the corners.

Lambertville.—On the top of the hill overlooking the ball-park at Lambertville, a coarse-grained trap-dike occurs. Its width on the surface is about eighty yards and its length nearly half a mile. It is a mile distant from the Sourland mountain trap, but may be an offshoot from it. Macroscopically the two rocks are closely alike. Another area of similar coarse-grained trap is found a mile northeast. Its length is one-third of a mile and its width one hundred yards or more. In both cases only weathered fragments on the surface are found. The surrounding shales are much contorted, altered and apparently faulted. It was found impossible to untangle the structure.

Hopewell.—Near the barite mines, two miles southwest of Hopewell, residuary trap soil occurs over a considerable area. Obscure exposures of disintegrated trap occur along the highways at several points. Whether there is here a complexus of dikes or a boss of trap it is difficult to determine. The barite occurs in veins traversing the decomposed and fractured trap. Fragments from the dump-piles often resembled friction breccias. This trap mass is near the great Hopewell fault, and the shattered condition of the trap and its consequent deep decomposition find explanation in this fact.

Arlington.—Near Arlington there are several small trap-dikes which have been carefully described by Darton in his paper, to which frequent reference has already been made. Many of the relationships described by him have since been destroyed by quarrying. The trap is now best shown near the cemetery and northward to the old copper workings. The trap sheet, which locally is twenty feet thick, is conformably bedded with the shales, but sends out offshoots into them. The shales are in places intensely altered near the trap.

Bogota.—A trap-dike forty feet wide is exposed on the Fort Lee-Hackensack turnpike half a mile east of Bogota. The adjoining shale has been changed in color for about ten feet on either side. Another exposure of the same dike is found in the fields about 200 yards north of the road. Here the trap can be seen to dip sixty-five degrees westward. The rock is dense and fine-grained.

Summary.—A summary of the origin of the various trap masses is here given. The extrusive sheets are (*a*) the Watchung mountains, *i. e.*, First mountain, Second mountain and Third mountain, including Long hill, Riker's hill, Hook mountain and Packanack mountain; (*b*) the New Vernon sheet; (*c*) the New Germantown sheet; (*d*) the Sand Brook sheet, and (*e*) the small masses north of Whitehall. All the others are intrusive, including (*a*) the great sheets like the Palisades, Rocky hill, Sourland and Cushetunk mountains; (*b*) the boss-like masses, such as Bald Pate and Pennington mountains, Round mountain and the Point Pleasant mass, and (*c*) the narrow dikes enumerated above.

AGE OF THE TRAP SHEETS.

The extrusive or overflow sheets must, by the very conditions of their formation, be contemporaneous with the beds between which they lie, if they are conformably bedded with them. The Watchung mountains occur well up in the Brunswick shales, apparently in the upper third of this member. The detached sheets, comprising the third ridge, are the highest, and First mountain is the lowest of the three. The fact that the latter rests upon conglomeratic sandstones, in the vicinity of Paterson, does not mean that it occurs near the base of the Newark system, for, as has already been shown, the Brunswick series increases in coarseness to the northeast, passing from fine-grained shales, near Somerville and Bound Brook, to sandstones west of Irvington, and to conglomeratic beds further north. The successive lava flows, therefore, which formed these sheets, occurred late in Newark time, as represented in New Jersey.

The New Germantown and Sand Brook sheets, both of which are extrusive, are also interbedded in the Brunswick shales, well above their base, certainly in the upper half, perhaps in the upper third. They are, therefore, in a general way, contemporaneous with the Watchung flows. There is no evidence that they are parts of the same sheet.

The intrusive sheets and dikes are later than the beds which they penetrate, and in a number of cases it is possible to determine quite closely their age.

The Palisade trap traverses beds belonging to the Stockton series, and in New York State ascends into strata probably belonging to the Brunswick series. The Rocky hill trap, near Hopewell, cuts Brunswick shales about the middle of the series, whereas near Dean's station, where it disappears beneath the Cretaceous beds, it cuts the Lockatong series. It is certainly older than the Cretaceous beds, and younger than the middle layers of the Brunswick series.

The coarse grain of the rock of both ridges indicates that it cooled slowly and presumably at a considerable depth from the surface. Microscopic studies * of the altered shale at Hoboken reveal contact phenomena, in so far as the alteration of the shales is concerned, characteristic of igneous rocks of deep-seated origin. Exactly similar altered shales adjoin the Rocky hill trap where it cuts the Brunswick shales. These shales, therefore, were probably deeply buried beneath the upper Brunswick beds, when the trap was intruded into them. The Rocky hill-Palisade sheet is due to an intrusion which occurred not earlier than the closing stages of Newark time, quite certainly after the volcanic overflows which formed the Watchung sheets.

The western half of Sourland mountain trap lies near the base of the Brunswick shales and the eastern end descends into the Lockatong beds. The longest dike, which branches off from the upper surface,

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* A. Andreae and A. Osann: Tiefencontacte an den intrusiven Diabasen von New Jersey.

penetrates a great thickness of Brunswick shales and affords conclusive proof that this sheet also was not intruded before the deposition of the latter part of the Brunswick beds. The dike which extends towards Mount Airy can be traced without interruption so long as the associated shales are not faulted. But when it reaches the area of confused structure southwest of Mount Airy village it cannot be traced. The inference is that the trap was intruded before the movements of the shales, which gave rise to the faults. The same argument can be used in the case of Rocky hill and the Palisades sheet. Both are cut by faults, the former terminating abruptly at the great Hopewell fault. The time of faulting cannot be definitely fixed, but it seems most probable that it was coincident with the elevation of the region above the sea and the tilting and warping of the beds. This being the case, the time of the intrusion of these three trap sheets is somewhat definitely fixed. It was after the deposition of the Stockton, Lockatong and by far the greater part of the Brunswick shales and before the faulting.

Bald Pate and Pennington traps traverse Brunswick shales far from the base of the series. Although near the Hopewell fault, they do not cross it, but end abruptly where they reach it. Their age is probably the same as that of the other sheets. Mount Gilboa, near Brookville, occurs in Lockatong beds, but is near the great Flemington fault. It may have ascended the fault line, although the fact that it does not follow the fault line may be urged against this view. The Point Pleasant trap occurs also in the Lockatong shales.

Cushetunk and Round mountain masses occur in Brunswick shales, far above the base and therefore they are not earlier than the latter part of the Newark time.

The trap dikes are almost entirely in the Brunswick shales.

In summing up, therefore, it may be said that the extrusive sheets occur in the upper half or third of the Brunswick shales, and therefore were outpoured late in Newark time. The intrusive sheets extend, for the most part, well up into the Brunswick shales, and, so far as the evidence goes, antedate the disturbances which closed the deposition of the Newark beds. There are good reasons for believing that many, perhaps all, of the intrusive sheets are younger than the extrusive, although the evidence is not conclusive. From *a priori* considerations it may be suggested that the lava formed intrusive sheets after the formation became so thick that it could not readily rise to the surface; whereas, earlier in Newark time the lava was able to break through the thinner beds and overflow.

CHAPTER III.—METAMORPHOSED SHALES.

Allusion has frequently been made to metamorphosed shales near the larger intrusive trap masses. The black argillites of the Lockatong series have been called "baked shales" by many writers, and their hardness and blackness ascribed to the contact with the trap, although no igneous rocks occur near them. This is an error. The argillites owe their color to the carbonaceous matter they contain, and their hardness to some other cause than local metamorphism. The metamorphosed shales differ in some radical respects from the argillites. The most marked macroscopical changes are (*a*) a greater or less induration, (*b*) change in color—red shales in general becoming purple and then a blue black, streaked with gray or green near the trap, and (c) the development of secondary minerals, commonly epidote and tourmaline. The rock often has a banded or mottled appearance, due to the formation of lime-silicate hornfels. Of these three changes the third is the most significant. Mere induration or change of color does not necessarily signify "baking," but when all three occur together, and only in layers in close proximity to certain trap sheets, proved to be intrusive by their structural relations, the changes can be safely ascribed to the igneous rock. Many of the altered shales on weathering become a pale blue or ashy gray color, a tinge never taken by other layers.

So far as I know, the only detailed microscopic study of the altered shales has been made by Messrs. Andreae and Osann * from specimens collected at the base of the Palisades at Hoboken and Jersey City. Their results, which were published in Germany, are inaccessible to most readers in this country, and therefore I shall summarize their views briefly. They group the metamorphosed rocks into four classes.

1. Normal slate hornfels, not distinguishable from hornfels formed by contact with intrusives which cooled at great depth.
2. Hornfels containing numerous tourmaline crystals.
3. Metamorphosed arkose sandstone, distinguished by the formation of a fibrous green hornblende.
4. Lime-silicate hornfels (kalksilikat hornfelse).

The first two groups differ only in the presence or absence of tour-

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* Tiefencontacte an den intrusiven Diabasen von New Jersey, loc. cit.

maline. They are very dense rocks, with a splinter-like cleavage and abound in biotite. Traces of the original stratification are preserved in the alternation of layers containing varying amounts of mica. The tourmaline always appears as a secondary mineral, in well-bounded black prisms up to three millimeters in length and one in width. They are without definite arrangement, the longitudinal axis being oblique to the stratification plane as frequently as it is parallel to it. Each of the tourmaline crystals is surrounded by a bright halo about half a millimeter in width, caused by the absence of biotite. This may be accounted for on the assumption that the iron and magnesia were consumed in the formation of the tourmaline. The biotite crystals have their tabular planes arranged parallel to the stratification planes.

Feldspar is the chief constituent of the tourmaline-bearing hornfels, and quartz is entirely wanting—a fact which indicates that the original sediment was very deficient in silica, but abounded in clayey materials.

From such rocks, presenting clearly a crystalline structure, a transition may be found to very dense stones in which, even when highly magnified, no constituent parts save biotite can be recognized.

The lime-silicate hornfels is bright grey to green grey in color, dense and hard, and discloses under the microscope an irregular aggregate of very small grains, with strong double refraction, whose nature can be determined only from the larger grains. The minerals common to rocks of this variety occur; a colorless pyroxene, closely related to diopside; green hornblende; colorless tremolite in fibrous and radiating aggregates; garnet; vesuvian; epidote; while feldspar occurs commonly in diminished quantity. This rock frequently exhibits an alternation of bright and dark layers, in the former of which diopside usually prevails; in the latter green hornblende and biotite. Solitary grains and crystals of titanite occur and frequent masses of calcite were observed. The lime-silicate hornfels effervesces with acid.

Similar metamorphic rocks are known elsewhere only in the case of sediments which have been altered by deep-seated intrusives. The importance of this conclusion, in its bearing on the date of the intrusion of the trap, has already been pointed out.

The association of the slate hornfels and the lime-silicate hornfels is extremely interesting. The former makes up the main mass of the altered beds. The lime-silicate hornfels forms in most cases small layers in the slate hornfels, the thickness of the former often being no greater than that of a sheet of paper. These layers are parallel to each other and to the original stratification of the shales. Frequently they form small elliptical masses, joining each other like a string of pearls in the stratification plane. From this it is but a step to rocks in which the lime-silicate hornfels forms only roundish eyes and knots in the hard black slate, the "incipient segregation," which gives the rock a mottled appearance. In still other cases the lime-silicate hornfels traverses the darker hornfels in veins and bands at various angles to the stratification. Before metamorphism these were probably veins of calcite, which together with the surrounding shales were altered on the intrusion of the trap.

In all these various relations the boundaries of these two rocks, of such different chemical composition, are sharply marked, both to the naked eye and microscopically. This is strong evidence that during the metamorphism these rocks were not molten, but that the changes occurred in solid, or at most, very slightly plastic beds. The authors conclude that the beds were originally argillaceous shales, locally strongly calcareous and traversed by veins of calcite and interbedded with layers of arkose sandstone. They find in the contact phenomena strong evidence that the trap was intrusive and cooled at great depths.

Metamorphosed shale, in every respect identical with these rocks, so far as macroscopical examination can determine, occurs along the Rocky Hill ridge, and is well shown along the canal near Rocky Hill village. Epidote and tourmaline-bearing shales occur on both sides of the Sourland mountain trap and are well exposed at Lambertville, where many of the features noted by Andreae and Osann can be seen. Fragments of altered shale can be found on the surface near the other intrusive trap masses, but there are no extensive exposures of the rock in place. Metamorphosed shales occur in considerable amount in New Jersey, but not all the hard black shales of the system are metamorphosed beds, as was formerly supposed.

CHAPTER IV.—STRUCTURE.

FOLDS.

The general structure * is that of a faulted monocline, the beds of which trend N. 30° to 50° E., and dip 13° or 15° to the northwest-

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* Many details of the structure were given in the annual report for 1896, pages 72–78.

ward. As a result of this, the layers to the northwest, save where faulting has occurred, are above and therefore younger than the layers on the southeastern side. When examined more in detail, the structure is seen to depart locally from the monocline.* Several broad, gentle flexures occur, in addition to a few sharply-marked folds in the vicinity of the intrusive traps and greater fault lines. A good example of the former is seen in the shales of the Hunterdon plateau, where the beds are so inclined that their outcropping edges describe a great curve, parallel on the east and southeast to the escarpment of the plateau. The structure is a shallow syncline, whose axis is inclined northwestward. Low folds occur in the valley of the Raritan, particularly in the region north of Somerville. From New Brunswick to Bound Brook the dip is quite uniformly to the northwestward, averaging ten degrees, but further to the west the monocline is interrupted by gentle flexures and swells which are difficult to trace because of the absence of individuality in the layers. The broad outcrop of the Brunswick shales in the Raritan valley is due in large part to these low folds.

More definite folds—all synclines—occur (*a*) near the Sand Brook trap sheet, southwest of Flemington, (*b*) the New Germantown trap sheet, and (*c*) the Watchung traps, whose great crescentic curves are due to the synclinal structure of the inclosing shales. Several examples of sharp folds occur near Glenmore, southwest of Hopewell, and not far from the end of Rocky hill. Other instances were noted near the faults.

In the area reported upon last year, the Stockton and Lockatong beds are the more constant in dip and strike, so that the monoclinal structure is most marked in these belts. The Brunswick shales are characterized by shallow folds, some of them covering an area of several square miles. These, combined with a fortunate arrangement of faults, have greatly increased the area of red shale outcrop, and so permitted the formation of the broad rolling lowland, so characteristic of the greater part of the Newark system.

The structure of the northern part of the Newark area does not differ materially from that already described. In general, the beds form a monocline tilting northwestward, but gentle folds are not uncommon. Owing to the glacial drift many details are not so distinctly shown as in the southwestern area.

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*The main facts of the structure are indicated on the maps shown on Plates II. and III.

Along the base of the Palisades the average dip is fifteen degrees and the strike N. 31° E. The average of all the observations made on the shales immediately overlying the trap is thirteen degrees for the dip and N. 34° E. for the strike. So far as could be determined, the monoclinal structure prevails with great regularity in the region between the Palisades and the Watchung mountains.

The extrusive trap sheets are excellent guides in interpreting the structure, once their conformity to the shales has been completely demonstrated. The curved outline of the Watchung mountains finds a ready explanation on the supposition that the structure is a gentle synclinal fold, the westward side of which has been cut off by a fault along the highland border of the formation. Observations on the dip of the sandstones substantiate this conclusion.

From Bernardsville to Far Hills the general trend of the shales is N. 85° E., with dips of fifteen to twenty degrees southward. Variations from this in the shales are matched by bends in the trap ridge. Between Far Hills and Martinsville * the strike is in general N. 45° to 50° W., with dip twelve to fifteen degrees northeast. Between Martinsville and Summit the strike averages N. 67° E., becoming more northerly near Summit, with dips of twelve degrees to the northwest. From Summit to Montclair the average strike is N. 47° E., with dip of twelve degrees northwest. Near Paterson the average strike is N. 20° E., with a constant tendency to swing towards the west, as one advances northward, owing to the synclinal fold which controls all these dips.

The axis of this fold extends northeastward from Liberty Corner through Madison and beyond. The axis itself is undulatory, not horizontal, due to gentle cross folds which affect it. Southwest of Liberty Corner it rises, so that the edges of the Watchung sheets outcrop continuously at the bow of the canoe or spoon. It rises also at the northeast, causing the trap ridges to curve towards the highlands.

The curved New Vernon trap ridge is due to an anticlinal fold whose axis dips southeast and crosses the synclinal axis near Green Village. Between Riker hill and Pine Brook, the synclinal axis is probably slightly depressed, as shown by the third trap sheet passing below the level of the alluvium at that place. It rises, however, where crossed by the anticlinal axis of Towakhow or Hook moun-

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* Outcrops on both sides of First mountain are included in these averages.

tain, which pitches northwestward. The apparently greater width of Second mountain ridge at Caldwell is probably due to this cross fold. A second syncline is indicated by the curving trap ridges west and north of Mountain View.

As a result of this fold the ends of the trap ridges are re-curved towards the highlands, and the shales outcropping along Mine brook next to the gneisses are at the same horizon as those between First and Second mountains at Martinsville and Little Falls. If, as seems probable, the Long hill trap and the New Vernon trap are parts of the same sheet, the shales within the New Vernon crescent are at the same horizon as those beneath Long hill at Millington, Stirling and Chatham, and are also to be correlated with the beds on the inner side of Hook mountain crescent. The highest beds, therefore, seem to be those beneath the Great swamp between Long hill and Green Village and those between Morristown and Boonton. These are apparently higher than any of the shales of the Raritan valley or of the region east of Frenchtown on the Hunterdon plateau.

FAULTS.

General Explanation.—Faulting is said to have occurred when motion has taken place on the two sides of a fracture in such wise that the layers on opposite sides do not exactly correspond. The amount of displacement may be only a fraction of an inch or it may be many thousand feet. The fault plane or plane of fracture may be vertical or inclined at an angle. Its departure from the vertical is termed the *hade* (Fig. 6, *A*). Those beds which have been depressed, relatively to the layers on the other side of the fracture, are said to be *downthrown;* the others, up-thrust or *upthrown* (Fig. 6).

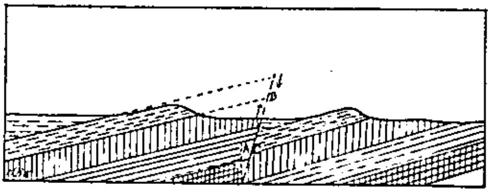

Fig. 6.
Diagram of a fault in tilted beds.

When a fault plane is exposed in a rock bluff or similar section, the fact of faulting is easily seen, and the lack of continuity on the two sides of the fracture is conclusive proof of such movement. If the displacement be comparatively rapid, and, geologically speaking, recent, the fault line on the surface would be marked by a cliff formed by upthrown beds. But when the fault plane is not exposed, and the surface on the two sides of the fault line has practically the same elevation, as is the case when denudation has destroyed the fault-cliff, if it ever existed, faulting is harder to detect. Under favorable conditions, however, it can be demonstrated as conclusively as if the actual dislocation could be seen.

Very commonly the rock surface along the fault plane is scratched or *slickensided* as a result of the motion. In other cases the rocks near the plane of motion are crushed, and the fracture is filled with these broken fragments, forming a *fault breccia.* The beds of the down-thrown side may be tilted close to the fracture so as to dip away from the fault plane, whereas those on the opposite side may be tilted in the opposite direction. The presence of a fault may therefore be indicated by slickensided surfaces, by a crushed and brecciated zone or by abnormal dips. If all three lines of evidence concur, the case is much stronger than for any one separately. All three, however, may not be conclusive in the absence of other evidence.

Necessarily, the beds on the surface, immediately adjacent to the fault line on opposite sides, are not exactly the same (Fig. 7). If the dislocation has been great, compared to the thickness of any of the faulted beds, the rocks on opposite sides of the fault may be very different in color, texture, composition, structure and age. The position of a fault line may often be determined by the aid of these facts.

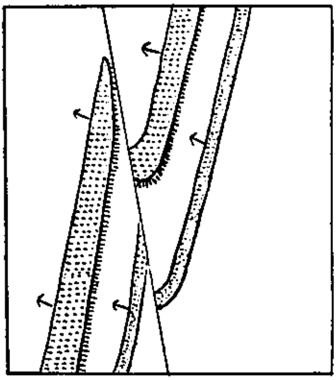
Fig. 7.
Diagrammatic sketch of a fault oblique to the strike.

When the fault has affected beds which are inclined, important results often follow. Suppose the fault plane to be parallel, or nearly so, to the strike of the beds. If the upthrow is on the side towards which the beds dip, beds which outcrop on the other side of the fault line are brought to the surface again and repeated (Fig. 6). The more complex the series of beds which is repeated in the same order, the stronger the evidence in favor of a fault. The number of beds repeated depends upon the amount of the fault, the thickness of the beds and the angle of dip.

On the contrary, if the downthrow is on the side towards which the beds dip, some are carried below the surface and do not outcrop at all. Some members of a series might in this way be entirely concealed. The fault might be exceedingly difficult to detect in this case, unless the complete series is elsewhere shown.

If the fault line is parallel to the strike of the beds, the latter will continue indefinitely on either side of the fault. But where it is oblique to the strike, each layer must terminate where it is intersected by the fault (Fig. 7). In the case of hard layers forming ridges, it would be found, under these circumstances, that the ridges would end quite abruptly when the invisible fault line was reached. Many of the trap ridges have steep easterly faces or even cliffs, and long, gentle westerly slopes. These steep escarpments are normally developed by erosion, and always face in the direction against the dip. If the hard ridges be cut obliquely by a fault, so that the trap on the east side of the fault plane abuts against shale on the other, a *westward*-facing cliff and talus will in time develop along the fault, because of the more rapid erosion of the softer beds. Under normal conditions the side of the ridge towards the dip will always have a gentle slope. A cliff and talus, therefore, facing in the direction of the dip, is good topographic evidence of a fault. The topography is, therefore, an important guide in determining the presence or absence of faults. These are some of the facts upon which the geologist has to depend in trying to locate fault lines in the field.

Owing to the monotonous character of many of the Newark beds, it is no easy matter to detect faults, particularly those the throw of which is less than the thickness of any one of the three members of the series.

In the Annual Report for 1896 the course of two faults of the first magnitude was traced, and I gave, in considerable detail, the facts which indicate their existence. The following is a summary of those statements:

The Hopewell Fault.—This fracture extends in a sinuous course from near the Delaware river, past Harbourton, Hopewell and thence along the foot of the Sourland plateau escarpment, passing a little west of Flagtown station, on the Lehigh Valley railroad. It probably crosses into Pennsylvania, but its exact location at the river could not be definitely determined.

The evidence of faulting along this line is as follows: (*a*) the repetition of the strata, Stockton, Lockatong and Brunswick beds occurring in the same order on each side of the fracture; (*b*) crushed and contorted shales, slickensided surfaces or overthrown dips at every exposure along or near the fault line; (*c*) diversity of structure—dip and strike—on opposite sides of the fault line; (*d*) contrasts in topography and the termination of ridges at the fracture. The repetition of the beds has been alluded to in describing the rocks. In the bed of every stream crossing the fault evidence of fracture was found in the crushed and slickensided condition of the rocks, but the fault was nowhere exposed. Locally, the rock has been so greatly sheared as to destroy all traces of the bedding planes. Very marked overthrown dips occur in a cut just west of Flagtown station, which increase in steepness towards the fracture. Folds in the Brunswick beds, on the southeast side, terminate abruptly against the fault and do not affect the beds on the opposite side. The high Sourland plateau, composed of hard trap and resistant Lockatong argillite, terminates abruptly where the fault crosses the strike of its beds. The height and prominence of the escarpment north of Skillman station is due to the contrast in hardness of the Lockatong and Brunswick shales brought into juxtaposition by the fracture.

The dislocation has been sufficient to bring to the surface the upper part of the Stockton beds and place them side by side with the middle layers of the Brunswick shales. On the basis of the estimates of the thickness of these beds made last year, the throw cannot be less than 10,000 feet. I am now inclined to believe that these estimates are too great, and therefore the throw is probably somewhat less than this. How much less I am not able to determine accurately. But the fault is certainly a great one, the throw measuring several thousand feet (probably 6,000 or 7,000). Its hade cannot be determined, since the fracture is nowhere exposed in section, and its location can rarely be determined within fifty yards. North of Flagtown, where the Brunswick shales occur on both sides of the fracture, its course could not be made out.

Flemington Fault.—This fault had been previously noted by other workers, but its exact location had not been determined. It is located along the bluffs of the Delaware river, by the juxtaposition of the coarse arkose conglomerate (Stockton) with the black argillite (Lockatong) a mile or so south of Stockton. The line of dislocation is concealed by the talus of a small ravine. Hence it extends in a northeasterly direction for three miles, thence curving a little to the north, so as to pass east of Headquarters, southeast of Sand Brook and a mile west of the center of Flemington. For much of this distance it extends along the foot of the Hunterdon plateau escarpment. For several miles north of Flemington its exact location becomes doubtful, owing to the similarity of the adjoining beds, but one, or perhaps both, of the faults along the border, west of Cushetunk mountain marks its northern extension. There is some reason for believing that the Round mountain trap, south of Cushetunk mountain, has ascended along the fracture, but this is not conclusively proven.

The evidence of this fault is as complete as in the case of the Hopewell fault. It consists of (*a*) repetition of the strata, (*b*) diversity of structure and topography on the two sides, (*c*) local disturbances, *i. e.*, crushed beds, overthrown dips and slickensides.

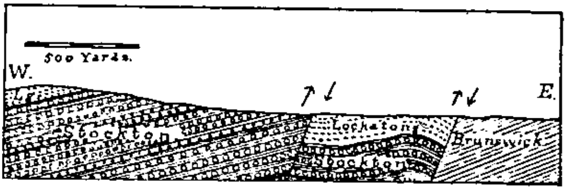

Fig. 8.

Cross-section of the Flemington fault (on the right) and its branch near Sand Brook.

The uplift was on the northwest and was sufficient to bring to the surface the base of the Stockton series, and just across the river, in Pennsylvania, the Paleozoic floor on which the Newark beds rest. East of Headquarters and Sergeantsville lower members of the Stockton series abut against beds apparently 2,600 feet above the base of the Brunswick series. The throw of the Flemington fault, near Headquarters, is certainly not less than that of the Hopewell fault.

Half a mile east of Sand Brook village a small fault splits off from the main fracture. By it a part of the Lockatong beds of the plateau have been downthrown so that they occur to the east and apparently below the Stockton beds (Fig. 8). The layers between the two faults are much confused in structure.

Dilts' Corner Fault.—Another and larger split fault was observed to branch from the main fracture, between Headquarters and Dilts' Corner. It crosses the Delaware about midway between Stockton and Lambertville, and from a cursory examination I am inclined to believe that it joins the Flemington fault again in Pennsylvania about a mile from the river. The rocks of this block belong to the Lockatong and Stockton series, with some intrusive trap masses. The general dip is south of west, although near the faults there is much diversity. The beds on the east and southeast have been downthrown relatively to the others. The combined throw of this fault and the Flemington fault is about equal to that of the latter further north. Figure 9 is a sketch map, showing the relationship of the two faults and the adjoining beds.

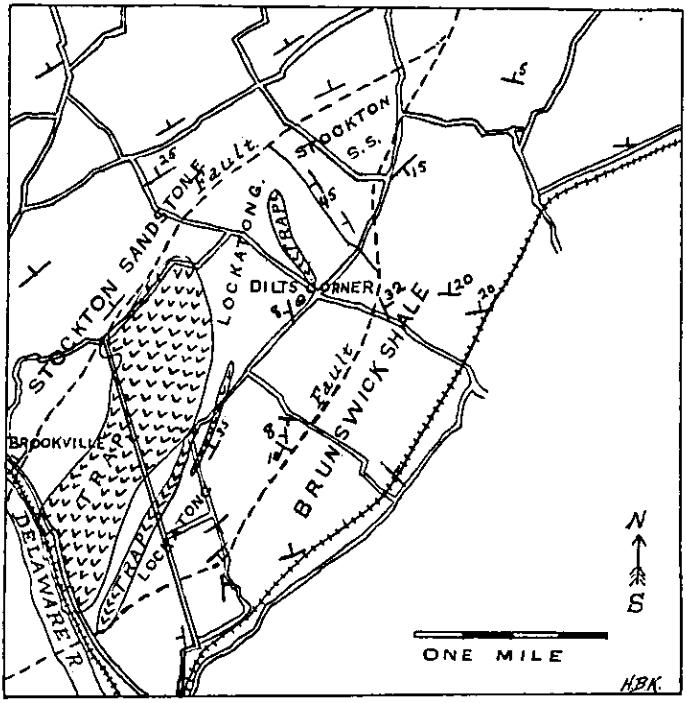

Fig. 9.

Map of the Flemington and Dilts' Corner faults, showing their junction.

Faults Along the Northwestern Border.—A number of faults probably occur along the northwestern border, but their presence cannot be demonstrated as conclusively as in the case of those just mentioned. From the Delaware river to the vicinity of Pattenburg the border is comparatively straight. The Newark beds are shales, quartzite conglomerates and limestone conglomerates. The pre-Newark rocks are gneisses and schists, with local narrow strips of limestone and shale between the gneiss and the Newark beds. The limestone conglomerate adjoins the areas of older limestone, but it is not limited to these. There is an absence of gneissic conglomerates, and there are no large areas of quartzite known from which the quartzite conglomerates may have been derived. These facts render it improbable that the present relative position of the two formations is that which obtained at the time of deposition of the Newark beds. If the hills of the crystalline rocks marked the immediate shore of the shallow sea in which the Newark beds were laid down, we should expect to find a closer connection between the constitution of the later beds and the adjoining older rocks.

On the other hand, such connection is not entirely wanting. Gneiss pebbles do occur in varying numbers in the conglomerates; the calcareous conglomerates are best marked near the areas of limestone. Faulting, if it has occurred, has not greatly changed the relative position of the beds.

A still stronger argument for faulting is found in the structure, particularly in the way in which the shales terminate against the older rocks. In New Jersey the actual contact cannot be seen, but the Newark beds in some cases dip toward the crystallines at various angles; elsewhere the strike is nearly at right angles to the border. Nowhere along this part of the border were the beds found to dip away from the older rocks. It has already been pointed out that the study of the structure has demonstrated that the conglomerates near Pattenburg are lower in the series than those on the Delaware river. In other words, along this part of the boundary, beds of a wide range in point of age abut against the pre-Newark beds. B. S. Lyman * has demonstrated that similar relationships obtain in eastern Pennsylvania. These facts are readily explicable on the supposition that faulting has occurred along this part of the border.

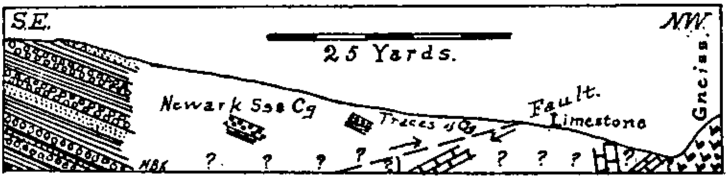

Fig. 10.

Section showing the probable relationship at Monroe, Pa., and the overthrust fault on the northwest border.

At the village of Monroe, Pa., the nearest approach to a contact was found. The relations are indicated by the diagrammatic section shown in Figure 10. The shale, sandstone and calcareous conglom-

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*Lyman. Penn. State Geol. Surv., Summary Final Report, vol. III., Part II., Maps.

erate dip towards the limestone at angles varying from twenty-three degrees to seventeen degrees. Seventy-five feet from the conglomerate, crumpled and serpentinous blue limestone appears, dipping in various directions. The gneiss is exposed a few rods beyond. The distribution of outcrops and talus indicates that the Newark beds overlie the limestones, the contact plane having an apparent dip of about fifteen degrees southeast. The facts here shown indicate that the hade of the fault, if fault there be, is great, and that the motion has been of the overthrust type. It must be admitted that the relations at Monroe are as readily explicable on the theory that the shales and conglomerates overlap unconformably the older rocks, as on the theory of faulting. But the indirect arguments in favor of faulting, *i. e.*, the distribution of the shales and conglomerate, and the truncated structures, are not invalidated.

That this part of the Newark border is marked by a fault cannot be positively asserted, in view of the inconclusive character of the evidence. But when the phenomena here are compared with those presented by the part described in the succeeding paragraph, the fact of a fault can hardly be questioned.

Between Pattenburg and the southwestern end of Cushetunk mountain, the border is irregular in outline. The older rocks are Hudson river shales and Trenton limestone, with small local areas of quartzite (Cambrian). There is a comparatively close resemblance between the constitution of the Newark beds and the older rocks. Hudson river shale pebbles form a large constituent in the coarse-grained sandstones. The Newark beds along this border are true basal beds and rest upon the eroded older rocks. Their strike is conformable to trend of the boundary line, and they dip away from the older beds. Their larger structural relations indicate that they are members of the Stockton series and are basal beds of the Newark system.

Four miles and a half southeast of Clinton the boundary line turns northward abruptly for a mile, and then northeastward for another mile. This sudden turn is in line with the probable northward extension of the Flemington fault. The shales—apparently members of the Brunswick series—dip towards the older rocks. There is an entire absence of a basal conglomerate, but for a part of the distance trap adjoins the Paleozoic limestone. The downthrow has been on the east, so that members of the Brunswick series, high in the Newark system, have been brought down on the east side of the same limestone as that on which the basal beds, half a mile westward on the other side of the fault, are resting.

The part of the boundary which is between the horns of Cushetunk mountain is probably along a fault. The Newark beds, which belong to the Brunswick series, either dip directly towards the older rocks or trend nearly at right angles to them. The shales are not conglomeratic, save locally near Lebanon, where a few quartzite pebbles occur. Gneiss pebbles, such as would be expected to occur had these beds been formed in their present position with reference to the gneissic hills, are absent.

Of that part of the border from Lebanon to a point three miles northeast of Pottersville, but little is known, since it is much obscured by drift. For most of the distance the calcareous conglomerate is apparently the bordering rock on one side and gneiss on the other. Limestone is known to occur at only one place, a very small area, and for much of the distance it is certain that it does not occur. The waves of any sea beating against the present line of hills would form a gneiss conglomerate, not a calcareous conglomerate.

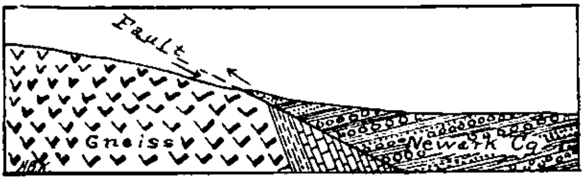

Fig. 11.
Diagram of the supposed relationship along the border north of Lebanon.

The structure is obscure, but the beds appear to dip in various directions with respect to the border. The sharp synclinal fold which has affected the New Germantown trap sheet, the outcropping edges of which give the best indication of the structure, seems to terminate against the border. These facts favor the hypothesis of a faulted boundary.

On the other hand, the occurrence of the coarse conglomerates indicates proximity to a shore-line. The limestone fragments are, on the whole, rather sharp and angular. Manifestly, they have not been transported a great distance. The readiest explanation of their origin is that they were accumulated along a shore-line, the rocks of which were at this point limestone. All these facts seem best harmonized by the assumption that the gneiss hills were bordered by belts of quartzite and limestone, along which these conglomerates were formed as shore deposits. By a subsequent thrust-fault, the Newark beds have been shoved over on the gneissic rocks, concealing the limestones and quartzites save in a few localities. Figure 11 represents this supposed relationship in a diagrammatic way. We know for a certainty that the Newark beds rest upon early Paleozoic and quartzites over considerable areas, as is shown by limestone foundation exposed in Pennsylvania by the Flemington fault.*

From the point where the border touches Peapack brook, two miles north of Gladstone, to a point half a mile southeast of Peapack (three and a half miles), its course is south by east and slightly irregular. The older rocks are Hudson river shale, Trenton limestone, Cambrian quartzite and granite. The Newark beds are coarse sandstones and conglomerates. The sandstones are composed of quartz and feldspar from the disintegrated granite, and of shale bits from the Hudson river beds. The conglomerates are chiefly of quartzite, but some heavy limestone conglomerates occur near the limestone border. Fragments of Hudson river shale enter largely into the conglomerates. The beds uniformly dip away from the older rocks, generally at a high angle. They are undoubtedly basal beds and rest upon the eroded edges of the older formation. They are not, however, members of the Stockton series, but apparently belong to the Brunswick series, and indicate a transition of the sea upon this area late in Newark time.

From a point a little southeast of Peapack to the New York State line, nearly forty miles, the border is remarkably straight. The irregularity near Morristown, shown on the State Geological map, has been proven by deep well-borings not to exist. A large fault undoubtedly determines this part of the boundary. The strongest evidence of this is found in the way in which the western part of the great Watchung syncline has been cut off, so that the shale which outcrops along Mine brook, near Bernardsville, is the same as that found between First and Second mountains, back of Plainfield and Bound Brook. West of Liberty Corner, Second mountain recurves to the northeast, diminishing in height and in width as the fault line cuts it obliquely. At Bernardsville an outcrop of trap close to the gneiss shows unmistakable evidence of fracturing and shearing. The rock is

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* See Map of the New Red Sandstone of Bucks and Montgomery Counties. Lyman, Second Penn. State Geol. Surv., Summary Final Report, vol. III., Part II.

literally crushed to pieces, so that it is practically a friction breccia. Further northeast higher beds of shale terminate at right angles against the highlands, while in other localities the beds dip directly towards the gneiss. Unfortunately, from Morristown northward the border is so deeply buried by drift that there is no possibility of obtaining a section showing the fault plane.

North of Pompton all three trap ridges decrease in elevation, as they approach the Newark border and the supposed fault, and disappear beneath the terrace deposits of the Ramapo river. No Newark beds are known to occur in the interval between the older rocks and the ends of the trap ridges, where they are covered by the drift. This interval is narrower than appears at first sight, since at several widely-separated localities along the bed of the Ramapo river a pre-Newark black shale or schist is exposed. It probably extends as a more or less continuous belt bordering the rocks of the crystalline highlands, and between them and the Newark beds. So narrow is the buried interval that I am firmly of the opinion that, were the drift to be removed, the trap would be found to abut against the pre-Newark beds, and to be separated from them by a fault. This, however, cannot be conclusively proven, although no adverse facts are known.

Summary.—A part of the boundary is formed by faults, but the part from Pattenburg to the southern limb of Cushetunk mountain and the part north and south of Peapack are not. At these points the beds rest upon the eroded edges of the older rocks. The evidence of faulting is indirect.

The contrast between the faulted and normal border is significant. The former is comparatively straight, the latter somewhat crooked. Along the former the shales dip in various directions in respect to the older rocks; along the latter they follow the trend of the contact and dip away from the older beds. In the one case Newark beds of very different horizons adjoin the border; in the latter they are basal beds. Along the faulted portion the Newark beds were not derived from the immediately-adjoining older rocks; along the normal contact the older layers have entered largely into the newer beds.

The exposure at Monroe, Pa., admits of either interpretation—a fault, contact or a depositional contact. If the former, then the hade is about seventy-five degrees and the fault is an overthrust. At one locality, Bernardsville, strong indications of fracturing and motion are observable.

Faults Along the Palisades.—Faults which intersect the trap sheets are more easily detected than those limited to the shales or sandstones. The reason is that any dislocation or offset of the trap sheet can be readily seen, whereas the lack of individuality in the shale beds renders it next to impossible to detect a small fault unless the actual plane of dislocation is shown.

Both Davis * and Darton † have described two faults in the Palisade trap. One is a longitudinal fault extending along Bergen Hill as far as Hoboken, the other cuts the trap diagonally, causing the offset at King's Point. The former can be detected in the sections made by the various railroads which cross the ridge. Along the Pennsylvania line there is a wide break in the trap wall a little east of Marion station. It is mostly filled with drift, but during the process of excavation red shales were found dipping towards the western trap wall. At the Jackson avenue station on the Newark and New York railroad, there is a break in the high trap wall of the cut. On the west side the trap ends abruptly, but as this part of the section is walled up, the rock is not shown. It certainly is not trap. Along the Morris canal still further south, there is a drift-filled break in the trap wall just east of the boulevard. A quarter of a mile southwest of this place red shales were found outcropping along the top of the hill. There is, however, no positive evidence that these shales occur along a fault line. They occur on a hill, not in a hollow, and although they are in line with the break in the Morris canal, they are not in line with the gaps along the two railroads. I am skeptical as to the existence of a single fault connecting all these localities.

Further east, on the Morris canal near the Central Railroad of New Jersey, there is a marked depression along the ridge. The trap outcrops on both sides, and the topography northward is favorable to the suggestion that the break observed at Marion and Jackson avenues is continuous as far south as Forty-ninth street. But all these facts, as far as yet seen, are explicable, either on the theory of a fault or of an intercalated bed of shale. The decisive evidence is found half a mile north of Marion, where the Delaware, Lackawanna and Western and the Erie roads penetrate the trap sheet by tunnels. Darton states that no shale occurs in these, but that a belt of crushed trap was found in line with the depression at Marion, and that still further north shales

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* Loc. cit., page 270, *et seq.*

† Loc. cit., pages 41, 44.

were found in excavating for the reservoir. The absence of shale in the tunnel is conclusive proof that the shales observed at Marion and elsewhere do not belong to an intercalated sheet, and also that they are not beds beneath the trap, brought up by the fault. They are overlying shales which have been protected from erosion by being inclosed in the depression between the trap masses. The fault must lie west of them, and the uplift has been on the west side (Fig. 12). The amount of the throw is indeterminable. It is certainly less than the thickness of the trap sheet.

Fig. 12.
Section of the fault at Marion.

At King's Point, Weehawken, the trap escarpment is abruptly offset to the east. A small valley followed by the Awichawken creek extends northward behind (west) the point. Indurated shale outcrops along this valley between the masses of trap. A deep boring (Darton) proves that the shales probably do not belong to an interbedded sheet. If continued upward along the strike to the east, they would abut against the trap of the point. Their dip is fourteen degrees, the offset is 360 yards, and the throw is about 270 feet, with uplift on the west. Part way up the valley the main fault appears to split, the smaller branch causing a slight offset in the trap wall on the west. The throw of this fault is estimated to be about seventy-five feet, and that of the main fault at this point is about 190 feet. The combined throw is very nearly equal to that of the main fault at the end of the point (Fig. 13). A somewhat swampy depression continues for a mile or more northward from the head of the ravine, and probably marks the continuation of the fault.

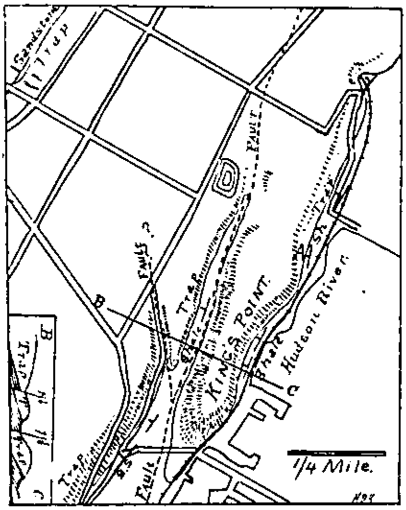

Fig. 13.
Map and cross-section of the King's Point faults, Weehawken.

New York, Susquehanna and Western Railroad Tunnel.—At the eastern entrance of the tunnel two faults are shown. One is visible in the north wall at the immediate entrance. The fault plane has a small hade (fifteen degrees) to the west. The uplift is on the west or dip side, causing a slight repetition of the beds, and the throw is seven feet. The fault plane trends about N. 45° E. On the south side the fracture is not visible at the level of the railroad on account of masonry-work, but can be seen higher up where it traverses the trap. The rock there is much shattered, being almost a breccia.

About forty yards east of the tunnel entrance another and larger fault cuts the trap and shale, but the fault plane is concealed by talus. The evidence of faulting is, however, complete (Fig. 14). The under contact of the trap and shale is exposed at the level of the wagon road, just above the tunnel entrance and just west of the fault-line. A few feet east, the escarpment of the trap, which here makes a sharp turn eastward, is broken by a deep ravine, extending north by west. A few yards east of the ravine the trap is found at the road-level, and one has to go 156 yards eastward from the first point of contact before the shale is again seen beneath the trap. The shale west of the ravine would abut against the trap on the other side if continued up the strike. The proof of the fault is (*a*) the repetition of the shales and the under contact, (*b*) the offset in the trap escarpment and (*c*) the ravine, with ledges of trap on either side, just where the escarpment makes its turn. The ravine has been excavated along the line of fracture. The offset is about 156 yards, the dip averages fourteen degrees and the throw is, therefore, about 115 feet, with uplift on the west side. The fault plane probably hades the same as the smaller one seen a few yards away.

The presence of this fault can be demonstrated independently of any argument derived from the offset in the escarpment and the ravine. These are, however, clearly the results of the fault, and therefore the presence of a similar offset with a ravine extending backward from the re entrant angle may be taken to indicate a fault even although other evidence may be largely lacking.

Edgewater.—A short distance south of Cody Bros'. quarry at Edgewater the trap escarpment is somewhat abruptly offset in exactly the same manner as at the tunnel, a quarter of a mile north. A deep, narrow ravine extending northward is followed by the Gorge road from Shadyside to Edgewater. From the head of this ravine, a mile north of Edgewater, a swampy depression extends obliquely across the ridge in a north by east direction. Just south of the Fort Lee-Leonia turnpike it passes into a deep ravine which opens upon the west side of the trap ridge, a mile or more south of Englewood. These ravines and the swampy depression follow the line of a fault, which can be traced continuously in its oblique course across the trap sheet. Figure 14 shows the relation of the fault at Edgewater. The indurated shale outcropping near the Gorge road, on the west side of the ravine, if continued along its strike, would abut against the high trap cliff on the opposite side of the fault at the offset. Continued upward along the dip it would pass many feet above the shales which underlie the trap at Cody's quarry.

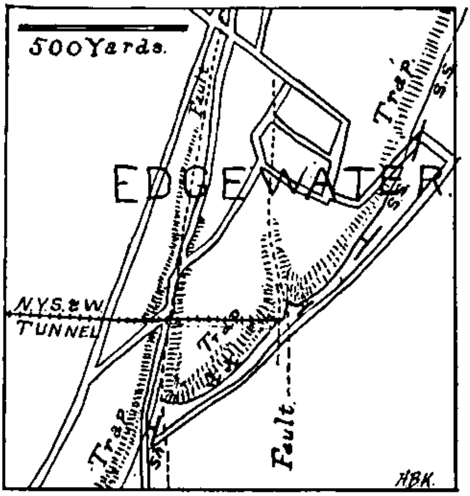

Fig. 14.

Sketch-map of the faults at Edgewater and the New York, Susquehanna and Western tunnel.

The offset may be explained on the hypothesis that the trap cuts across the beds downward, as was the case at South Weehawken. But at that locality there was no ravine leading backward into the ridge from the re-entrant angle, neither was there any depression along the top of the ridge. All things considered, the only permissible hypothesis is that of a fault, oblique to the ridge, along the line of the ravine.

Up the gorge the trap walls rise steeply on both sides, with talus slopes at their bases. The *west-facing* cliff is conspicuous. Owing to the debris which clogs the ravine, no shale was found between the faulted trap blocks.

The amount of offset is difficult to estimate, owing to the absence of any distinguishable horizon on opposite sides of the fault. Judging from the general topography, it is probably somewhat greater than at the tunnel fault, and the throw is probably somewhat larger, but probably does not exceed 175 feet. Since the offset is in the same direction in both faults, the uplift is on the west side.

If a fault exists along this ravine, some evidence of it ought to be found in the tunnel of the New York, Susquehanna and Western railroad. About 180 yards from the entrance, the tunnel wall is arched with brick for a space of twenty-seven yards. At the east end of the arch the rock is trap, at the west it is indurated shale, on top of which can be seen the trap forming the roof of the tunnel. The shales dip westward, so that the contact line reaches the floor of the tunnel about 245 yards from the eastern end. Where the tunnel is walled up the rock was broken and shattered, undoubtedly due to the fault which has brought the indurated shales above the level of the tunnel floor. The throw is estimated to be about 140 feet, taking the average dip of fourteen degrees.

As laid down on the map, the course of the Edgewater fault up the ravine would cross the line of the tunnel about 300 yards from the entrance, somewhat west of the fault just described. About 350 yards from the entrance another brick arch indicates a second brecciated zone in the trap. The Edgewater fault is probably to be correlated with one or the other of these.

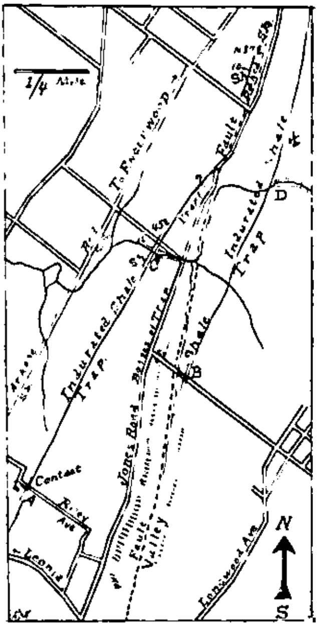

Fig. 15.
Map of the region south of Englewood.

Further evidence of the fault is found where it leaves the trap sheet south of Englewood. Figure 15 shows the offset which occurs along the upper contact line, and also the location of the upper shale in the valley along the fault. The offset near Englewood is considerably greater than at Edgewater, and the throw of the fault has increased to about 200 feet.

Fort Lee.—At Fort Lee the escarpment is again offset towards the east, and a deep ravine extends northward behind the offset mass for a mile, beyond which a shallow drift-filled depression can be traced for several miles along the top of the ridge. The topographic relations are almost exactly identical with those noted at Edgewater, and Davis, long ago, drew the natural inference that another fault cuts the trap at this point. The indurated shale outcrops beneath the trap on the west side of the ravine along the roadside and between the two trap bluffs. It also outcrops just beneath the trap at the south end of the offset bluff, and also northward along the river. The contact, at the first-mentioned locality, is unconformable, but the abrupt offset in the escarpment and the westward-facing cliff and talus along the ravine are certainly not due merely to the change of horizon.

The offset is estimated to be about 200 yards, which, with a dip of twelve degrees, makes the throw 130 feet, with uplift on the west side. The hade of the fault is not known, nor could its course be determined further north than Englewood.

North of Fort Lee the escarpment is fairly regular. Whatever slight departures from a straight course occur seem to be due either to erosion or the change in horizon of the intrusive sheet. No positive evidence of faulting was found between Fort Lee and the State line.

Faults Along First Mountain.—Two faults are well shown at Garrett Rock, Paterson, along the Delaware, Lackawanna and Western railroad, and have been described and pictured by both Davis and Darton. The larger one, throw of seventy to seventy-five feet, has determined the location of the larger ravine shown in the accompanying picture (Fig. 16). The other—throw about eight feet—follows the line of the smaller ravine. In both cases the uplift has been on the west side, thus increasing the width of outcrop of the trap. The actual fault planes are concealed by talus, but the shales outcrop west of the larger fault in such a position that if they were continued upward along their dip they would abut against the trap seventy-five feet above those on the other side of the ravine. The fault plane is undoubtedly nearly vertical. The picture shows the westward-facing trap cliff with talus at its foot.* This has been developed by erosion where the fault has brought the hard trap east of and against the soft shales.

Ascending the steep slope of this ravine one finds himself in a shallow, narrow valley which extends southward for several miles along the back of the ridge. For much of the distance westward-facing ledges occur, and an eastward-facing escarpment follows it for its entire length. Between the Great Notch and Montclair Heights the valley widens and deepens, and is followed by the Greenwood Lake railroad. The trap ridge on the east decreases in elevation and finally terminates half a mile north of the Heights

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*The cliff is partly hidden by the foliage, but can be seen just above the vertical line marking the greater fault.

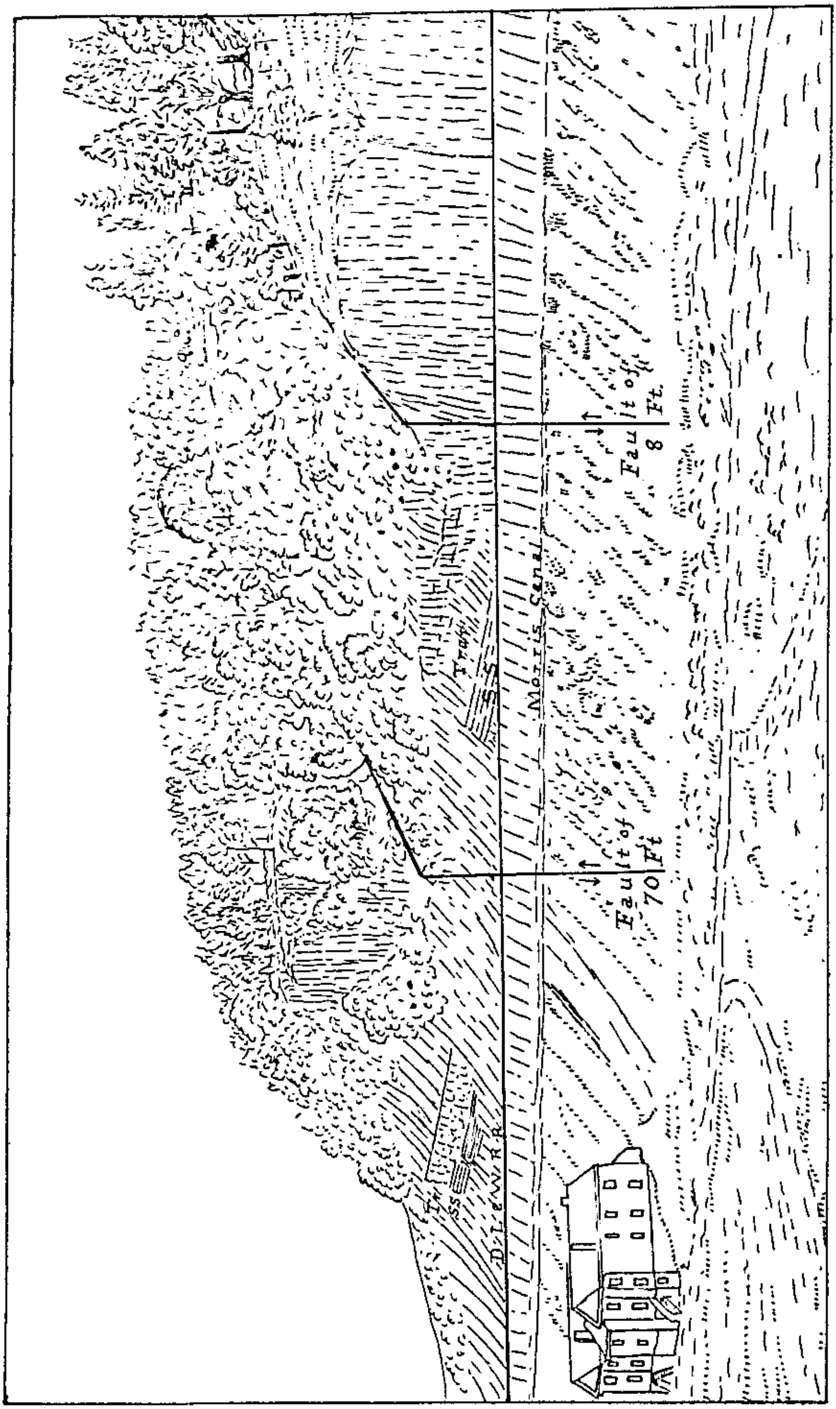

Fig. 16.

Sketch of the faults at Garrett Rock, Paterson.

station. Sandstone was found in a well a few rods south of the end of the trap ridge, and also in several wells along the valley between the ridges. Judging by the topography, the sandstone occurs in the valley certainly as far north as the Great Notch road, but it has not been observed. The fault lies along the east side of the valley, close to the line of trap outcrops. Where it intersects the low cross-valley at Great Notch, it is apparently bent sharply westward, implying a westward hade, which agrees with the hade of similar faults across the Palisades. Breccias observed in Wright & Lindsey's trap quarry, and in the railroad cut just west of the valley at Great Notch, extend parallel to the greater fault. Judging by the width of offset near Montclair Heights the throw has apparently increased to nearly 300 feet. Figure 17 shows the relations in a cross-section a mile north of Montclair Heights.

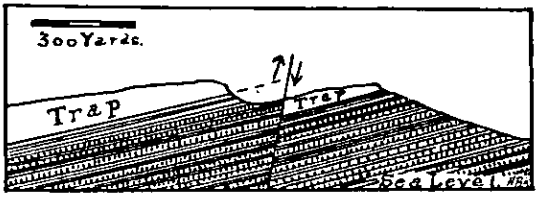

Fig. 17.
Section of the Montclair-Garrett Rock fault.

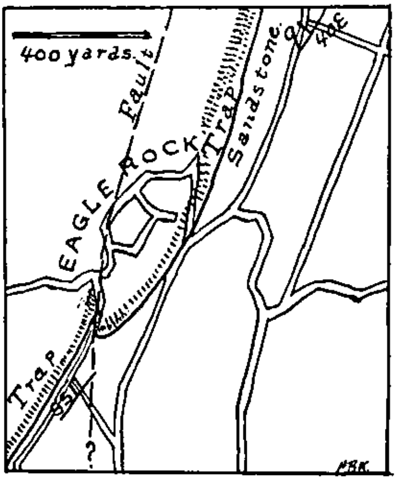

Fig. 18.
Map of the fault at Eagle Rock.

Near F. J. Marley's quarry, two miles south of Paterson, the steep escarpment of the ridge is slightly offset to the east. A narrow, steep ravine extends northward from the re-entrant angle. These features are universally found where oblique faults cut the trap ridges, and their occurrence here, although on a minor scale, suggests at once a small fault with a throw of less than fifty feet and uplift on the west side.

Eagle Rock.—At Eagle Rock the escarpment is slightly offset in a similar manner (Fig. 18). The road follows a steep ravine with walls of trap on either side. The cliff which is so prominent half a mile south of the rock gradually disappears, but its place is taken by the Eagle Rock ledge, which overlaps it for a short distance.

The offset of the escarpment and the overlapping of the cliffs are probably caused by a fault, the uplift of which was on the west and the throw of which is not more than fifty feet. The line of shallow ravines north of Eagle Rock, towards Verona, may mark the extension of the fault.

From Eagle Rock southward, to the gap at Millburn, the eastern face of First mountain is remarkably straight and is apparently not intersected by any oblique faults. A fine example of a fault breccia, however, was found in the deep cut of the Orange Mountain inclined railroad, west of Orange Valley. It lies 125 yards west of the edge of the cliff and trends N. 35° E. parallel with the escarpment. Its width varies from thirty inches to six feet. Within the brecciated zone the trap is much crushed, locally almost powdered, and usually reduced to fragments one to two inches in diameter. Where widest only the central portion is finely broken, the rock on the sides being broken into thin sheets parallel to the sides of the breccia, which has a slight hade to the east. A similar breccia, probably the same one, occurs in the Geo. Spottiswood & Co. quarry, half a mile northward, at about the same distance from the edge of the trap.

From Millburn to Pluckamin the front of First mountain is not interrupted in such a manner as to suggest faulting. The transverse gaps back of Bound Brook and Plainfield show no indication of faulting and the alignment of the ridge is not broken. They are due simply to erosion. A small fault was found in the American Copper Mine, north of Somerville. Its trend was about northeast, at right angles to the strike of the shales, and its throw was between four and six feet, but so far as discernible the crest of the ridge was not broken.

In the Report for 1896 (page 81) I indicated that there was some reason for believing that First mountain is terminated near Pluckamin by a fault. On the other hand, the facts can be as readily explained in other ways.

Darlington.—At the north end of First mountain a narrow ridge of trap one and three-fourths miles long and about 200 yards wide lies parallel to the main sheet and a third of a mile east of it. In the valley between them the glacial drift is so heavy as to conceal effectually all outcrops. There can be but little doubt, however, that sandstone underlies the drift. The relation of the two trap masses is unknown. The smaller ridge may be a part of the larger, cut off by a fault, with downthrow on the east side, or it may be a separate sheet. The fault, if it exists, has a throw of over 800 feet.

Faults on Second Mountain.—The width of outcrop of the trap along Second mountain varies greatly. Along much of its course the crest is double, and in the intervening valley the shale has been found at a number of places either in well-borings or at the surface. Two hypotheses may be considered in reference to the origin and relationship of this shale. First, that it is an interbedded layer between two trap sheets, *A*. Second, there is but one trap sheet, which is traversed by a longitudinal fault, causing the repetition of the trap and the appearance of the shale in the valley between. In the event of faulting the shales may be either underlying beds brought up by the fault, *C*, or they may be overlying beds protected from erosion in the trough between the uplifted and downthrown blocks, *B*. The hypothesis of faulting necessitates a fracture which has followed closely the curve of the ridge, since the double crest is most marked in the curved portion northeast of Somerville. The various relationships possible are indicated in Figure 19.

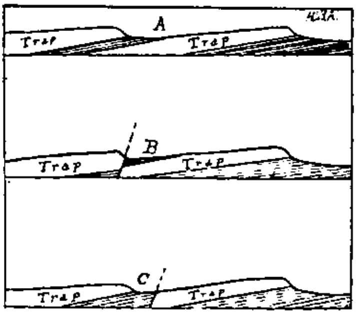

Fig. 19.

Diagrams showing the possible relationship of the shale in the valley between the double crest of Second mountain.

The evidence which bears upon these various hypotheses is to some extent contradictory, and it is impossible to arrive at a positive conclusion.

If the shales belong to an interbedded sheet, we must suppose two overflows of trap separated by an interval long enough for the deposition of the sedimentary beds. The fact that at both ends of the ridge the crest is single, is a strong argument against this hypothesis. No trace of shales is found at either locality, and the topography is decidedly against the supposition that they exist. In fact it is a strong argument in favor of the unity of the trap sheet. Furthermore, an interbedded sheet ought to be discernible in the deep gorge at Little Falls, but no indications of one could be found. Moreover, in a well at Caldwell at the Mount St. Dominic Academy the following section was found: Glacial drift 100 feet; trap rock 775 feet; total 875 feet. Shale was reached at the bottom.*

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*These data were obtained from the Sister Superior. Somewhat different figures were obtained through the kindness of Messrs. Conlan from a workman who was employed during the drilling, but the main facts are the same.

The location of this well is such that it would pass through an interbedded layer of shales at a depth of between 500 and 600 feet, if such existed.

All these considerations weigh heavily against the supposition of an interbedded layer. But there are other data to be considered. A well bored for Mr. Keane on the second crest of Second mountain near East Livingston, revealed the following section, which was obtained from the contractor, Mr. Baker, of Orange.

Soil	5 feet.
Trap rock	90 feet.
Brown sandstone	51 feet.
Trap rock	381 feet.
Total	527 feet.

These data seem to indicate positively that there is a layer of the shale or sandstone between the trap. In this connection must be mentioned the fact that Darton * found what he took to be evidence of two or more flows of trap at the north end of Second mountain, at the southwest end near Bernardsville, and in the gorge at Little Falls. The evidence, however, is far from conclusive.

It is difficult to understand the conflicting data furnished by the Caldwell and Livingston wells. They are only three miles apart and in similar positions considered with reference to the double crest line. I was not able to secure samples of the "brown sandstone" reported from the Livingston well. After carefully balancing all the evidence I am inclined to question the correctness of the indentification of the pulverized material brought up by the drill.† At a number of widely-separated points along Second mountain a red-brown variety of trap has been found. It is frequently vesicular but not always so. Hand specimens are easily mistaken for a hard, fine-grained red sandstone. When pulverized by the drill and brought to the surface, it could be distingushed from sandstone only with great difficulty. This red trap is known to have a thickness of at least forty-five feet. In view of the facts from the Caldwell well, the apparent absence of any shale layer at Little Falls, and the single crest line at the ends of Second mountain, I cannot but conclude that the "brown sandstone" found in the Livingston well was in reality red trap, and that the shale found in the valley between the crests does not belong to an interbedded sheet. My conclusion is that the trap of Second moun-

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* Darton, loc. cit., pages 24, 25.

† No cores were obtained, as work was not done with a diamond drill.

tain is but a single sheet, although it may be made up of more than one flow following each other at close intervals, but without intervening beds of shale.

The fault hypothesis needs to be considered. If faulting has occurred, the uplift of necessity has been upon the westward or dip side, causing the repetition of the trap. No direct evidence of faulting, beyond that furnished by the topography—the repetition of the beds—was found.

Darton,* however, has stated the indirect evidence derived from a study of the width of outcrop of the trap and the apparent thicknesses along different section lines. All three of the Watchung trap sheets are extrusive in origin. On the assumptions, first, that the sedimentary beds were not deformed during the intervals between the lava flows, and second, that sedimentation proceeded at an equal rate in all parts of the area affected by the flows during the interval of quiescence, and third, that each lava sheet was of approximately the same thickness throughout, their bases must have been originally parallel. Therefore, any lack of parallelism at present must be due to faulting. He finds that the base of the second Watchung sheet is quite uniformly 1,200 feet above that of the first Watchung sheet, where allowance is made for the known faults in First mountain. This indicates that the above assumptions, in so far at least as they apply to the first Watchung sheet and the overlying shales, are correct.

The distance from the base of the second sheet to that of the third sheet varies greatly along different sections. The variation is ascribed to faults either in the second trap sheet or in the overlying shales. The apparent differences in the horizons of the bases of the trap sheets are greatest along those sections where the double crest is the most marked. Assuming that the faulting is all in the trap and not in the shales, Darton estimates that the thickness of the Second mountain sheet is 700 feet along a section four miles northwest of Paterson, with faults amounting to 500 feet; near Little Falls the thickness is 600 feet, apparently without faults; in the latitude of Orange the thickness is 850 feet, with faults amounting to 500 feet; at Feltville it is 650 feet, faulting 350 feet; north of Bound Brook the thickness is 600 feet, with faulting to the amount of 800 feet.

In using these estimates, the assumptions on which they are based must be kept in mind. The latter may or may not be correct. There is no conclusive reason for supposing that the faulting is restricted to

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* Loc. cit., pp. 18–23.

the trap area. If it is not, then the estimates of the thickness of the trap sheets must be changed. In so far as the bases of the second and third trap sheets were not originally parallel, either because of great variations in the thickness of the second sheet or of the overlying shales or of both, these figures are open to question. But in spite of this element of uncertainty, these estimates are of value as indicating quite clearly that some faulting has occurred, and they strengthen the argument derived from the topography of the double crest. It is safe to assume that Second mountain is traversed for much of its extent by a curving longitudinal fault. It begins southwest of Liberty Corner, and extends nearly, if not quite, to Little Falls, following the valley between the crests. The amount of the fault varies considerably. If the shale in the valley underlies the trap (Figure 19, *C*) the fault is greater than the thickness of the sheet. If it is the overlying shale (Figure 19, *B*) the fault may be much less. I was unable to find decisive evidence on this point.

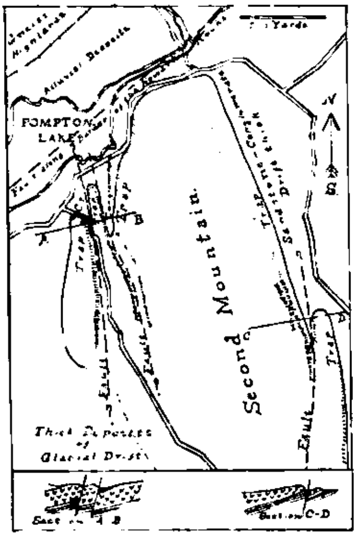


Fig. 20.
Map and sections of the faults at the north end of Second mountain.

At the north end of Second mountain near Pompton lake three small faults were found. Their position is shown in Figure 20. Their existence is shown by the offset in the border of the trap, the escarpment and the ravines leading back from the re-entrant angles. Owing to the absence of outcrops of shale in the vicinity, the throw cannot be calculated accurately. It is, however (in each case), small. The uplift is always on the west side.

Haledon.—Southeast of Haledon, near Paterson, the escarpment is slightly offset to the east and a narrow ravine extends northward from the re-entrant angle. For several miles north of this point a series of ravines cuts the back of Second mountain, forming in some places a well-marked double crest. Their location has probably been determined by the fault which causes the offset of the escarpment. The uplift is on the west side and is probably not more than 100 feet. Figure 21 shows its position.

Franklin Lake.—Southeast of Franklin lake the escarpment turns abruptly westward and at the same time its continuity is interrupted. Four narrow ravines or cloves, trending north and south, cross the trap sheet. Owing to the heavy accumulations of glacial drift in this vicinity it was difficult to determine exactly the location of the trap boundary and to make out whether it was offset opposite these cloves. So far as could be determined the trend of the shales (N. 40° to 50° W.) cannot account for this abrupt turn in the trap ridges. If, however, the northwestward trending beds be cut by a series of north and south faults with uplift on the west side, the topographic requirements will be fulfilled. North by east of this locality First mountain is crossed by several drift-field depressions along which no outcrops of trap could be found. Taking all these things into consideration it seems highly probable that southeast of Franklin lake, Second mountain is cut by four faults, some of which also cross First mountain, although the evidence favoring this cannot be considered conclusive. Figure 22 shows the positions of these faults.

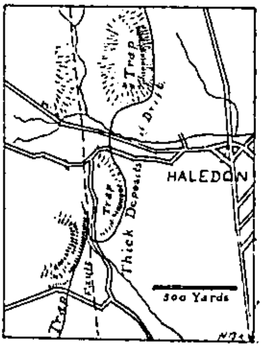


Fig. 21.
Map of the fault near Haledon.

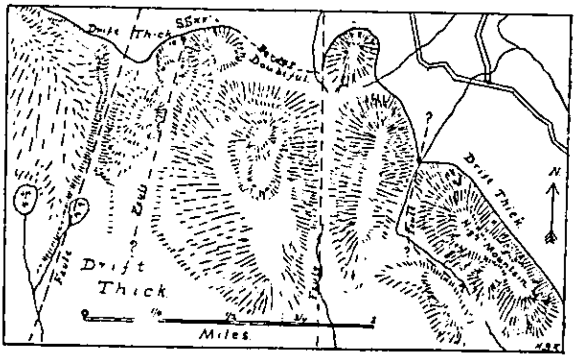


Fig. 22.
Map of the cloves across Second mountain, near Franklin lake, and the probable faults.

Several small faults were noted in the Granton trap and at Snake Hill, and reference has already been made to them in describing those areas.

Faults in the Shales and Sandstones.—It is extremely difficult to detect faults which traverse the members of the sedimentary series, unless they are of sufficient magnitude to repeat some one of the three major subdivisions, or the fault-plane itself is exposed. This is due to the absence of individuality in the beds of each subdivision. Even when faults are detected it is difficult to arrive at any reliable estimate of the amount of dislocation. In the following list I have given all the cases noted. In some instances the fault is only inferred, in others its presence is known beyond a doubt. In nearly all the amount of dislocations is probably small. In none is it necessarily great, although in some it is *not necessarily small.* The great faults near Flemington, Hopewell, Dilts' Corner and along the northwest border have already been described and are not included in this list.

1. In the Trenton Brownstone Co.'s quarries at Wilburtha several very slight faults occur. Beds belong to the Stockton series.

2. Faulting in a nearly horizontal direction has occurred in the rocks exposed in the quarry of Dennis Roe, Wilburtha. Stockton beds.

3. A fault was found in the bed of the creek almost directly south of the southwest termination of the trap mass, two miles northwest of Pennington. The fault plane trends N. 22° E., nearly parallel to the strike of the adjoining shale, and it hades twenty-seven degrees southeast. Continued northward, it passes along the westward margin of the trap, the termination of which may be due to the fracture. Hard, green argillaceous sandstone outcrops on the westward side of the fault plane and red-brown shales on the other. The fault plane is not marked by a breccia. Judging by the slickensided surfaces, the uplift has been on the westward or dip side, causing a reverse fault. The amount of dislocation cannot be determined at this exposure. The fault plane was observed again in the bed of a brook half a mile further south, but no traces of it could be found beyond this point. Beds belong to the Brunswick series.

4. In the bed of a brook a mile and a half west of Harbourton a fault plane is exposed, whereby heavy black argillites abut against red flagstones (Lockatong series). The fault plane strikes N. 65° W., and its hade is 40° S. W. Judging from the slickensided surfaces the motion was nearly horizontal and the vertical component was small. This fracture is near the Hopewell fault. The amount is indeterminable.

5. In the bed of a small ravine midway between Moore's station

and Lambertville a vertical slickensided face of dark-red shale (Lockatong) indicates a horizontal motion in a direction N. 40° E. The amount of dislocation is unknown. The adjoining rocks are considerably crushed.

6. North of Lambertville a fault is shown in the bed of the second tributary to Alexsocken creek. Green-black shales abut against red shales. Both beds are somewhat shattered. The fault plane trends N. 12° E., but cannot be traced beyond this exposure.

7. An obscure line of faulting along which the rocks are much crushed was found in a ravine half a mile west of Mount Airy. All along this ravine the dips are irregular, and the rock shows frequent indication of dislocation and shearing. These beds are not far from one of the smaller trap masses and their disturbed condition may be due in part to its intrusion.

8. A fault is seen in a high ledge of shales exposed along the bank of the brook one and an eighth miles south of Bowne station, Flemington branch of the Pennsylvania railroad. The throw is only three feet, but the fault is of interest because it is one of the very few cases where the downthrow is on the dip side, thus causing the elimination of some layers.

9. In the "pebble rock" bluffs, above Milford, five faults were noted. In two cases the throw, forty to sixty feet and ten feet, could be determined. In one case the fact of faulting was not demonstrable; the apparent throw is probably between thirty and forty feet. In the fourth case faulting is manifest with a minimum throw of twenty feet; it may be many times greater. In the fifth case the throw is certainly thirty feet, perhaps more. In all cases the uplift has been on the side towards which the beds dip, thus causing a repetition of the layers. There are numerous other localities along these bluffs where the continuity of outcrop is interrupted by talus or ravines. Other faults may occur at these points.

10. In the bluff along the right bank of the Raritan river, below New Brunswick, three fault breccias occur. Their widths are three to four feet, two to five inches and five feet respectively. They are nearly vertical and are oblique to the trend of the shales. Neither the amount nor direction of motion can be determined.

11. In the bluffs, half a mile below East Millstone, a small reverse fault has dislocated the beds about one foot.

12. A small fault is visible in the west side of the rock cut, 100

yards south of Belle Meade station, on the Philadelphia and Reading railroad. It causes a dislocation in the beds of about two feet.

13. In the railroad cuts west of Flagtown station, on the Lehigh Valley road, several small faults are seen with uplifts on the west side. These are in line with the probable northward extension of the great Hopewell fault, and are undoubtedly associated with it.

14. In a bluff at the head of the Raritan Water Power Company's raceway, west of Raritan, several small faults and breccias are exposed. They trend N. 65° E. and N. 25° E., and the uplift is on the southeast side. Since the shales dip eastward, the faults increase the width of outcrop. In two cases the throw is four feet and two feet; in a third case it is certainly as much as eight feet, and may be more.

15. In the railway cuts two miles west of Raritan, three faults are exposed, two of the normal type, one reversed. In two cases the throw need not be more than eight feet, in the third it is unknown. Figure 23 shows the flexing of the beds near the fault.

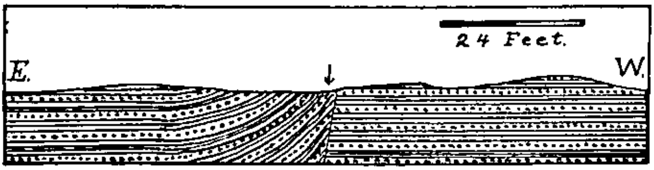


Fig. 23.

Cross-section of the fault on the Central Railroad of New Jersey, west of Raritan.

16. Three miles north of Flemington the line between the Stockton and Lockatong beds is apparently offset sharply to the northeast. So far as could be determined there is no corresponding change in the strike of the beds involved. Exposures are few, and the weathered and disintegrated surface material furnishes the only available data. The facts are explicable on the theory of a fault trending northeast, and crossing the beds nearly at right angles to their strike. In this event the uplift is on the south. The amount of faulting is several hundred feet. The evidence for this fault, however, can hardly be considered as demonstrative.

17. In William E. Bartle's quarry at Martinsville two nearly horizontal fault planes were found. The extent of the dislocation could not be determined. Overthrust faults with a fault plane so nearly horizontal are, however, exceptional in the Newark beds.

18. There is strong evidence of a fault on the Raritan-Pluckamin road, one and a quarter miles south of the latter place, where the road crosses a tributary of the north branch of the Raritan. The beds normally dip eastward, but at the bridge they dip sharply westward for a few feet, and in addition are much crushed. The fault trends northward, and the beds on the west side have been depressed. The downward drag of the beds on this side has probably caused the reversed dips there seen. This fault is in line with the great Hopewell fault, but is not associated with it, since the uplifts are on opposite sides.

19. A short half mile west of Bedminster Corners a fault is shown in the shales along the roadside. The actual fault plane is concealed by talus, but near the fracture the beds are crushed, and for thirty to fifty yards west of the fault plane they have abnormal dips. The upthrow is on the east side. The fault plane trends northward, and if extended southward would apparently coincide with the fracture (18), three and a half miles distant.

20. Along the same road another fault is visible in a ledge of shale a few rods east of Greater Cross Roads. The fault plane is marked by a breccia one foot in width, and is nearly vertical. The rock on both sides is red shale, but that on the east is more heavily bedded. The throw is at least six feet, and may be many times that. The trend is N. 30° W. There is nothing to indicate positively the upthrown side.

21. Two small, obscure faults occur in the shales exposed in the cut on the Philadelphia and Reading railroad, a mile east of Bound Brook. In neither case is the throw necessarily more than two feet.

22. Again, along the same railroad two other faults occur in a cut a mile south of New Market. Their trend is about N. 36° E., and the larger is marked by a narrow fault breccia and slickensided surfaces. Neither the direction of motion nor the amount could be determined with any accuracy. The throw is certainly more than six feet.

23. A short distance west of the New Market station, on the Lehigh Valley road, the shales are at one point crushed and upbent as if faulted. But there is no direct evidence as to the amount of dislocation. All of the faults last mentioned would, if continued along their apparent trend, intersect the first Watchung trap. The fact that no offsets are discernible in line with these fractures indicates that they

either die out completely before reaching the trap or are of very small amount.

In the region where the shales are drift-covered, it is even more difficult to detect faults. A few have been noted in quarries or railroad cuts.

24. At Avondale two small overthrust faults were visible at the time of my visit (1895) in the excavations of the Passaic Quarry Company. They are extremely local, not affecting all the beds of the quarry.

25. Three faults are shown in the walls of the Arlington cut on the Greenwood Lake railroad. The first, sixty yards west of Kearny avenue, is nearly vertical and is a clean-cut fracture. The uplift, one and a half feet, is on the west or dip side. The second, 250 yards west of Kearny avenue, hades westward at an angle of thirty-seven degrees. The rock is considerably shattered, although the amount of the dislocation is less than a foot, with uplift on the west. The third is much more conspicuous and has long been recognized. It is thirty yards west of the second, and is marked by a breccia varying in width from three to six feet (Plate IX.) The breccia hades to the west at an angle of thirty degrees and trends N. 50° E. The uplift causes a repetition of a few layers, the throw being about twenty feet.

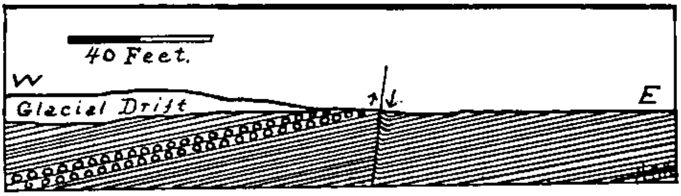
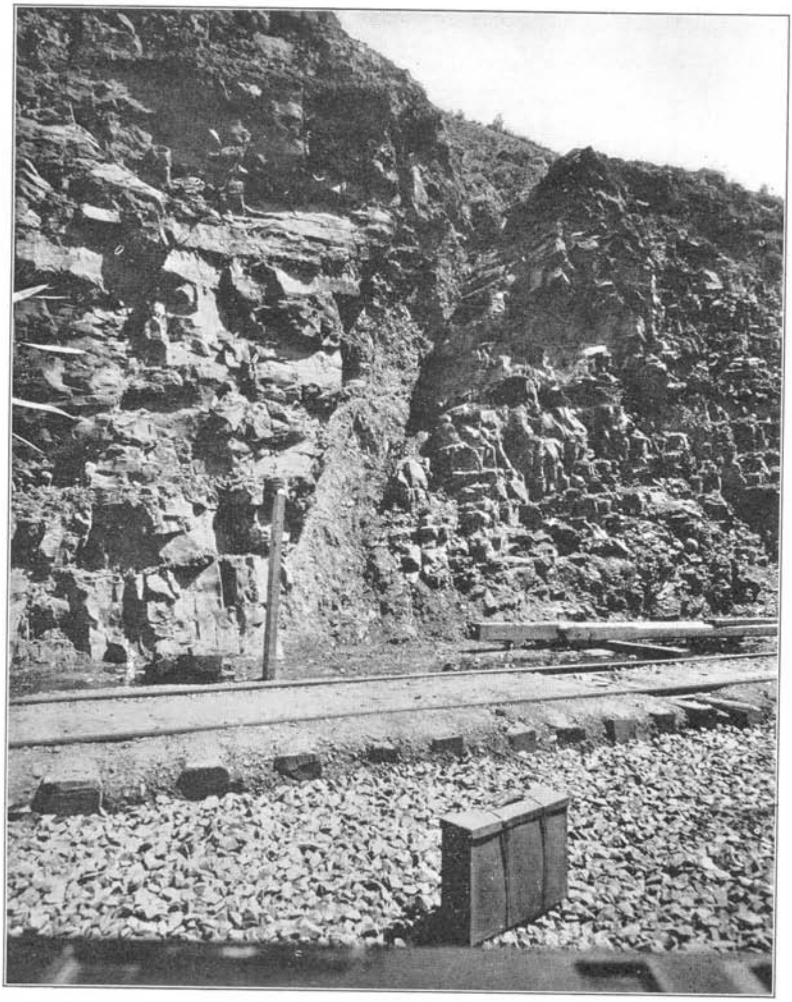


Fig. 24.

Cross-section of the fault at Prospect avenue station on the New York, Susquehanna and Western railroad.

26. At Prospect avenue station, Hackensack, on the New York, Susquehanna and Western railroad, the shales are well exposed. Near the western end of the cut a vertical fault plane is exposed. On the east side the shales are upturned for a foot or more, so as to dip eastward (Fig. 24). This is taken to indicate an uplift on the west side. West of the fault there is a heavy bed of sandstone. Since this layer is not exposed in the cut east of the fault the throw must be greater than the thickness of the beds there shown, *i. e.*, 140 feet. How much greater than this it is impossible to say.



The Fault Breccia in the Arlington Cut on the New York and Greenwood Lake Railroad.

27. At the crest of the ridge on the road from Hackensack to Nordhoff an overthrust fault is exposed, as shown in Figure 25. Its hade is sixty degrees and the beds on the west or dip side have been shoved over the beds on the east. The amount of dislocation is apparently ten feet. Near the fault plane the shales are somewhat crushed.

Allusion has already been made (p. 47) to the views of some investigators that the parallel ridge structure which characterizes the Newark area in Bergen county is due to the repetition by faulting of harder sandstone layers. Apart from the topography, which is as readily explicable on other hypotheses, no evidence, either direct or indirect, was found.

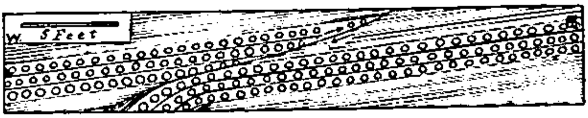


Fig. 25.
Section of an overthrust fault in the shales on the road from Tea Neck to Hackensack.

Summary.—Many faults are known to occur, and two of them, the Flemington and Hopewell faults, are of great magnitude and extent. Both cause the repetition of all three divisions of the Newark beds. The northwestern border is formed in part by a series of faults. The trap ridges, notably the Palisades and the first and second of the Watchung ridges, are cut by a number of faults, which trend obliquely to the strike of the beds. Owing to the contrast in the rocks, the offset of the trap ridge can be closely measured and the amount of throw accurately determined. It rarely exceeds 200 feet, save in the case of the longitudinal fault of the Second mountain, where it is probably 700 feet or over. In the sedimentary members all estimates of the amount of throw are generally unreliable, owing to the absence of distinctive beds. Most of the faults found are either in the Stockton or Brunswick beds, and the total number observed is hardly more than those found in the trap areas. The disparity in numbers between the faults in the shales and sandstones as compared with those in the trap areas is the more marked when the relative surface extent of the two rocks is taken into account. On this basis the observed faults are many times more abundant in the trap areas. The question whether this disparity is real or apparent is important in its bearing on the thickness of the series. There is no reason, so far as I can see, why they should be localized in the trap areas. I am, therefore, inclined to believe that were it possible to detect them with equal readiness, they would be found in approximately equal numbers and equal amount in both trap and shale. The fact that in no case has it been possible to trace even the largest faults for any distance from the trap areas, adds weight to the above conclusion. I am strongly inclined to believe, therefore, that there are many undiscovered faults, particularly in the Stockton and Brunswick beds, with throw equal to those in the trap areas. With but few exceptions all the faults are reverse faults.

THE THICKNESS.

The question of the thickness of the Newark series is so intimately associated with that of faults, that its consideration has been reserved until the other question had been discussed. In the Annual Report for 1896 some estimates were given. These were so large as to raise a doubt as to their accuracy, and yet the facts as then known did not permit any other interpretation. The following were the figures given:

Stockton	4,700	feet.
Lockatong	3,600	"
Brunswick	12,000	"
	20,300	"

At that time it was felt that not all of these estimates were equally reliable. Six sections were made across the Lockatong beds with the following results: Across the belt on the Hunterdon plateau, 3,540 feet, 3,450 feet, 3,500 feet; across the Sourland mountain area, 3,600 feet, 3,650 feet, 3,660 feet. The sweeping curve of this belt in the Hunterdon area, its uniform width, and the possibility of tracing certain subordinate but well-marked layers continuously along the strike preclude the idea that any great part of its apparent thickness is due to repetition by faulting. Furthermore, the fact that the beds on the Sourland plateau agree in thickness so closely with the same beds on the Hunterdon plateau is further reason for believing that the figures here given represent very closely the actual thickness. To suppose otherwise is to assume that these two separate areas are each traversed by faults, whose throw, by a remarkable coincidence, is almost exactly the same, but of which no traces have been discovered by areal work of the most detailed character.

The thickness of the Lockatong beds, near Ewingville and Princeton, seems to be only half of that in the other two regions, *i. e.*, 1,700 to 1,800 feet. The same relative thinness was observed in the Stockton beds, near Trenton, as compared with those further north. The explanation of this may lie in the fact that the beds of the former belt are nearer the old shore-line than the others. Stratified deposits have the form of an unsymmetrical lens which thins out very rapidly shoreward and very gradually seaward. It is to be expected, therefore, that the thickness of this belt, which is nearest the old shore, would be somewhat less than that of the others. The weight of evidence indicates that in the deeper parts of the estuary the Lockatong beds were 3,500 or 3,600 feet thick.

The estimates for the Stockton and Brunswick beds are more uncertain. In favor of the estimates given above these facts may be urged: West of Ringoes the Brunswick shales form a syncline whose axis plunges northwest. Between 6,000 and 7,000 feet of shales are involved in this fold. It is improbable that a fault could follow the curving strike so as to repeat the beds the same amount on both sides of the fold. Furthermore, a narrow trap dike was traced uninterruptedly from the back of Sourland mountain, near Rocktown, to Copper hill, a distance of five miles. The dike crosses the strike at an angle of forty-five degrees, and the thickness of the shales thus traversed is between 6,000 and 7,000 feet. There are reasons for believing that the trap was intruded before the tilting and faulting. If these reasons are valid the continuity of the dike is proof that the shales traversed by it are not cut by faults along the strike. Since such great thicknesses prevail in these beds, which are only a part of the whole, there is some reason for believing that the entire thickness of the Brunswick shales is near 12,000 feet.

On the other hand the disparity in the number of known faults in the trap areas and in the sandstone and shale areas indicates that there are probably more faults in the sedimentary beds than have been discovered. The apparent thickness of the Palisades and the two Watchung ridges has been increased from one-half to one-third by faulting. If the same proportions hold for the Stockton and Brunswick shales the figures given above will be somewhat reduced. The revised estimate, therefore, is as follows:

Stockton	2,300 to	3,100	feet.
Lockatong	3,500 "	3,600	"
Brunswick	6,000 "	8,000	"
	11,800 "	14,700	"

There is so much uncertainty connected with all measurements where there are so many unknown elements that these estimates may be far from correct. It certainly can be claimed for them, however, that they rest upon a much larger basis of fact than many previous figures.

Of the Trap Sheets.—The thicknesses of the various trap sheets are not included in the above estimates.

The Palisades at Jersey City Heights have a minimum thickness of 364 feet (well-boring), with a total thickness, including the amount removed by erosion, of 700 to 800 feet, according to estimates made from the angle of dip and the width of outcrop. At Fort Lee the thickness is about 950 feet (page 62).

The thickness of First mountain at Paterson is estimated to be 600 to 675 feet; at Orange Valley about 670 feet; at Scotch Plains about 680 feet, and at Chimney Rock about 580 feet.

With the exception of the thickness at Scotch Plains these figures agree closely with those obtained for First mountain by Darton along the same sections. At Scotch Plains the outcrop is narrower than elsewhere, but the dip of the inclosing shales is steeper and his estimate of 450 feet is probably too low.

The thickness of Second mountain is apparently somewhat greater than that of First mountain, but owing to the faults which traverse it, the estimates are liable to error. Darton's figures range from 600 to 850 feet. My own estimates, based on the width of outcrop and the dip, range from 840 feet to 990 feet. At Caldwell the well at the Mount St. Dominic Academy penetrated the trap for nearly 800 feet, but some addition must be made for what has been removed from the crest of the ridge by erosion.

At Millington the thickness of the Long hill trap sheet is about 300 feet. At Pompton a well drilled at the Norton house is reported to have passed through but seventy feet of trap before reaching sandstone. Hook mountain, east of White Hall, has an apparent thickness of 400 feet or more.

The New Vernon trap sheet has a thickness of about 250 feet, measured at the gorge near Green Village.

The outcrop of the New Germantown sheet is comparatively narrow, but the dip is steep and the thickness is estimated to be at least 400 feet.

The same thing is true of the Sand Brook sheet, the thickness of which is apparently not less than 425 feet.

Too little is known of the relations of the Sourland mountain, Pennington mountain, Bald Pate and Rocky hill traps to the inclosing shales to venture estimates of their thickness.

CHAPTER V.—CONDITIONS OF FORMATION.

Deposition.—The consensus of opinion among geologists is that the Newark beds were accumulated in broad, shallow estuaries, whose shores were laid bare by the retreating tide, and in which the varying currents alternately deposited coarse and fine materials. Professor Newberry * describes the conditions prevailing in New Jersey as follows:

"Many of the beds show ripple-marks, sun-cracks and raindrop impressions, which prove that they were once beaches or mud flats, sometimes exposed to the air. They are also frequently impressed by the tracks of large and small animals. Everything indicates that these tracks were made by animals that frequented the shores of bays and estuaries where the retreating tide left broad surfaces which were their feeding grounds. Inasmuch as many successive beds show ripple-marks, sun-cracks and tracks, the conclusion seems inevitable that the areas where these strata were deposited were slowly sinking, and that the land-wash spread by the tide constantly formed new sheets, upon which fresh records were inscribed."

No facts were observed during the recent survey which are not in accord with this interpretation. At the beginning of Newark time, therefore, we must conceive of a broad, shallow estuary, extending across the northern part of what is now the State of New Jersey. Whether the estuary was wider than the present area of the beds it is impossible to say. On the one hand the Newark beds have been greatly eroded since deposition, and in so far forth their original extent has been diminished. On the other hand the width of outcrop has been greatly increased by faulting, particularly in the western part of the State. Which of these factors has been the more effective

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* United States Geological Survey Monographs, vol. 14, 1888, page 5.

is uncertain. Probably along the Delaware river section the gain by faulting has exceeded the loss in width by erosion. In the north this may not be the case.

The estuary was bordered on the northwest and southeast by areas of granite, gneiss and schist, probably pre-Cambrian in age, with narrow belts of Paleozoic quartzite, limestone and shale. The latter rocks formed in part the floor of the estuary, the foundation on which the Newark deposits were made. This is shown by the "island" of limestone and quartzite brought to the surface in Pennsylvania by the Flemington fault. For long periods previous to the formation of the estuary and the deposition of the Newark shales, the older rocks on which they now rest had been a land area and were deeply eroded. The proof of this is found in the absence from this region of all the later members of the Paleozoic series.

The streams from the bordering land areas carried into the estuary, rock debris which was distributed over the bottom by the waves and tidal currents. The waves beating against the shore contributed their quota of material. The sediment was furnished both from the northwest and the southeast. The constitution of the arkose sandstones of the Stockton series, in the Trenton belt and beneath the Palisades, indicates that this material was derived from the adjoining crystalline areas on the southeast. But although the sandstones rest upon the gneiss, pebbles of that rock are very rarely included in it. The sandstones are composed of quartz, feldspar and mica, which are disintegration products. The crystalline rocks must have been deeply covered with a mantle of residuary material, so that the streams, although they had velocity enough to carry pebbles two or three inches in diameter, did not corrade the bed rock, but were cutting in the residuary material.

The Stockton series contains also some pebbles of limestone and sandstone which were probably derived from the southwest, where, in Pennsylvania, these rocks now form part of the southeastern border of the Newark beds. Their presence in the series in New Jersey indicates a northward trend of the currents along this border.

The sudden alternation from shales to conglomerates; the rapid thinning out of individual layers; the presence of ripple-marks, raindrop impressions and mud-cracks indicate that these beds were formed in close proximity to the shore-line. Sticks and trunks of trees were frequently imbedded in the layers of sand and gravel. These deposits were formed quite widely over the floor of the estuary, near the middle, as well as near the present border, since the Hopewell and Flemington faults bring similar beds to the surface.

In both the Lockatong and Brunswick series the argillaceous element greatly predominates. The black color of the former beds is due, to a large extent, to a carbonaceous pigment, the redness of the latter to ferric oxide formed, perhaps, during the accumulation of the debris of which they are composed.* The beds of both were accumulated in shallow water, as is shown by the ripple-marks, mud-cracks, raindrop imprints and footprints of reptiles and other vertebrates, which occur at all horizons. Residuary clays formed by decomposition of the feldspar of the gneiss and by the decay of limestone were probably the chief source of supply. Quartz from the disintegration of the crystalline rocks is the next most abundant constituent. The composition of these rocks also points to the deep sub-aerial decay of the ancient land surface.

Faulting has occurred along a part of the northwestern border. This is demonstrated in part by the absence of any close relationship between the older terranes and the constituent material of the Newark beds, particularly the conglomerates. As a consequence of these faults, beds of quartzite and limestone, which are believed to have occurred between the crystallines and the Newark system, have been largely cut out. But during the formation of the shales and conglomerates, the waves of the estuary beat against cliffs of limestone and quartzite to a much greater extent than against gneiss and granite. Only in this way can the great accumulation of calcareous and quartzite conglomerates and the comparative absence of gneiss or granite conglomerates be explained.

On the other hand the rivers drained considerable areas of crystalline rocks. This is shown by the large amount of quartz, feldspar and mica in the sandstones and shales associated with the conglomerates. The gradient of these rivers was considerable, sufficient to permit the transportation of pebbles several inches in diameter. The comparative absence of crystalline pebbles cannot be due to the lack of carrying power by the streams which drained those areas. It is rather due to the fact that the crystalline rocks on the northwest, like those on the southeast, were buried by a thick mantle of residuary products.

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*Russell. Bulletin, United States Geological Survey, No. 52.

The constitution of the Newark beds points, therefore, to the conclusion that in pre-Newark times the old land surface was deeply covered with residuary material, the product of long-continued subaerial decomposition. On the crystalline areas it was chiefly quartz and feldspar or kaoline. The limestone was buried beneath a mantle of clay. In both cases the residuary products had been formed chiefly by chemical agencies. The sandstone and quartzite rocks were less affected by chemical changes, and relatively more by mechanical agents. Their surface, therefore, was more or less covered with subangular fragments, which were the result of the rending action of the frost and the expansion and contraction due to changes of temperature. The bulk of the Newark beds is so great as to indicate that these residuary products must have been very thick. Their accumulation was aided by gentle slopes, hindered by steep declivities. We are led, therefore, to conclude that previous to the formation of the Newark beds the neighboring land surface was one of low relief with gentle slopes, across which transportation was reduced to a minimum. In other words, the land surface was a peneplain.* Had the land been high and the slopes steep during the formation of these residuary products, their accumulation in a thick mantle would seem to have been improbable.

The size of the materials handled by the streams during the Newark time, however, indicates a velocity inconsistent with streams on a peneplain. We must suppose, therefore, that with the beginning of the Newark deposition the land regained something of its former elevation. The rivers were able to carry from the crystalline areas pebbles several inches in diameter, and to handle quartzite cobbles ranging up to a foot in size.

Locally, in the limestone conglomerates, bowlders two, three or even four feet in diameter have been seen, and they have been reported to occur in New York State as large as twelve feet. Many of the limestone fragments are poorly rounded and have suffered but a slight amount of transportation. It may be doubted whether bowlders of this size were transported by the streams. The coarser conglomerates were probably accumulated by the waves which beat against the limestone and quartzite ledges. The greater rounding which is character-

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*Practically the same conclusion has been reached by Professor Davis in regard to the surface on which the Newark beds in Connecticut were deposited His argument, however, was along an entirely different line of reasoning, being based upon the present topography.

istic of the quartzite cobbles implies that they were transported further than the limestone fragments. Much of the quartzite is identical with beds of the Green Pond mountain series, but it is not necessary to suppose that they were derived from the present area of that rock, since the latter have undoubtedly been greatly restricted in area by the enormous erosion of post-Newark time. The view that in Newark time the crystalline rocks of the New Jersey highlands were buried beneath the Paleozoic beds was held for a time as a working hypothesis, as an alternative to the one here supported. It was thrown aside as untenable, however, since it did not account for the quartz and feldspar constituents in the sandstones, nor for the areas of gneissic conglomerate afterwards discovered.

It must be borne in mind that the conglomerates along the northwestern border do not belong to a single horizon. They are the shoreward correlatives of the shales and sandstones formed where the conditions of quiet water prevailed. Some occur low down in the series, whereas others grade into the red shales many thousands of feet from the bottom.

By some geologists these conglomerates have been taken to be glacial accumulations.* No striated nor glaciated pebbles of any sort were found in the conglomerates although careful search was made for them. The arguments cited by Russell against this hypothesis are valid in so far as my observations go. The conglomerates seem readily explicable on the theory set forth above.

Frequent mention has been made of the fact that the Newark beds are shallow-water deposits throughout their entire thickness. At no time apparently was the water of the estuary so deep that the outgoing tide did not expose broad areas of sand or mud. It follows from this that there must have been a progressive subsidence of the estuary during the deposition of these beds, since their thickness is to be measured by thousands of feet. The subsidence went on *pari-passu* with the deposition of the sediments, so that the shallow-water conditions prevailed continually. The progressive elevation of the adjoining land areas, shown by the material carried by the rivers, was complementary to this subsidence of the trough. If the subsi-

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*For a complete statement of the question of Newark glaciation the reader is referred to I. C. Russell's discussion in Bulletin 85, United States Geological Survey pages 47–53. The evidence on both sides is judicially considered, and the conclusion is reached that the hypothesis of Newark glaciation is unfounded.

dence were greater along one side of the trough than the other, the central axis must have shifted toward the side of greater depression, and the shore-line on that side must have encroached upon the land. If this occurred to any marked degree during the later stages of sedimentation, the shore conglomerates of that time might rest upon the older rocks and so be basal conglomerates. At the same time they would be the correlatives of the topmost shales found further from shore. In this sense they would be the uppermost members of the series. It is not positively known that this is the case with any of the conglomerates along the northwestern border, but it is only in this sense that they can be called basal beds.

The Lava Flow.—Before the completion of the Newark sedimentation the quiet course of deposition was interrupted by great flows of lava. Whether the lava issued from a single vent or group of vents or from a fissure is unknown. Certain it is, however, that the molten lava flowed over the soft mud in the bottom of the estuary. Locally the mud was forced up into cracks in the under side of the lava or was thrown into low billows by the enormous pressure of the overflowing mass. The molten rock issuing forth into the water generated an enormous amount of steam, causing the mud to froth up and mingle with the scoriaceous lava. So, too, the dense and the scoriaceous lava streams flowed over each other, forming the ropy structure so commonly seen in the Watchung trap sheets. Locally, perhaps somewhat generally, the lava flows were so thick as to rise above the sea-level. In these cases the scoriaceous surface was readily eroded; the waterworn trap fragments were commingled with the red mud brought into the estuary by the rivers, and a layer of trap conglomerate or sandstone was formed. Such was the origin of the conglomerate in the back of the first Watchung sheet near Feltville. In other localities the vesicles on the upper surface of the lava were filled with the red mud as the lava flow was buried beneath the succeeding sediments.

The three Watchung trap sheets give us evidence of at least three periods of eruption separated by long intervals of quiet, during which the deposition of the shales went on as regularly as before. In these intervals of quiet, fish lived in the waters and huge reptiles wandered over the mud flats. Whether the small sheets near New Germantown and Sand Brook are due to additional eruptions or whether they are parts of one of the Watchung sheets is unknown. The latter hypothesis assumes that they have been separated from the main sheets by some unknown faults. The first supposition is more probably the correct one. The second of the three great flows was the thickest, whereas the period between the second and the third was longer than that between the first and second. These lava flows occurred much nearer the close than the beginning of Newark time as measured by the beds in New Jersey.

The intrusive sheets were probably formed after the overflow sheets, but this has not been conclusively demonstrated. A number of facts point to a later origin.

Since both the intrusive* and extrusive sheets are cut by the faults, the volcanic phenomena preceded the faulting.

Elevation, Tilting and Faulting.—At length there began the movements of the earth's crust which resulted in the elevation and deformation of these sediments. The beds were not only raised above the sea-level, but they were also tilted gently to the northwest or thrown into low folds. Probably at the same time and as a result of the same forces, they were faulted. In the case of two of these faults, *i. e.*, the Hopewell and Flemington dislocations, the amount of throw was equal to one-half or two-thirds of the thickness of the entire series. The surface must have been broken into blocks bounded by fault escarpments, which in the two cases mentioned were several thousand feet high. The general slope of the surface of the blocks must have been parallel to the dip of the beds, *i. e.*, northwestward. The drainage established must have been in accordance with the slope of the surface, *i. e.*, down the back of one block and then along the foot of the fault escarpment bounding the block on the northwest. The present arrangement of the streams, however, is very different from the early consequent drainage. Streams cross the fault lines at will and in scores of cases flow directly contrary to the slope of the beds. The scope of this report, however, does not permit the discussion of the many adjustments by which these changes have been brought about.†

The nature of the force by which the beds were elevated, tilted and

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*Some of the dikes may be exceptions to this statement.

†The history of the drainage of northern New Jersey has been discussed by W. M. Davis in two interesting papers, "The Rivers and Valleys of Northern New Jersey," "The Geographical Development of Northern New Jersey," Davis and Wood. "Proceedings of the Boston Society of Natural History."

faulted is not well understood. Prof. Davis,* in discussing the origin of the tilted and faulted structure in the Connecticut area, arrived at the following conclusions, which are applicable to the New Jersey area as well: First, the strata were not deposited as they now lie, but have been actually tilted and gently folded. Second, "the disturbance occurred after the deposition was essentially completed, and therefore involved the whole thickness of the formation." Third, the intrusive trap sheets did not disturb the strata more than was necessary to give them room. The extrusive trap sheets cannot have been concerned in their own distortion. The disturbing force, therefore, must have acted upon the formation from without, after the entrance of the intrusive trap sheets. Fourth, the great magnitude of the faults requires that they do not fade away within the thickness of the Newark beds. Their depth must be commensurate with their throw, and this would carry them down into the underlying rocks. The disturbing force must therefore have affected a greater mass than the Newark beds alone. Fifth, since the structure of all the Newark areas from Nova Scotia to the Carolinas is in many respects similar, the disturbing force must have been felt over a wide area. Its action would seem to have been determined less by the structure of the Newark sediments than by the arrangement of the widespread and deeper-seated crystalline mass on which they generally rest. Sixth, the disturbing force was probably "a long-enduring and slow-acting horizontal compression, exerted in an east and west or southeast and northwest direction." Prof. Davis suggests, therefore, that the explanation of the tilted and faulted structure is to be found in the writhing and rising of the inclined layers of underlying gneiss and schist, as they were subjected to this horizontal compression. The foundation on which the Newark sediments rest would thus be faulted and canted, and "the overlying beds, unable to support themselves unbroken on this uneven foundation, settle down upon it as best they may."

This explanation is the best that has ever been offered. It is accepted as fully applicable in its general features to the New Jersey area.

Erosion of the Newark Beds.—Immediately upon their elevation above sea-level, the Newark beds were subject to erosion by all the forces of denudation. During the geological ages which have elapsed since their elevation, the old constructional surface has entirely disappeared. The fault escarpments have been worn down. Thousands

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* Davis. United States Geological Survey, Seventh Annual Report, pages 481-490

of feet of sediment have been removed from the general surface of the country. The topography of the fault blocks and escarpments was replaced by that of a lowland of denudation, a gently-rolling plain, but little above sea-level. This plain was very widespread and was formed by the long-continued action of the denuding agents upon the land mass. It is known as the Kittatinny or Schooley mountain peneplain. When the land had been worn down nearly to sea-level, the streams could denude it no lower. Erosion was for a time at a standstill.

Then came a period of elevation by which the land mass was bodily raised. The velocity of the streams was increased; their erosive power was restored; their energies were revived and with renewed vigor they once more set about their task of reducing the land to base-level. As the result of this new cycle of erosion, the softer shales have been again worn down to a gently-rolling plain. The harder trap ridges, the broad belts of argillite and the massive quartzite conglomerates retain to a large degree the altitude gained by uplifts since the formation of the Kittatinny peneplain. Their summits and level tops are the surviving remnants of that peneplain, which can be reconstructed in imagination by filling up all the lowland to the level of the Hunterdon plateau, the Watchung mountains and Sourland mountain. If we except for the moment the glacial accumulations, and the alluvial plains along some rivers and tide waters, the present topography is due entirely to erosion. The hills rise above the level of the valleys because they have been worn down more slowly. The valleys sink below the level of the hilltops because along those lines erosion has been more rapid.*

Summary.—The Newark beds were deposited in shallow estuaries whose shores were laid bare for considerable distances by the retreating tide and in which varying currents deposited coarse and fine materials. Shallow-water conditions prevailed throughout the entire period of deposition. Since the beds are many thousand feet thick, subsidence of the estuary bottom took place simultaneously with the sedimentation. The material was derived from the adjoining land areas on the northwest and southeast. The comparative absence of crystalline pebbles and the great abundance of crystalline residuary

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*For a more detailed statement of the erosion history of the Newark rocks the reader is referred to the two papers of Professor Davis already cited, and to The Final Report of the State Geologist, Vol. IV., by Professor R. D. Salisbury, entitled, the Physical Geography of New Jersey.

material indicate that at the beginning of Newark time the rocks were very deeply disintegrated. The thickness of this mantle is best explained by supposing that the adjoining land was at or near base-level. The presence of pebbles several inches in diameter in the Newark beds indicates that during the period of deposition the streams had a velocity not consistent with streams on a peneplain. It is believed, therefore, that an elevation of the neighboring land areas marked the beginning of the Newark time. The subsidence of the estuary bottom was probably complementary to the elevation of the adjoining areas.

Along the northwestern shore of the estuary the waves beat upon cliffs of limestone and quartzite more than of gneiss or granite and so formed chiefly quartzite and limestone conglomerates. But the rivers drained large areas of crystalline rocks. No evidence of glacial action was found in connection with the massive conglomerate beds, which are undoubtedly the work of the waves and ocean currents. They do not belong to any single horizon, but are shoreward correlatives of the various shales of the middle of the estuary.

The deposition of the sedimentary beds was interrupted by at least three great lava flows, separated by long intervals of quiet, during which sedimentation continued as before. The lava flows occurred much nearer the close than the beginning of Newark time as represented by the New Jersey beds. At some period, probably after the surface lava flows, great sheets of molten rock were intruded into the shales, but did not reach the surface within the area under discussion.

The period of sedimentation was brought to a close by the elevation of the beds above sea-level. This was accompanied by tilting and gentle folding. The faulting is believed to have occurred at the same time. The nature of this force is not well understood. The view which connects the tilting and faulting with widespread movements in the underlying rocks by virtue of which the old surface was deformed so that the Newark sediments settled down upon it as best they could, seems best to accord with all the facts.

Since their elevation they have been greatly eroded. The constructional surface consequent upon the faulting and folding has entirely disappeared. The region has been base-leveled once, elevated, nearly base-leveled again on the belts of softer rock and again elevated.*

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* Several minor oscillations are not included in this general statement. The erosion history of the Newark belt is given in detail in Professor Salisbury's Report on the Physical Geography of the State, Vol. IV. of the Final Report of the State Geologist.

Leaving out of account the comparatively slight modifications due chiefly to the glacial period, the present topography is the result of erosion. Thousands of feet have been denuded from the present surface. The hills and ridges owe their height solely to the fact that their rocks have better resisted the agents of denudation than have the rocks in the valleys.

CHAPTER VI.—ECONOMIC RESOURCES.

STONE.

The economic resources of Newark rocks are not large. They consist chiefly in building stone, trap blocks for paving and crushed stone for road material.

Building Stone.—The fine quality of the red sandstone, or brownstone, or freestone, which occurs in several parts of the series, has long been recognized even beyond the limits of the State. The finer-grained beds furnish admirable building stone for handsome residences, churches and public buildings. The coarser layers are used for foundation work, rough wall work, bridge abutments, viaducts, &c. There are three principal areas within which the sandstone is quarried extensively. The first is along the Delaware river, near Wilburtha, five miles above Trenton. Several quarries are in constant operation. The quarries are close to the railroad and to the canal, so that transportation facilities are ample. The beds worked belong to the Stockton series. The second area is on the Delaware river above Stockton. The quarries here are more extensive than at Wilburtha, and employ a larger force of men. The beds worked belong to the Stockton series. In general, the rock quarried is the same as that at Wilburtha, although there are minor differences. Transportation facilities are by rail and canal. The third area is at Avondale, near Newark. Many quarries in this vicinity were worked at an earlier period and are now abandoned. Several, however, are in active operation and employ a large force of men. The beds belong to the Brunswick series, but the rock is a feldspathic red-brown sandstone. In addition to the quarries in these three areas, there are others at various points which are given in the list below.

Paving Blocks.—In years past, trap blocks have been in great demand for street-paving purposes. The coarse-grained rock of Sourland mountain and of the Palisades has been largely used for this purpose. In general, however, the blocks have been worked out of bowlders on the surface or in the talus along the foot of the Palisades. Large quarries have not been opened for this purpose. With the increased use of vitrified brick and asphalt for paving, the demand for rough trap blocks has fallen, and in the last two or three years but comparatively few blocks have been made. With the present small demand it is hardly profitable to manufacture them unless the transportation facilities are exceptionally good.

Crushed Stone.—The demand for crushed stone for the construction of macadam and telford roads has increased greatly the last few years. The co-operation of the State and county in the construction of "stone" roads under the supervision of the State Road Commissioner has been a large factor in this increase. Trap-rock is almost universally used for this purpose, although at Byram, on the Delaware river, there is a large crushing plant which has been in operation in the hard blue argillite. Crushed-stone quarries are located at many points along the trap ridges, and are enumerated in the following list of quarries, grouped according to geological horizons: *

THE STOCKTON BEDS.

1. Trenton Brownstone Co., Wilburtha (Peter Fresco, lessee). Rock is brown sandstone with intercalated layers of soft, red shale, and in the bottom of the quarry, grey arkose sandstone and conglomerate, the pebbles of which are an inch or less in diameter. The quarry is being worked.

2. Charles Moore, Wilburtha. Brown and grey sandstone is quarried here. In the bottom of the quarry the rocks are the heavy-bedded sandstone, but near the surface they are thin and shaly. In operation.

3. Dennis Roe, three-fourths of a mile above Wilburtha. Grey feldspathic sandstone with occasional pebble-bearing layers. The rock is somewhat crushed in places and shows some evidence of faulting. Not worked.

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* No attempt has been made to include all the small abandoned quarries in this list.

4. There are three or four other quarries near Wilburtha, in all of which the stone is about the same as that in those described. None of them are being worked.

5. Similar arkose sandstone is found in the line of abandoned quarries along the canal southeast and east of Princeton.

6. S. B. Twining & Son, Stockton. This firm control several of the largest quarries above Stockton. Rock is either a brown, purple-grey, yellow or steel-blue sandstone, with intercalated layers of shale. It is usually distinctly feldspathic, and some layers are pebble-bearing. Stems of wood and imprints of reptile tracks occasionally occur. In active operation.

7. At Hunt's quarry and Smith's quarry, at Prallsville, half a mile back from the Delaware river, similar beds are exposed. In operation a part of the time.

8. John Ledger quarry, Stockton, next above the Twining quarries. Brownstone and white arkose sandstone. In operation.

9. Pennsylvania Railroad Company, Stockton. Arkose sandstone. Not operated continuously.

10. William Ledger & Co., Stockton. Rock similar to that found in other quarries. In operation.

11. John Ledger, Raven Rock. The rock quarried is a grey to very light-brown sandstone, fine-grained and even texture. Percentage of quartz is larger than in much of the other stone.

12. Heisenbuttle quarry, Ridgefield, Bergen county. Rock is a coarse-grained arkose sandstone, generally white to grey in color. It occurs in beds three to four feet thick. In operation.

13. G. Guilo, Tenafly. Quarry located a mile and a half east of Closter. Rock a white, coarse-grained sandstone, composed entirely of quartz and feldspar. Grains one-sixteenth to one-eighth of an inch in diameter are common. Color of the rock varies from white or grey to yellow and steel blue, depending on the color of the feldspar and the percentage of feldspar and quartz. The quarry is equipped with machinery for sawing the rock into blocks of the desired size. In operation.

14. Tavenier & Johnson, Closter. Quarry one and a half miles east of Closter. Rock is similar to that in Guilo's quarry. It can be readily quarried into large blocks—layers six feet thick occurring in the quarry. In operation.

IN THE LOCKATONG BEDS.

15. Savage's quarry, one mile above Wilburtha. Rock is black and dark-green shale, most of it in very thin layers. Some beds are highly calcareous. Not in operation.

16. Ayers' quarry, Somerset (F. McCarty, lessee). Rock is a hard, fine-grained, black or dark-green sandstone and argillite. Stone is used as foundation stone for telford roads. In operation part of the time.

17. Scudder's quarry, Lawrenceville. These beds are near the base of the Lockatong series. The section in the quarry is as follows, beginning at the top: (*a*) Thick-bedded, fine-grained, hard red shale, approaching a flagstone, twelve feet. (*b*) Heavy-bedded, dark-green, fine-grained sandstone and argillite, fourteen feet. (*c*) Thin-splitting, soft, carbonaceous black shale, with some impure limestone layers, ten feet. All the beds are frequently traversed by veins filled with calcite. Occasionally worked.

18. Stephen Margerum, Princeton. This quarry gives good exposures of the Lockatong beds. Hard, dark-red shale and black or dark-green argillite occur. The joint surfaces are frequently coated with calcite. Some layers of the stone are traversed by minute cracks due to tension. These are generally filled with calcite. Stone is used for foundations of buildings chiefly. Some flagstone has been quarried. In active operation.

19. J. K. Brown, Princeton. Rock is very similar to that found in Margerum's quarry, although the layers are not identical. In operation.

20. A mile and a half south of Kingston there is a line of abandoned quarries along the canal and also on the west side of the Millstone river. Various layers of hard, dark-red flagstone, black shale and argillite are exposed. None of them have been worked for many years.

21. Pennsylvania Railroad Company quarry, Kingston. Rock is a dark-red, green or black shale and flagstone. The courses of rock are ten to fourteen inches in thickness. It is not continuously in operation.

22. J. L. Burroughs' quarry, one mile east of Woodsville. Rock is a black-green flagstone with some dark-red shales. Slabs twelve

by six feet by six inches have been quarried here. Ripple-marks occur on some layers. Not worked at present.

23. P. M. & J. F. Shanley, Byram. Quarry is in the blue-black argillite, which is here exceedingly hard and dense. The rock is considerably jointed, and all the stone is crushed for ballast or road metal. A large force of men have been employed here, but it was not in operation during the summer of 1897.

IN THE BRUNSWICK SERIES.

There are no quarries of any account in the shaly layers of the Brunswick series, but some of the largest and most profitable quarries are located on the beds of sandstone in this series. At Lambertville there are several quarries in beds which have been somewhat metamorphosed by the trap sheet. They have not been worked, however, for many years. A line of valuable quarries is found in the valley between the first and second Watchung trap ridges. These are as follows:

24. Compton's quarry, Pluckamin. The under contact of the trap on the sandstone is shown here. Below the slightly-altered beds of sandstone, which do not measure more than four feet, the rock is a hard, brittle, steel-grey sandstone, composed mostly of quartz, but bearing some feldspar and mica. Quarry is worked occasionally, furnishing stone for local consumption.

25. Todd's quarry, Pluckamin. These beds are slightly lower than those in Compton's quarry. The workable stone is a light-brown and grey sandstone, which is heavily bedded in courses five to six feet thick. Weathering breaks these thick courses into thinner layers. The rock is somewhat micaceous. Not in operation.

26. William E. Bartle, Martinsville. Mr. Bartle operates two quarries at Martinsville and one at Washingtonville. At Martinsville the workable stone is chiefly a fine-grained, even-texture sandstone, with varying tints of grey and green color. Within the courses of stone, which are several feet thick, the stratification lines are indistinct. Mud-cracks, ripple-marks and imprints of trees occur in the associated shales. At Washingtonville the workable stone is a layer of red-brown sandstone about eight feet thick. All three quarries were in operation at the time of my visit.

27. William H. Smith, Warrenville. The workable stone is a grey-yellow or straw-colored sandstone of very even texture, occurring in beds in courses two to four feet in thickness. Twenty feet or more of this stone is exposed. Its original color was steel-blue, but weathering has altered this to tints of grey and yellow. The original color is discernible in the center of the larger blocks. The rock is composed of quartz, feldspar and white mica, but the minute rust-colored specks, characteristic of the rock in the Wilburtha and Stockton quarries, do not occur. In operation.

28. F. W. Shrump, Pleasantville. The workable rock is mostly a red-brown sandstone with some grey and yellowish-green layers. It is somewhat micaceous, fine-grained and even-textured, but the laminæ are plainly marked. Bits of coal are occasionally found and wave-marks occur. This quarry has been in operation continuously for many years and the stone has been shipped to neighboring States.

29. Little Falls. The brownstone quarries at Little Falls have in the past supplied a large amount of high-grade building stone, but they have been worked only at intervals for several years, and several of them are now full of water.

30. New Jersey Brownstone Co., Haledon. The quarry is in the sandstone and shale immediately beneath the trap sheet. The workable beds are fine-grained, red-brown, feldspathic sandstone, slightly micaceous. They occur in thick layers and afford dimension stone of good size. The wall of trap thirty feet high above the sandstone increases greatly the cost of quarrying the latter. Some green sandstone in the bottom of the quarry frequently contains stems of trees. Not in operation.

In the region north of Newark many quarries have been opened upon the various beds of brown and grey sandstone which there occur in the Brunswick series. Most of these have been abandoned, but a few have continued to produce a high-grade stone and will probably continue to do so for many years. These are all at a much lower horizon than those last enumerated, although for reasons given in another part of this report (pp. 44 *et seq.*), the beds are believed to belong in the Brunswick series.

31. Bloomfield avenue, Newark. The large quarries on Bloomfield avenue, Newark, were abandoned several years ago, after thousands of cubic feet of excellent stone had been taken out of it them. With the onward march of the city the quarries are being filled up.

32. Passaic Quarry Co., Avondale.

33. Belleville Sandstone Co., Avondale. These two quarries are side by side, and are being worked on the same general set of beds. The workable rock is a red-brown or grey feldspathic sandstone, occurring in courses four or five feet thick. Between these are red shales and reedy beds. Occasional pebble-bearing layers occur. These are among the most extensive quarries within the Newark area, and have been in operation for many years. Mud-cracks, ripple-marks, imprints of reptile tracks and bits of coal are not infrequently found.

34. A mile north of these two there is a third large quarry. At the time of my visit it was not in operation, but I understand that work has been commenced again. The workable rock is chiefly red-brown, fine-grained sandstone, in some layers of which the stratification laminæ are clearly marked.

35. Passaic. A quarry has recently been opened at Passaic from which stone very similar to that of the Belleville quarries is obtained.

36. Bellis' quarry, Arlington. This quarry is in beds at a lower horizon than those at Belleville. The rock outcrops on the east side of the ridge overlooking the salt meadows. The workable beds are chiefly grey or greenish sandstone, composed mainly of quartz but containing some feldspar. The beds are from three to six feet in thickness. In operation.

37. Lewis Cook's quarry, Arlington. This is situated three-fourths of a mile northward from Bellis' quarry, at about the same horizon. The rock is chiefly light-reddish brown sandstone. In operation.

38. Pope's quarry, Devlin's quarry and Thomas' quarry, in the sandstone immediately beneath the trap at Garrett Rock, Paterson, are no longer worked. They are much higher in the series than the Belleville quarries. The rock is a coarse-grained, brown and grey sandstone with some conglomeratic layers. It is well fitted for foundation and rough masonry work.

39. McKiernan & Bergin, Paterson. Both trap and sandstone are quarried here. The latter is reddish-brown in color, composed chiefly of quartz and feldspar, with a few pebble-bearing horizons. The trap is crushed for road metal.

40. Ryle avenue quarry, Paterson. About forty feet of sandstone is exposed beneath the trap. It is a red-brown sandstone with some layers of pebbles and occasional pebbles scattered through it. It furnishes foundation stone chiefly.

41. Whitehall quarry. From this quarry, which is in sandstone immediately underlying the trap of Hook mountain, the finest slabs of shale, with reptile footprints, have been obtained. Apart from an occasional load of stone for local use, it is no longer worked.

42. Milford quarries. At a number of points northeast of Milford flagstones have been quarried. Some layers are a dark-green, thin-bedded sandstone, which splits readily into slabs of suitable dimensions for flagstones. Fossil plants in considerable variety, and also footprints, have been found in these beds. None of the quarries have been worked for several years. At Tumble station there is an old quarry from which fine specimens of footprints were once obtained.

Along the northwest border of the Newark system there are a number of quarries in the calcareous conglomerate. They were opened for the purpose of obtaining limestone for burning into lime. The consumption was chiefly local. Some of them are intermittently worked as there is a demand for burnt lime. The list of them is as follows:

43. Lebanon Stock Farm. Small quarry. Limestone cobbles up to one foot in diameter. Red clay matrix.

44. Another quarry near the above. Rock made up of limestone fragments of all sizes, up to eighteen inches in diameter; very little red mud matrix.

45. James Ramsey's quarry, one and a quarter miles northwest of Potterstown. The rock is made up almost entirely of limestone fragments up to bowlders three feet in diameter. The red mud matrix is generally absent.

46. Small quarry a mile northwest of Apgar's Corner. Rock is composed almost entirely of limestone fragments; very little of the red clay matrix.

47. Small quarry three-fourths of a mile due north of New Germantown. The limestone pebbles in the conglomerate here range up to six inches in diameter.

48. Robert Craig quarry, two miles north by east of New Germantown. The average size of the cobbles is six inches. The bulk of the material is limestone, but a few quartzites occur and a red mud matrix cements the whole.

QUARRIES IN THE TRAP RIDGES.

Palisades.—49. John S. Lane & Son's quarry and stone-crusher, Guttenberg. Shut down in 1897.

50. Meek's quarry and crusher, Guttenberg.

51. Cody Bros.' quarry and stone-crusher, Edgewater.

52. Carpenter Bros.' quarry and crusher, Linwood.

53. Brown & Fleming's quarry and crusher, due east of Englewood.

54. Large quarry and crusher two miles above Alpine.

Granton Trap Mass.—55. Wagner & Duff's quarries and crusher

56. F. J. Marley's quarry.

Snake Hill Trap Mass.—57. Hudson County Penitentiary quarry and crusher.

First Watchung Trap Sheet.—58. McKiernan & Bergin's quarry and crusher, Paterson.

59. Ed. Doulan's quarry and crusher, one mile south of Paterson.

60. F. J. Marley's quarry and crushers, one mile south of Paterson. At work in the talus only.

61. Wright & Lindsley, quarry and crusher, Great Notch.

62. Francisco Bros., quarry and crusher, near Great Notch.

63. Osborne & Marcellis, quarry and crusher, Upper Montclair. Both trap and sandstone are quarried here, but the trap is the chief stone.

64. Geo. Spottiswoode & Co., quarry and crusher, Orange.

65. Chas. A. Lighthite, quarry and crusher, Millburn.

66. Stewart Hartshorn, quarry and crusher, one mile west of Springfield.

67. Basset's quarry and crusher, one mile east of Summit.

68. Cook's quarry and crusher, Scotch Plains.

69. Wahl & Hatfield, the Fanwood stone-crusher, Scotch Plains.

70. Richards' quarry and crusher, Scotch Plains.

71. J. H. Wilson, quarry and crusher, Plainfield.

72. Smalley Bros., quarry and crusher, Plainfield.

73. Wm. Haelig, quarry and crusher, Chimney Rock, near Bound Brook.

Second Watchung Trap Sheet.—74. A group of quarries a mile west of Haledon.

75. A second group a mile east of Preakness.

76. Frank Marley, quarry and crusher, Little Falls.

77. V. G. Smyth, quarry and crusher, West Summit. The radiate columnar structure of the trap is well shown here.

78. Bebout & Potter, quarry and crusher, Murray Hill.

Third Watchung Trap Sheet.—79. Standard Paving Co., quarry and crusher at end of Hook mountain, Mountain View.

80. Morris County Crushed Stone Co., Morristown, quarry and crusher, near Millington.

Rocky Hill Trap Ridge.—81. Rocky Hill Stone Storage Co., three quarries and large stone-crushers, Rocky Hill.

82. Pennsylvania Railroad Company, quarry and crusher at west end of the ridge, near Hopewell.

83. Small quarry and crusher, half a mile east of the above quarry.

On the Trap Masses Along the Delaware River—84. Quarry and crusher at Moore's station, west end of Bald Pate mountain.

85. Mercer County Workhouse, quarry and crusher, at south end of Bell mountain, near Moore's.

86. P. M. & J. F. Shanley, quarries and crushers, Goat Hill, Lambertville.

87. Barbour & Ireland, quarry and crusher, south end of Mount Gilboa, north of Lambertville.

88. Berger's quarry and crusher, Byram station.

COAL.

Occasional bits of coal are found in the sandstone quarries, marking the places where stems of trees were imbedded in the sand. But no workable seams of coal are known to exist in any part of the Newark system in New Jersey. Many layers of the Lockatong series consist of very soft carbonaceous black shales, which, under favorable conditions in a hot fire, may burn very slightly, but they are not coal. In some cases the hard, black argillites have been crushed and the broken surfaces somewhat polished by the resulting motion. This polish has a close enough resemblance to the luster of coal to mislead the unwary observer into thinking that he has discovered a coal seam.

More or less money has been wasted in the past in the vain endeavor to find coal, but in every case it has been proven fruitless. The minute character of the present survey has rendered it more certain than ever that such efforts will always fail.

COPPER.

Copper deposits occur in extremely limited amounts in the shales and sandstones in close connection with the trap sheets. Extensive search was made many years ago at various points along the trap dike between Copper Hill and Flemington. The finds, however, were inconsiderable in comparison with the labor and money expended. At various points along the under contact of the first Watchung trap ridge, shafts and adits have been run. All these, however, have been long since abandoned save at the mine, four miles north of Somerville, where the American Copper Mining Co. is engaged in prospecting. An adit has been run for several hundred feet down the contact of the trap and sandstone in the hope of finding a workable body of ore. As yet this hope has not been realized.

Years ago more or less ore was taken from various openings at Schuyler's Corner, near Arlington, but the works have long since been abandoned. The Schuyler mine was first opened about 1719, and the ore shipped to England. This was one of the most famous copper mines in the early history of the country. It must be confessed that the outlook for valuable copper deposits in these rocks is not encouraging. Nothing was observed in the course of this survey to warrant the inference that in the future prospecting for copper would be more remunerative than in the past.

BARITE.

Deposits of barite occur near Hopewell and were mined quite extensively a few years ago, but nothing has been done for some time and the shafts are full of water. Whether or not the deposits are exhausted I was unable to learn. It has also been found near Lambertville, but not worked.

SUMMARY.

The rocks of the Newark system are not rich in mineral wealth. The building stones, paving blocks and road metal are the only valuable products. The calcareous conglomerates furnish burnt lime for local use, but do not supply a wide demand.

PART III.

REPORT UPON THE UPPER CRETACEOUS FORMATIONS.

BY

WILLIAM BULLOCK CLARK.

REPORT UPON THE UPPER CRETACEOUS FORMATIONS.

BY WILLIAM BULLOCK CLARK.

LETTER OF TRANSMITTAL.

Professor J. C. Smock, State Geologist, Trenton, N. J.:

DEAR SIR—I present herewith a summary of the investigations conducted by my associates and myself during the past five years upon the Upper Cretaceous formations of the North Atlantic Coastal Plain, chiefly in the States of New Jersey, Delaware and Maryland. During the time that these investigations have been in progress I have had associated with me Messrs. C. W. Coman, H. S. Gane, R. M. Bagg and G. B. Shattuck. Dr. Bagg was connected with the work for over four years. They have all aided materially in the investigations and I desire to cordially acknowledge my obligations to them.

The report which is here presented gives the results of only a part of the investigations which have been carried on upon the Cretaceous formations of the New Jersey-Maryland area, and which are still in progress. Considerable advance has already been made both in the interpretation and the cartographic representation of the other divisions of the Costal Plain series, and they will be made the subject for further contributions at a later time. These investigations have been conducted under a plan of co-operation between the United States Geological Survey and the State Surveys of New Jersey and Maryland. The boundaries of the formations have been platted upon the United States Geological Survey atlas sheets, the areal mapping having been carried on upon the scale of one mile to the inch throughout the entire district, with the exception of Delaware and the eastern shore of Maryland.

Somewhat extensive changes have been made in the classification of formations adopted by previous writers and some modifications in the use of the formation names employed by myself and my associates in earlier articles. This has been the result of more complete knowledge of the formations, based upon later work in Delaware and Maryland, which has shown that certain divisions that are important in one area lose their identity and become merged with contiguous members of the series in other areas, so that they can no longer be stratigraphically or faunally separated. The major divisions which have now been adopted are capable of application to the deposits throughout the entire region from the Raritan to the Potomac, and are the only ones which can be so employed with satisfactory results.

The Upper Cretaceous formations of New Jersey, Delaware and Maryland here classified and mapped constitute a circumscribed province which is represented in a few isolated occurrences off the New England coast and at one locality in Massachusetts. South of the Potomac the strata become covered by a mantle of later deposits. The records of certain well-borings point to the occurrence of Cretaceous deposits in eastern Virginia, but their character and extent have not been fully determined. Similar deposits occur in surface exposures in the Carolinas, but they have not as yet been sufficiently studied to show to what extent they may be correlated with the formations of the northern Atlantic belt.

JOHNS HOPKINS UNIVERSITY,
BALTIMORE, Md., Nov. 15th, 1897.

REPORT UPON THE UPPER CRETACEOUS FORMATIONS, 1897.*

BY WILLIAM BULLOCK CLARK, WITH THE COLLABORATION OF R. M. BAGG AND GEORGE B. SHATTUCK.

INTRODUCTION.

The Cretaceous formations of the Atlantic Coastal Plain have been the subject of frequent discussions throughout the present century, while scattered references to the district are found in the works of still earlier date.

The first contribution to the subject of Coastal Plain geology which is worthy of special mention is found in the publications of Professor Kalm,† who was sent out to America in 1749 under the auspices of the Royal Academy of Sciences of Sweden to make a study of the various branches of natural history in this country. He visited the northern part of the district now under consideration and recorded many observations of interest.

In 1777 Dr. Johann David Schoepf,‡ of Germany visited America in order to study the geological features of the eastern portion of the continent. His observations and comparisons of the Coastal Plain formations mark considerable advance over those of Kalm. The importance of his investigations has not been very generally recognized by later writers, but he showed a remarkably keen insight into the geology of eastern America, which was lacking on the part of some of his successors.

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*Portions of this chapter were read before the Geological Society of America at Washington, December 31st, 1896, and printed in the society's Bulletin, vol. VIII., pages 315-358, pls. 40-50. April, 1897.

†En Resa til Norra America, 8vo., 3 vols., 1753-61, Stockholm. Translations in English by J. R. Foster; 1st ed., 1770-71; 2d ed., 1772; another edition in J. Pinkerton's voyages, vol. XIII., 1812; in German by J. H. Murray, 1754-64; in French by L. W. Marchand, 1859.

‡Beiträge zur mineralogischen Kenntniss des östlichen Theils von Nord Amerika und seiner Gebürge, 8vo., 1787, 194 pp., Erlangen.

The first attempt at a correlation of the deposits of the Coastal plain with the geological column then established in Europe was made by William Maclure,* in 1809, in his "Observations on the Geology of the United States." In this publication the coastal deposits are collectively referred to the "Alluvial Formation," the fourth of the main divisions of geological strata proposed by Werner. The work was subsequently revised and enlarged, appearing in book form in 1817.†

A few years subsequent to the appearance of Maclure's articles, H. H. Hayden ‡ published a volume of "Geological Essays," in which an explanation is given of the great accumulation of "Alluvial Deposits" in the eastern and southern portions of the United States, and the stratigraphy of the region is described in much greater detail than by his predecessors. Reference is made to the wide distribution of fossil shells and vertebrate remains, and many localities are cited.

A second work of the same general character, so far as it relates to the geology, was published somewhat later by Parker Cleveland.§ It is entitled "An Elementary Treatise on Mineralogy and Geology," and on page 785, under "Remarks on the Geology of the United States Explanatory of the Subjoined Geological Map," the author defines the limits of the "Alluvial Deposits," and in general terms describes their lithological character.

Samuel Akerly, ‖ in an essay published in New York in 1820, discusses the "Alluvial Deposits" of northern New Jersey. In this paper the marl beds, together with some of their fossils, are described, but no evidence is adduced that the author recognized their taxonomic position.

James Pierce,¶ in a "Notice of the Alluvial District of New Jersey," published a few years subsequently, describes the marl deposits of Monmouth county in that State.

Professor John Finch,** of England, was the first to recognize, when

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* Amer. Phil. Soc. Trans., vol. VI., 1809, pages 411-428. Translation in Journal de Physique, vol. LXIX., 1809, pages 204-213, and vol. LXXII., 1811, pages 137, 138.

† Philadelphia, 8vo., 130 pp.; also in Amer. Phil. Soc. Trans., new series, vol. I., 1817, pages 1-92, and Leonhard's Zeitschrift, band 1, 1826, pages 124-138.

‡ Geological Essays, &c., Baltimore, 1820, 8vo., vol. VIII., 412 pp.

§ An Elementary Treatise on Mineralogy and Geology, 1822.

‖ An Essay on the Geology of the Hudson River and the Adjacent Regions, &c., New York, 1820, 12mo., 69 pp., and one plate.

¶ Amer. Jour. Sci., vol. VI., 1823, pages 237-242.

** Amer. Jour. Sci., vol. VII., 1824, pages 31-43.

visiting this country in 1824, that the Coastal Plain deposits represented more than a single horizon. His contribution on this subject contained the first attempt at a correlation of the several deposits of the Coastal plain with other areas, and although thus early in the study of the subject minute comparisons, which the facts did not warrant, were made, yet the knowledge of Atlantic Coastal Plain stratigraphy was materially advanced. In this article he says:

"I wish to suggest that what is termed the alluvial formation in the geological maps of Messrs. Maclure and Cleveland is identical and contemporaneous with the newer Secondary and Tertiary formations of France, England, Spain, Germany, Italy, Hungary, Poland, Iceland, Egypt and Hindustan."

During the year 1825 Jer. Van Rensselaer * delivered a course of lectures in the New York Atheneum, on geology, that were subsequently published in book form. The author adopted the classification proposed by Finch, although he confined his description to the northern representatives of the Cretaceous-Tertiary series.

The credit for the first definite recognition of the Cretaceous deposits of the Atlantic Coastal Plain must be ascribed to Professor Lardner Vanuxem. The results of his observations were placed in the hands of his friend, Dr. S. G. Morton,† for publication in the Journal of the Academy of Natural Sciences of Philadelphia. His views were again stated under his own signature in the American Journal of Science,‡ in which reference is made to the earlier publication.

In the years immediately succeeding the publication of Professor Vanuxem's articles several contributions were made by Dr. S. G. Morton, both in the Journal of the Philadelphia Academy of Natural Sciences and the American Journal of Science, upon the organic remains of the Cretaceous deposits, and these were finally embodied in 1834 in an important work entitled "Synopsis of the Organic Remains of the Cretaceous Group of the United States." §

In 1835 ‖ Dr. Morton proposed a general division of the Cretaceous of the United States into three groups, the uppermost of which,

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* Lectures on Geology, 1825, 8vo., 358 pp.

† Jour. Acad. Nat. Sci. Philadelphia, vol. VI., 1829, pages 59-71.

‡ Amer Jour. Sci., vol. XVI., 1829, pages 254-256.

§ Philadelphia, 1834, 8vo., 88 pp., xix. plates.

‖ Amer. Jour. Sci., vol. XXVIII., 1835, pages 276-278.

however, is now generally regarded as belonging to the Tertiary. His views on this point were again stated in 1842.*

During the decade 1830 to 1840 the three States of New Jersey, Delaware and Maryland established State geological surveys under the direction respectively of H. D. Rogers, J. C. Booth and J. T. Ducatel.

The first attempt at a local and detailed differentiation of the Cretaceous deposits in the northern Atlantic Coastal plain appears in Professor Rogers' first report, published in 1836, and is more elaborated in his final report, published in 1840, in which he recognizes the following formations, beginning with the lowest: *Clays and Sand, Greensand, Limestone, Ferruginous Sand, Brown Sandstone.* Although these several divisions were not clearly defined, and widely different materials were included in the same formation, yet the easterly dip of the strata was observed and the border distinctions in the formation were recognized.

Ducatel, in his annual report as State Geologist for 1837, records the presence of Cretaceous deposits along the Sassafras river on the eastern shore of Maryland, while Booth in his "Memoir of the Geological Survey of the State of Delaware," published in 1841, which was based upon his two annual reports for the years 1837 and 1838, divides the "Upper Secondary" of his State into the "Red Clay" and the "Greensand" formations.

The visit of Charles Lyell to the United States in 1841 was an important event in the history of Coastal Plain geology. The inspiring presence of the author of the epoch-making "Principles of Geology," coupled with his wide knowledge regarding similar deposits in Europe, led to renewed activities in the field of Coastal Plain geology and the correct interpretation, under his leadership, of many points which had up to that time been but imperfectly understood. Although Lyell's work had reference more to the Tertiary than the Cretaceous, yet his observations in several instances were turned either directly or indirectly to the latter. In his contributions † he correlated the American Cretaceous rocks with the divisions between the Gault and the Maestricht of Europe, and also showed that Morton's upper division of the Cretaceous was of Eocene age.

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* Jour. Acad. Nat Sci. Philadelphia, vol. VIII., 1842, pages 207-227.

† Quart. Jour Geol. Soc. London, vol. I., 1843, pages 55-60; Proc. Geol. Soc. London, vol IV., 1845, pages 31-33; Amer. Jour. Sci., 1844, vol. XLVII., pages 213, 214.

Dr. T. A. Conrad * in 1848 first suggested that the upper portion of the greensand series of New Jersey was of later age than the Cretaceous, a conclusion which he more fully elaborated at a later date.

The earlier State surveys having come to an end, a considerable period elapsed during which the several States of the district under consideration were without official organizations. In 1847 Maryland made provision for a State agricultural chemist, while a few years subsequently to this the State of New Jersey established a second geological survey. Under the direction of the first agricultural chemist, Dr. James Higgins, little geological work was attempted in Maryland, but the survey of New Jersey, under the direction of William Kitchell, had as assistant geologist, George H. Cook, who was later to become himself the head of the survey, and in that capacity to add more to the knowledge of the stratigraphy of the Cretaceous formations than any one who had preceded him. In the first of Kitchell's reports, for the year 1854, Cook already recognized the fact that "there are three distinct beds of marl." These three marl beds were examined by him with much care, and the characteristic features of each portion of them described in the later survey reports.

During the decade 1860 to 1870 many special articles dealing with the paleontology of the several formations under consideration appeared, although most of these publications are confined to the New Jersey portion of the region. Conrad, Cope, Marsh, Credner, Gabb, Meek and others contributed to the same, with the result that a fuller knowledge was gained of the paleontology of the New Jersey area than of any other Cretaceous district throughout the Coastal plain.

In 1860 Dr. Philip T. Tyson, who had been appointed State agricultural chemist to succeed Dr. James Higgins, published his first annual report on the geology of Maryland, in which he discusses the Cretaceous formations of that State. His second and last report appeared in 1862. Although he recognized the presence of some of the New Jersey divisions upon the eastern shore of Maryland, he made little attempt at their accurate discrimination.

Professor George H. Cook, having been appointed State Geologist of New Jersey, presented his first report of progress for the year 1865. Reports were published during successive years until his death

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* Jour. Acad. Nat. Sci. Philadelphia, new series, vol. I., 1848, p. 129; Proc. Acad. Nat. Sci. Philadelphia, vol. XVII., 1865, pages 71, 72.

in 1889. Associated with him in much of his work was Professor J. C. Smock, the present head of the survey. It is unnecessary at this time to view the advance made each year or to refer in detail to each report. In 1868 a general volume appeared, entitled "Geology of New Jersey," in which an extensive description of the Coastal Plain deposits is found. In this report Professor Cook divided the Cretaceous deposits as follows:

Upper marl bed	Blue marl. Ash marl. Green marl.
Yellow sand.	
Middle marl bed	Yellow limestone and lime-sand. Shell layer. Green marl. Chocolate marl.
Red sand	Indurated green earth. Red sand. Dark micaceous clay.
Lower marl bed	Marl and clay. Blue shell marl. Sand marl.
Clay marls	Laminated sands. Clay containing greensand.
Plastic clay	Lignite. Potter's clay. Lignite.

In 1870 Dr. Hermann Credner,* above referred to, published the results of his observations upon the New Jersey Cretaceous. He regarded the deposits as closely related to the Upper Cretaceous of Europe, and mentioned upward of forty species of fossils as being identical with those of the Senonian of northern Europe.

In later years Professor R. P. Whitfield has been engaged in an exhaustive study of the fauna of the Cretaceous belt of New Jersey. Two monographs of great importance have been published. The first, entitled "The Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey," appeared in 1885, and the second, "The Gasteropoda and Cephalopoda of the Raritan Clays and Greensand Marls of New Jersey," in 1892.

Dr. C. A. White,† in an admirable essay upon "The Cretaceous of

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* Zeitschrift der Deutschen Geol. Gesell. Jahr., 1870, pages 191–257, and map.

† Bulletin 82 of the U. S. Geological Survey, 1891, page 273.

North America," published in 1891, describes the formations now under consideration and discusses the evidence for their correlation with the deposits of other areas. He does not attempt to separate the individual members of the series, however, beyond the reference of the upper division to the Eocene, as was also done by the senior author of this paper in his report upon "The Eocene of the United States." *

Investigations embracing portions of the Cretaceous series of the northern Atlantic Coastal plain have been in progress at times during later years by Uhler,† Darton‡ and Hollick.§ Messrs. Uhler and Darton have confined their investigations almost exclusively to the Cretaceous upon the western shore of Maryland, Darton having described a considerable portion of the Upper Cretaceous of this area under the name of the Severn formation, while the observations of Mr. Hollick have chiefly embraced the deposits in northern New Jersey beneath those now under consideration, although the basal members of the Upper Cretaceous in this area, as well as the transported fragments of the same formations upon Staten Island and Long Island, have been discussed.

During recent years Mr. Lewis Woolman, of Philadelphia, has collected a large amount of valuable information regarding the well-borings throughout the northern Atlantic Costal plain. These data are of much value to the field geologist in helping him to control his conclusions. Mr. Woolman's records have been frequently consulted, although the authors have often differed from him in the interpretation of the data.

The later history of investigation of the Upper Cretaceous formations in this district is confined largely to the work carried on under the direction of the senior author by the instructors and students of the Johns Hopkins University. Several papers have already appeared and others are in course of preparation, in which more detailed discussions will be found regarding both the geological and paleontological aspects of the subject.

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* Bulletin 83 of the U. S. Geological Survey, 1891, page 173.

† Trans. Md. Acad. Sci., vol. I., 1889-90, pages 10-32, 45-72, 97-105.

‡ Bulletin Geol. Soc. Amer., vol. II., 1891, pages 438, 439; Trans. Amer. Inst. Min. Eng., 1894.

§ Trans. New York Acad. Sci., 1895, pages 1-10.

TOPOGRAPHIC FEATURES.

The formations of Upper Cretaceous age constitute a part of the great area of low land which borders the Atlantic coast of North America, and has been designated the Coastal Plain. It extends with constantly narrowing limits from the southern Atlantic States across the area now under consideration, beyond which its continuity becomes broken, although represented in the southern portions of New England and in the various islands along the coast. The width of the northern Coastal plain varies from somewhat over 100 miles in central Maryland to scarcely twenty-five in eastern New Jersey.

The Upper Cretaceous formations occupy a belt within the Coastal plain, which extends from northeast to southwest, and which is separated from the Piedmont plateau by a tract some ten or fifteen miles in width, composed of Lower Cretaceous deposits. This belt of Upper Cretaceous strata varies in width from about twenty-five miles in New Jersey to barely a mile in southern Maryland. Its more unyielding deposits have produced a ridge of high land, which, with varying elevations, extends along the center of the belt. This ridge forms an escarpment toward the west, but generally declines gradually seaward.

The *Cretaceous escarpment*, as it may properly be called, stretches across New Jersey from the vicinity of Sandy Hook to the head of the Delaware bay, and forms for much of the distance the divide between the streams entering the Atlantic ocean on the east and the Raritan and Delaware rivers on the west. Beginning on the prominent headland of the Highlands of Navesink, which rises to 276 feet, it extends westward as a clearly-defined ridge (south of Keyport reaching its greatest height at 391 feet) for a distance of about fifteen miles to the vicinity of Morganville, beyond which the range broadens, and with a general elevation of 200 feet continues to Freehold. From this point the ridge turns to the south-west as far as Clarksburg, in the vicinity of which is a group of hills more than 300 feet in height, Pine hill being 372 feet above sea-level.

From the Pine hill region the Cretaceous escarpment extends southward into central New Jersey, being clearly shown in such points as Red hill (234 feet), Arney's mount (230 feet), Mount Holly (180 feet), and Mount Laurel (173 feet), although the elevation of the country does not generally exceed 150 feet. In the valley of Rancocas creek is an area of low land which falls considerably below 50 feet, and which marks the line of a depressed belt crossing southern New Jersey. To the south of Mount Laurel the escarpment is less clearly shown; although appearing at Haddon heights, Woodbury heights, with the exception of an area of high land to the east of Swedesboro, the escarpment is less pronounced, while throughout Salem county, in southern New Jersey, it is hardly apparent.

To the south of the Delaware river in the State of Delaware and upon the eastern shore of Maryland the escarpment practically disappears, but upon the western shore of the Chesapeake, throughout Anne Arundel and Prince Georges counties, extending nearly the entire distance to the Potomac river, the escarpment is clearly shown, but nowhere rising into the marked ridge which characterizes it in central and northern New Jersey. In Anne Arundel county it appears in several isolated hills, which, however, are in part made up of the overlying Eocene deposits. Such elevations are seen at Mount Misery, on the Severn river, and to the east and south of Millersville. Beyond the Patuxent, in Prince Georges county, the escarpment is somewhat broken, but appears to the southeast of the Baltimore and Potomac railroad. Farther to the south it skirts the shore of the Anacostia river, and thence following the line of the Potomac river valley continues as far as Piscataway creek.

The escarpment throughout the area described is determined in part by the character of the Upper Cretaceous strata and in part by underlying and overlying formations. The great difference in the volume of the Upper Cretaceous deposits in passing from the northern to the southern portions of the district is very marked, and the strata become a constantly less important factor in determining the topography.

The escarpment faces the more readily eroded deposits of the Lower Cretaceous, and, throughout the larger portion of New Jersey, the lowest member of the Upper Cretaceous series as well. This formation, however, rises also into the base of the escarpment, although the escarpment proper is made up of the higher members of the series and the formations which overlie them. As these upper members gradually disappear to the southward the Tertiary becomes a more and more prominent factor in the formation of the escarpment, which in Maryland is largely to be accounted for upon these grounds. In no portion of Maryland, not even upon the western shore, where the country is much higher than upon the eastern shore of the Chesapeake, are there elevations in any way comparable with those found in northern New Jersey; yet the edge of the escarpment, especially to the south of the Severn river, frequently reaches a height of 200 feet, and does not fall much below that elevation even in the valley of the Potomac river.

The streams show a marked difference in their valley characters, dependent on whether they drain directly to the Atlantic by easterly and southerly courses, or whether they flow to the west toward the fall-line. The valleys of the Atlantic drainage are broad, the land rising gently on either bank, while the channels of the streams flowing toward the fall-line have much steeper slopes and are generally U-shaped. An explanation for this may be found in the stratigraphy of the region, since the strata dip slightly to the southeastward, so that the streams flowing in that direction follow the slope of the beds, while those flowing to the northward must cut across their upturned edges. As the beds vary in hardness the widening of the channel must be retarded by the hardest layers.

DESCRIPTION OF THE FORMATIONS.

General Statement.

The geological formations of the Coastal area of New Jersey, Delaware, and Maryland represent a nearly complete sequence from the base of the Cretaceous to the Pleistocene. They form a series of thin sheets which are inclined slightly to the southeastward, so that successively later formations are encountered in crossing the district in that direction. Variations in the angle and direction of tilting and later denudation have occasioned in many instances a marked divergence from these normal conditions, and detached outcrops are at times found far removed from the main body of the deposits. The formations discussed in the following pages are as follows:

Eocene	Shark river formation.	
Upper Cretaceous	Manasquan formation.	
	Rancocas formation.	Vincentown lime-sands. Sewell marls.
	Monmouth formation	Redbank sands. Navesink marls. Mount Laurel sands.
	Matawan formation	Hazlet sands. Crosswicks clays.

Glauconite characterizes all of the deposits from the base of the Matawan to and including the Shark river formation, and appears in varying amounts and under different conditions in the several formations. Their lithologic features are in general sufficiently distinctive and persistent to be of the greatest value in the determination of the horizons. The presence of greensand *in situ* has not been observed in the Raritan formation which underlies, nor in the Chesapeake formation, which overlies this sequence of glauconitic deposits.

Matawan Formation.

Name.—The Matawan formation receives its name from Matawan creek, in Monmouth county, New Jersey, where the deposits of this horizon are typically developed. The name was originally given by the senior author of this paper in an article published in the Journal of Geology,* and was made to embrace in a general way the division to which Professor Cook had earlier assigned the name of Clay Marls, although his characterization of the deposits was not complete and was confined almost entirely to their development in northern New Jersey. Furthermore, the term Clay Marls does not adequately describe the deposits, although beds of that nature are found at various horizons, particularly in the lower portions of the formation.

Areal Distribution.—The Matawan formation extends as an irregular belt from the shores of Raritan bay to the Potomac river. In the extreme north, in Monmouth county, New Jersey, the width of the band is from nine to twelve miles, but in proceeding southward it gradually narrows, with some exceptions due to the topography of the land, and in the southern counties of New Jersey does not exceed six miles in width. Upon the western shore of the Delaware river, in the State of Delaware, it has still further narrowed until it has a width of scarcely more than two or three miles. Farther to the south, upon the eastern shore of Maryland, it again slightly broadens, and below the mouth of the Sassafras river has a width of some five miles. Upon the western shore of Maryland, in Anne Arundel county, its areal distribution is very variable on account of the extremely broken character of the country, but upon the whole has narrowed in extent as compared with the eastern side of the Chesapeake. In places it reaches three or four miles in width, but more often is less than one

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* Vol. II., 1894, page 163.

mile. Farther to the south, in Prince Georges county, it is found simply as a narrow strip, at no point reaching a mile in width, and continues in and out along the slopes of the hills, following the contours of the valleys.

Character of Materials.—The deposits of the Matawan formation are very variable. Sands and clays predominate. The sands are at times white and coarse, but are more commonly fine-grained and deeply colored by iron, which may even cause local induration, or they are mixed with argillaceous materials, forming either a silvery micaceous sand or a chocolate-colored marl, in the latter case grains of glauconite being present in greater or less amounts.

The clays are generally black or drab in color, but may locally carry seams and pockets of glauconite, which give it a greenish tinge. At a few points the deposits are somewhat calcareous as the result of their molluscan contents, but in general the beds are not highly fossiliferous.

Strike, Dip, Thickness.—The strike of the beds is north-northeast to southwest, with apparent local variations where the overlying Cretaceous and Tertiary deposits have been either more largely eroded or more fully preserved, causing the line of outcrop to be at times diverted at a considerable angle from the normal strike. This is seen in northern Monmouth county, where the stripping off of the cover of the later Cretaceous formations has caused the widening out of the belt of the underlying Matawan and has turned the line of contact very nearly at right angles to the strike. Such variations may be easily detected when the normal dip is present, but may lead to considerable complication when it is not.

The dip of the formation is upon the average about twenty-five feet in the mile, but locally it may be either slightly increased above or slightly decreased below this amount. The determination of the dip depends for the most part upon records afforded by well-borings, although some of the natural section lines, especially in the Mount Pleasant hills, New Jersey, and along the Severn river, Maryland, afford valuable data.

The thickness of the Matawan formation is very variable, but in general becomes gradually reduced in passing from the northern to the southern portions of its area of outcrop. In Monmouth county it has been found to be about 275 feet, with a gradual thickening toward the southeastward, as is shown in the wells at Asbury Park, where it has a thickness of about 400 feet. Along the strike toward the south it is already less than 200 feet in thickness in northern Burlington county, while in the region directly to the east of Philadelphia and Camden it has further declined to 125 feet. In Gloucester county it thickens again, having been found in well-borings to exceed 175 feet in places. Farther to the south it thins, and in the vicinity of Salem has declined to 80 feet. In the State of Delaware it is not over 60 feet, but it gradually thickens through the eastern counties of Maryland until, near the mouth of Sassafras river, it again exceeds 100 feet in thickness. In eastern Anne Arundel, upon the western shore of Chesapeake bay, its thickness has already declined to 60 feet, while in the region farther south, in western Anne Arundel and Prince George's counties, it has still further diminished, until at the Fort Washington bluffs it is but little more than 15 feet thick. Its last appearance to the southward, so far as observed, is in the valley of Piscataway creek. Upon the opposite side of the Potomac the Eocene is found resting directly upon the Potomac.

Stratigraphic Relations.—The Matawan formation rests unconformably upon Lower Cretaceous strata throughout the northern Atlantic Coastal Plain. Locally the line is at times not readily discernible, especially when the upper portion of the Lower Cretaceous contains beds of dark-colored clay, such as characterize the strata to some extent in the northern portion of the region. Commonly, however, the line of contact is sharply defined, since the upper portion of the Lower Cretaceous consists generally of white sands or fine gravel, which can be readily distinguished from the overlying Matawan. Not infrequently, however, in the interstream portions of the country, the line of contact is obscured by late Tertiary or Quaternary deposits, so that its location has to be hypothetically determined for cartographic purposes, unless well-borings can be found or the beds reached by the geologist's auger.

The Matawan formation is conformably overlain by the succeeding formation, but the lithologic differences are so clearly marked throughout the whole area of occurrence of the two formations that the line of contact can be readily determined.

Divisions—General Characteristics.—The Matawan formation can be readily subdivided upon lithologic grounds throughout the northern portions of the area, while to the south these differences become gradually obscured, until in the southern portion of New Jersey, in

Delaware, and in Maryland the divisions observed in the north can be no longer recognized.

The northern series will be considered under the head of the Crosswicks Clays and the Hazlet Sands, so called from localities where they typically occur, the first obtaining its name from the village of Crosswicks, upon Crosswicks creek, Burlington county, where the clays are well developed and extensively worked, and the second from the town of Hazlet, in Monmouth county, situated in the center of the sands, which are well developed in the surrounding territory.

Crosswicks Clays.—These clays constitute the lower portion of the Matawan formation in Monmouth, Middlesex, Mercer, Burlington and Camden counties. This lower division consists primarily of very dark colored or black clays, which become at times slate or drab colored toward the top, or, as in the vicinity of Matavan creek, interstratified with layers of white sand. The dark clays are frequently quite glauconitic, but the glauconite is confined generally to thin seams and pockets. This marly feature becomes less pronounced toward the upper portion of the series and often entirely disappears. These clays, particularly in the lower part, are quite unctuous when wet, but become more and more brittle toward the top, while there is also a marked decrease in the amount of iron sulphide. The Crosswicks clays are well exposed upon the shores of Raritan bay and in the valleys of Matchaponix creek, Crosswicks creek, Black creek and other streams entering the Delaware river. Toward the south the Crosswicks clays gradually become more arenaceous and more micaceous and cannot be readily separated from the overlying deposits.

Hazlet Sands.—These sands comprise the upper portion of the Matawan formation throughout the same area as the Crosswicks clays. This upper division consists primarily of sands, highly ferruginous and brown in color in the lower portions and often affording indurated crusts. Above this brown sand there is frequently found a well-developed dark-colored clay, which is very much like the lower Crosswicks clays in many of its characteristics, although oftentimes partaking to a considerable extent of the micaceous features of the overlying sands. These upper sands, generally very micaceous and at times quite dark in color, are very persistent at the top of the Matawan formation throughout the northern portion of the district. They become more argillaceous and darker in color to the southward and lose to a considerable extent their characteristic features.

Toward the south the division of the Matawan into Crosswicks clays and Hazlet sands becomes gradually obscured as the lower member becomes more and more arenaceous and micaceous, while the upper member becomes more and more argillaceous, until finally in Gloucester and Salem counties, New Jersey the materials are practically identical and consist of dark-colored arenaceous clays, generally glauconitic and micaceous. These features continue upon the south bank of the Delaware river in the State of Delaware and throughout Maryland, but the glauconitic element gradually becomes reduced to the southward and the clays become finer and more micaceous.

Fossils.—The fossils of the Matawan formation, although not so numerous or well preserved as in some of the other members of the Cretaceous series, afford a large number of different species which have been obtained with sufficient frequency to establish beyond all doubt the stratigraphic limits and areal distribution of the formation throughout its entire extent from northern New Jersey to southern Maryland. Many of the species range upward into the overlying formation, while others are limited to the Matawan itself. Among the characteristic and common species found in the formation and determined by the authors are the following:

Rhabdogonium tricarinatum, var. *acutangulum*, Reuss.
Frondicularia pulchella, Karrer.
Hemiaster parastatus, Morton.
Terebratella plicata, Say.

Ostrea larva, Lamarck.
Exogyra costata, Say.
Gryphœa vesicularis, Lamarck.
Anomia tellinoides, Morton.
Amusium conradi, Whit.
Camptonectes burlingtonensis, Gabb.
Neithea quinquecostata, Sowerby.
Spondylus gregalis, Morton.
Plicatula urticosa, Morton.
Dianchora echinata, Morton.
Gervilliopsis ensiformis, Conrad.
Inoceramus sagensis, Owen.
Pinna laqueata, Conrad.
Arca quindecemradiata, Gabb.
Idonearca antrosa, Morton.
Idonearca vulgaris, Morton.
Axinea mortoni, Conrad.
Nucula slackiana, Gabb.
Trigonia mortoni, Whit.
Crassatella vadosa, Morton.
Crassatella delawarensis, Gabb.
Lucina smockana, Whit.
Cardium dumosum, Conrad.
Cardium tenuistriatum, Whit.
Cardium perelongatum, Whit
Cardium multiradium, Gabb.
Leiopistha protexta, Conrad.
Cymella meeki, Whit.
Veniella conradi, Morton.
Veniella subovalis, Conrad.
Callista delawarensis, Gabb.
Aphrodina tippana, Conrad.
Cyprimeria densata, Conrad.
Tenea pinguis, Conrad.
Tellimera eborea, Conrad.
Linearia metastriata, Conrad.
Veleda lintea, Conrad.
Pholadomya occidentalis, Morton.
Panopœa decisa, Conrad.
Clavagella armata, Morton.

Pyropsis naticoides, Whitfield.
Pyropsis reileyi, Whit.
Pyrifusus cuneus, Whit.
Odontofusus slacki, Gabb.
Odontofusus typicalis, Whit.
Volutomorpha conradi, Gabb.
Turbinella (?) *verticallis*, Whit.
Voluta (?) *delawarensis*, Gabb.
Volutoderma abotti, Gabb.
Volutoderma woolmani, Whit
Rostellites nasutus, Gabb.
Rostellites angulatus, Whit.
Rostellites texturatus, Whit.
Cithera crosswickensis, Whit.
Alaria rostrata, Gabb.
Anchura abrupta, Morton.
Anchura compressa, Whit.
Natica abyssina, Morton.
Lunatia halli, Gabb.
Gyrodes altispira, Gabb.
Gyrodes obtusivola, Gabb.
Gyrodes infracarinata, Gabb.
Gyrodes petrosa, Morton.
Margarita abyssina, Gabb.
Xenophora leprosa, Morton.
Endoptygama umbilicata, Toumey.
Scalaria thomasi, Gabb.
Scalaria sillimani, Morton.
Turritella encrinoides, Morton.
Turritella vertebroides, Morton.
Turritella pumila, Gabb.
Turritella lippincotti, Whit.
Modulus lapidosa, Whit.
Avellana bullata, Morton.
Dentatium subarcuatum, Conrad.
Dentalium falcatum, Conrad.

Ammonites (*Placenticeras*) *placenta*, De Kay.
Ammonites delawarensis, Morton.
Ammonites vanuxemi, Morton.
Scaphites hippocrepis, De Kay.
Scaphites nodosus, Owen.
Baculites ovatus, Say.

Monmouth Formation.

Name.—The Monmouth formation receives its name from the county of Monmouth, in New Jersey, throughout which the deposits of this horizon are most characteristically developed. A more local reason for its use is found in the fact that the famous Revolutionary "Monmouth Battle Ground" is situated upon this formation. The name is now proposed, for the first time, to embrace the Navesink and Redbank formations* of previous contributions, and to include, as well, certain sands which underlie them, but which are so insignificantly developed in the northern portion of New Jersey as not to have been regarded of special significance at the time these formations were established and characterized. This increase in the limits of the formation has been rendered necessary by the discovery throughout the southern portions of the region now under consideration of conditions which render the differentiation of the several members quite impossible. This division of the series still holds good for the northern counties, but as a classification is sought which may be strictly applicable to the entire northern Atlantic Coastal Plain, a

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*Journal of Geology, vol. II., pages 164-166, 1894.

revision becomes necessary, the older terms being retained to designate the subdivisions wherever they occur.

Areal Distribution.—The Monmouth formation occupies the country to the east of the Matawan formation and extends as a narrow belt from Raritan bay to the valley of the Patuxent river, in southern Maryland, beyond which it does not appear in association with the Matawan formation except at a single doubtful locality in the valley of the Potomac river near Fort Foote. In Monmouth county the outcrop of the main body of the formation increases rather rapidly from a maximum width of nearly eight miles in the vicinity of the Mount Pleasant hills to barely three miles at Freehold, and with the exception of marked local increases in width when the face of the escarpment juts far out to the westward, continues to hold this width for the most part throughout southern New Jersey. The belt of outcrop is, however, very irregular, and along some of the deeper valley lines crossing the escarpment does not exceed a mile in width. In Delaware and upon the eastern shore of Maryland the belt again broadens and in the valley of the Sassafras river reaches five miles in width. Upon the western shore of Maryland it is much narrower and gradually tapers down until it entirely disappears just beyond the border of Prince George's county, with the possible exception of a single occurrence near Fort Foote, on the Potomac river.

Character of Materials.—The deposits of the Monmouth formation are variable, but sands largely predominate. As different types of materials to a large extent characterize the subdivisions, a more accurate description will be given of them in that connection. In general the sands are highly ferruginous and to a large extent glauconitic, becoming also at times very argillaceous toward the south. The sand deposits are frequently indurated either by iron or by carbonate of lime, the latter being furnished by the fossil shells which at times crowd the beds.

Strike, Dip, Thickness.—The strike and dip of the Monmouth formation are essentially the same as in the case of the Matawan formation, but can be somewhat more readily determined on account of the topographic situation of the strata.

The thickness of the deposits is less variable than in the case of the Matawan formation, but gradually declines from about 150 feet in northern Monmouth county to 60 feet to the east of Philadelphia, beyond which point it continues to increase, reaching somewhat over 60 feet in Gloucester county and about 85 feet in Salem county. In Delaware it is about 60 feet, and on the eastern shore of Maryland it increases in the region of the Sassafras river to 85 feet. Upon the western shore of the Chesapeake bay, in the valleys of the Magothy and Severn rivers in Anne Arundel county, its thickness is again reduced to 50 feet, beyond which it rapidly declines, until in the valley of the Patuxent it is only 10 feet, and shortly thereafter entirely disappears.

Stratigraphic Relations.—The Monmouth formation lies conformably upon the Matawan formation throughout the area observed. The division line is generally sharply defined where the basal red sands come in contact with the micaceous sands and the sandy marls of the Matawan.

The relations between the Monmouth formation and the overlying Rancocas formation are not so clear on account of the very great difference in the upper members of the Monmouth formation itself in the different portions of its area of outcrop, the Rancocas formation resting throughout a portion of the region upon red sands, while elsewhere it lies upon micaceous sandy clays. This may find its explanation in either one of two ways. It may be the result of actual unconformity, or it may be brought about by the change of the sandy members of the upper Monmouth in northern New Jersey, until they gradually become replaced by clays toward the south, to be succeeded by sands upon the eastern shore of Maryland, where the formation again thickens. The structural relations are not sufficiently clearly defined to absolutely determine this point, although there are strong indications in certain places, shown in the marked change in the general aspect of the materials and the sharp lines of contact, to indicate that unconformity exists. In that case it is not impossible that the sands of the upper Monmouth have suffered removal through central and southern New Jersey, although this would not be necessary, since both the thinning out of the sands and gradual replacement by clays, as well as unconformity, could occur, and the explanation of the relations observed may be found in a combination of the two hypotheses. The unconformity, if it exists, doubtless represents a very brief interval, since the general conditions did not largely change, while the life-forms of the previous age persisted in a number of instances into the later period. Although most careful and detailed observations and measurements have been made in the area where the sands finally disappear, there is still some question as to the presence of conformity; yet it may safely be assumed as a tentative hypothesis, with the reservation that it may wholly or in part be accounted for by the marked change in the character of sedimentation.

Divisions—General Characteristics.—The Monmouth formation can be subdivided upon lithologic grounds throughout a large part of its area into three members, which are especially well marked in the northern portion of the district and upon the eastern shore of Maryland, but are less clearly defined in central and southern New Jersey and upon the western shore of Maryland. The three divisions in ascending order are the Mount Laurel sands, the Navesink marls and the Redbank sands. The latter two have been previously named from typical areas in Monmouth county, while the first receives its designation from Mount Laurel, situated to the east of Camden, in Burlington county, where the sands of this horizon are most extensively developed.

Mount Laurel Sands.—These sands are, on the whole, perhaps the most constant member of the Monmouth formation, although very variable in thickness and changing considerably in their character as they extend southward into Maryland. They consist typically of coarse red sands that are often indurated on account of the large amount of iron present in them. They are more or less glauconitic, especially toward the south, and in their more unweathered portions, when reached by well-borings are frequently grayish or light greenish gray in color. They have a thickness of about five feet in the vicinity of Atlantic Highlands, which slowly increases to the southward, until in the region to the east of Philadelpdia they have increased to over 25 feet. Beyond that point they increase more rapidly throughout the southern counties, reaching 50 feet in Gloucester county and fully 80 feet in the vicinity of Salem. In Delaware and in the eastern counties of Maryland they are between 30 and 40 feet, but on the western shore of the Chesapeake they cannot be sufficiently well differentiated to be separated from the overlying members. They have often been confused with the Redbank sands, which overlie the marls. Both on faunal and stratigraphic grounds their association with the Navesink marls and Redbank sands as part of the Monmouth formation is unquestionable.

Navesink Marls.—These marls, embracing the Lower Marl bed of Cook, extend with a remarkably constant thickness of from 40 to

50 feet from the Highlands of Navesink throughout Monmouth and northern Burlington counties, beyond which they cannot be very well differentiated from the overlying Redbank sands until eastern Maryland is reached, where the two members re-appear, although the marls are of very much less thickness, generally not exceeding 12 feet. The Navesink marls are typically glauconitic sands which themselves admit of further subdivision throughout much of Monmouth county. The basal portion consists generally of arenaceous beds that have been hitherto referred to under the name of sand marl and which are generally highly fossiliferous wherever found. A great variety of fossil species has been obtained from this horizon. Above the sand marl, in the northern portion of the area, is a very compact blue marl which is highly glauconitic and frequently fossiliferous in its central portions, a firm shelly layer at times resulting. The upper portion of the Navesink marls is commonly more micaceous, and just at the top is at times quite sandy. Farther to the south, in central and southern New Jersey and in Delaware, the Navesink marls become much more argillaceous, the glauconite being much reduced in amount. Whether the argillaceous marls throughout this district represent the Navesink marls alone, or a part or all of the Redbank sands as well, cannot be altogether satisfactorily determined. If unconformity exists, as seems probable, it is even possible that these argillaceous marls may not in all cases even repressnt the full development of the Navesink in the north. The changes which have taken place in the materials make it difficult to say just how much of the middle and upper Monmouth should be included.

Redbank Sands.—These sands, comprising the Red Sand of Cook, are most typically developed in the region about Red Bank, Monmouth county, and in the highlands forming the Cretaceous escarpment in the region to the north and west of that town. Throughout most of Monmouth county the Redbank sands have a thickness of about 100 feet, which declines gradually to the southward until in the Pine Hill region it has dropped to about sixty feet, from which point it still further declines to the region of Red hill, in Burlington county, beyond which the Redbank entirely disappears unless replaced by the argillaceous deposits which have been above described.

The Redbank sands, as developed in the north, do not occur throughout southern New Jersey, but re-appear in Delaware and the eastern counties of Maryland, where their characteristic features are again developed and where they have a thickness in the Sassafras river basin of about sixty feet. They decline somewhat in thickness toward the Chesapeake bay, and upon the western shore of the Chesapeake cannot be distinguished from the other members of the Monmouth formation. The deposits, in the two areas where all the members are characteristically developed, consist typically of very red sands which in their more unweathered portions carry grains of glauconite. Beds of dark sandy marl and black micaceous clay are at times interbedded with the sands, the former frequently occurring at the base, while the latter is more common higher in the series. A greenish gray or reddish clay, more or less indurated, occurs at the very top of the formation in Monmouth county and forms a firm unyielding capping for the Monmouth formation.

Fossils.—The fossils of the Monmouth formation are very numerous and well preserved, at times forming solid shelly layers. Many of the species are identical with those found in the Matawan formation, while a few are found ranging upward into the Rancocas formation. A considerable number of forms are restricted, however, to the Monmouth itself. Among the characteristic and common species found in this formation and determined by the authors are the following:

Bolivina punctata, D'Orbigny.
Marginulina trilobata, D'Orbigny.
Vaginulina strigillata, Reuss.
Cristellaria cultrata, Montfort.
Catopygus pusillus, Clark.
Cassidulus florealis, Morton.
Terebratella vanuxemi, Lyell and Forbes.

Ostrea larva, Lamarck.
Ostrea tecticosta, Gabb.
Ostrea crenulimarginata, Gabb.
Gryphæa convex, Morton.
Gryphæa vesicularis, Lamarck.
Exogyra costata, Say.
Anomia argentaria, Morton.
Camptonectes parvus, Whit.
Neithea quinquecostata, Sowerby.
Spondylus gregalis, Morton.
Plicatula urticosa, Morton.
Radula pelagica, Morton.
Lithodomus ripleyana, Gabb.
Trigonarca transversa, Gabb.
Cibota rostellata, Morton.
Cibota multiradiata, Gabb
Idonearca antrosa, Morton.
Idonearca vulgaris, Morton.
Axinea alta, Whit.
Axinea mortoni, Conrad.
Nulculana protexta, Gabb.
Trigonia mortoni, Whit.
Trigonia cerulea, Whit.
Crassatella vadosa, Morton.
Crassatella subplana, Conrad.
Diceras dactyloides, Whit.
Cardium eufaulensis, Conrad.
Cardium dumosum, Conrad.
Cardium multiradiatum Whit.
Leiopistha protexta, Conrad.
Veniella conradi, Morton.
Callista delawarensis, Gabb
Aphrodina tippana, Conrad.
Cyprimeria excavata, Morton.
Periplomya elliptica, Gabb.
Panopæa decisa, Conrad.
Legumen planulatum, Conrad.
Clavagella armata, Morton.

Pyropsis retifer, Gabb.
Pyropsis richardsoni, Toumey.
Pyropsis obesa, Whit.
Pyropsis septemlirata, Gabb.
Pyrifusus cuneus, Whit.
Neptunella mullicaensis, Whit
Odontofusus typicus, Whit.
Odontofusus medians, Whit
Volutomorpha conradi, Gabb.
Volutomorpha ponderosa, Whit.
Vasum conoides, Whit.
Rostellites nasutus, Gabb.
Volutoderma ovata, Whit.
Turbinopsis hilgardi, Conrad.
Turbinopsis curta, Whit.
Cithara mullicaensis, Whit.
Rostellites compacta, Whit.
Rostellaria spirata, Whit.
Rostellaria hebe, Whit.
Anchura compressa, Whit.
Gyrodes abbotti, Gabb.
Gyrodes infracarinata, Gabb.
Gyrodes altispira, Gabb.
Lunatia halli, Gabb.
Amauropsis punctata, Gabb.
Margarita abyssina, Gabb.
Margaritella abbotti, Gabb.
Xenophora leprosa, Morton.
Turritella encrinoides, Morton.
Turritella vertebroides, Morton.
Turritella lippincotti, Whit.
Actæon forbesiana, Whit.
Cinulia naticoides, Gabb.
Dentalium subarcuatum, Conrad.

Nautilus dekayi, Morton.
Baculites ovatus, Morton.
Belemnitella americana, Morton.

Rancocas Formation.

Name.—The Rancocas formation previously named[*] and characterized, is so called from its typical development in the valley of Rancocas creek, in Burlington county, New Jersey. It comprises in general terms the Middle Marl bed of Professor Cook, although portions of that author's Yellow Sand may possibly be here included, while other portions may fall within the next higher division. It seems more probable, however, that certain yellowish sands in eastern Monmouth county, derived in part from the underlying greensand marls, but of Miocene age, were regarded by Cook as part of the Upper Cretaceous, so that in that case the Yellow Sand is not to be sought for in the Cretaceous at all, and need not be further considered.

Areal Distribution.—The Rancocas formation occupies the country to the east of the Monmouth formation, and extends from Raritan bay to the valley of Severn river in Maryland, where its last outcrop occurs. In the northern part of the Cretaceous belt the width of outcrop of the main body of the formation to the south of the escarpment is generally between three and four miles, but this width is considerably increased by the exposures which are made by the easterly-flowing streams, but more especially by the outliers which are found upon the higher points of

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[*] Journal of Geology, vol. II., page 166, 1894.

the escarpment. Its areal distribution decreases in width in central Monmouth county to some extent on account of the topographic configuration of the country, but in central and southern New Jersey, on account of the greater thickness of the deposits, considerably expands, until in Camden and Gloucester counties it reaches a width of five or six miles. Toward the south, in Salem county, it again somewhat contracts. In Delaware and the eastern counties of Maryland, on account of the extremely level character of the country, its area of outcrop is increased, but it narrows southward toward the shore of Chesapeake bay, and is only represented in a few isolated remnants on the western side, and entirely disappears on the north bank of Severn river.

Character of Materials.—The deposits of the Rancocas formation consist for the most part of greensand marls, at times very highly calcareous, especially in central and southern New Jereey. Some of the beds are crowded with fossils, so that shelly bands occur which are often locally indurated. The greensand marls frequently become highly argillaceous, producing a chocolate-colored marl.

Strike, Dip, Thickness.—The strike and dip of the deposits of the Rancocas formation conform more or less closely to those of the preceding members of the Upper Cretaceous, and can be quite readily determined on account of the topographic relations of the strata. The dip, obtained by connecting the beds upon the crest of the escarpment with the main body of the deposits to the eastward, is shown to be on the average about twenty-five feet in the mile.

The thickness of the deposits is fairly constant throughout the northern portion of the area to the north of Rancocas creek, and has been estimated to be between 45 and 50 feet. To the south of this region it slightly increases in thickness through Camden and Gloucester counties, and then suddenly expands in Salem county, where it attains a maximum thickness of 125 feet. To the south of the Delaware river, on the Delaware peninsula, it declines rapidly in thickness, and at the Maryland State line has again become reduced to about 50 feot. Near the shore of Chesapeake bay it has still further declined to 30 feet, while upon the western shore of the bay, in eastern Anne Arundel county, the deposits are only a few feet in thickness at the isolated points observed.

Stratigraphic Relations.—The relations between the Rancocas formation and the underlying Monmouth formation have already been described. The materials of the Rancocas formation are very distinct from the beds beneath and give indication, both upon this and other grounds, as has been above shown, of unconformity, although this has not been absolutely proven.

The Rancocas formation is overlain conformably by the Manasquan formation, although but few points of contact have been observed on account of the very general overlapping of the Miocene deposits throughout this area. The best exposures are seen in the valley of Manasquan river, near Freehold, and on the southwest branch of Rancocas creek, in the vicinity of Medford, where the lime-sands of the Rancocas formation are overlain by the light-colored clay at the base of the Manasquan.

Divisons — General Characteristics. — The Rancocas formation throughout New Jersey admits of subdivision, upon both lithologic and paleontologic grounds, into two members, but beyond the Delaware river in Delaware and Maryland the distinctions, so clearly marked in the north, are gradually lost. The two divisions in New Jersey are, in ascending order, the Sewell marls, so named from Sewell, in Gloucester county, and the Vincentown lime-sands, so called from Vincentown, in Burlington county, in both of which localities the deposits are characteristically developed.

Sewell Marls.—These marls form a very constant horizon that can be readily traced the entire distance across the State of New Jersey. They consist typically of dark greensand marls, throughout which the glauconite is thickly disseminated, although this substance diminishes in amount in passing southward. The Sewell marls have a thickness of about thirty feet in northern New Jersey, but become somewhat reduced in amount in the southern counties, declining to less than twenty feet in Salem county.

The Sewell marls are characterized by a highly fossiliferous band near the top, although casts of molluscan shells and the bones of saurians are found throughout this division. The fossiliferous zone at the top is often packed with shells, the lower portion of it being made up almost exclusively of the shells of *Gryphæa vesicularis*, while the upper part is often composed of the shells of *Terebratula harlani*. These fossil layers are remarkably persistent, extending as an almost continuous band across the State.

Vincentown Lime-sands.—These lime-sands are well developed throughout the central and southern counties of New Jersey, and consist of highly calcareous greensands, the calcareous element being supplied by the vast number of Bryozoan shells which crowd the beds. At times the beds are almost purely calcareous, and at many points, especially near the top of the Rancocas formation, become consolidated into firm, limestone ridges. The Vincentown lime-sands have a constant thickness of about twenty feet in northern and central New Jersey, but increase gradually to the southward and in Salem county suddenly expand until they attain a thickness of about 100 feet.

To the south of New Jersey, in Delaware and Maryland, this subdivision of the Rancocas into two members becomes gradually obscured, although the lime-sands still continue to characterize to some extent the upper portions of the formation on the eastern side of the Chesapeake, but at the same time the *Terebratula harlani* is no longer limited to its former horizon at the top of the Sewell marls, but occurs frequently within and even at the top of the lime-sands. The lower member also changes its character, becoming less glauconitic and grayish or reddish gray in color.

Fossils.—The fossils of the Rancocas formation are less varied in species, but very numerous in individuals, and at times largely make up the strata, as above described. A few of the species are identical with those found at lower horizons, while a few continue on into the succeeding Manasquan formation, but the majority have not yet been found elsewhere. Among the characteristic and common species found in this formation, and with one or two exceptions obtained and determined by the authors, are the following:

Verneuilina triquetra, Munst.
Lingulina carinata, d'Orb.
Flabellina sagittaria (Lea).
Polymorphina communis, d'Orb.

Pentacrinus bryani, Gabb.
Goniaster mammillata, Gabb.
Cidaris splendens, Morton.
Cidaris walcotti, Clark.
Salenia tumidula, Clark.
Salenia bellula, Clark.
Pseudodiadema diatretum, Morton.
Coptosoma speciosum, Clark.
Trematopygus crucifer, Morton.
Catopygus oviformis, Conrad.
Ananchytes ovalis, Clark.
Cardiaster cinctus, Morton.
Hemiaster parastatus, Morton.
Hemiaster stella, Morton.
Hemiaster ungula, Morton.

Terebratula harlani, Morton.
Terebratula harlani, var. *fragilis*, Morton.
Cistella beecheri, Clark.

Gryphæa vesicularis, Lamarck.
Gryphæa bryani, var. *precedens*, Whit.
Gryphæostrea vomer, Morton.
Idonearca medians, Whit.
Teredo tibialis, Morton.
Gastrochæna americana, Gabb.

Perissolax trivolva, Gabb.
Cavoscula annulata, Morton.
Pleurotrema solariformis, Whit

Nautilus bryani, Gabb.
Nautilus dekayi, Morton.
Ammonites (*Sphenodiscus*) *lenticularis*, Owen.

Manasquan Formation.

Name.—The Manasquan formation* receives its name from the Manasquan river, in Monmouth county, New Jersey, where the most complete section of the deposits of this horizon is found. If the Yellow Sand described by Professor Cook really constitutes a part of the Cretaceous series, then a part of it should be referred to the basal portion of the Manasquan formation. As above explained, it is highly probable that the Yellow Sand, as described by Professor Cook, is really of Miocene age, and does not belong to the Upper Cretaceous series at all. The Manasquan formation embraces the lower and middle members of the Upper Marl bed of Professor Cook, including what was described under the name of the Green marl and the Ash marl of that division.

Areal Distribution.—The Manasquan formation is confined exclusively to the northern portion of the New Jersey area, extending from the region just south of Long Branch, in Monmouth county, across the northern portion of Ocean county into Burlington county, but entirely disappearing a short distance beyond its border in Camden county. The width of outcrop of the formation is very variable, on account of the encroachment of the Miocene deposits, which very frequently entirely bury the strata of the Manasquan from view, thus temporarily interrupting its continuity. Where the Miocene deposits have been stripped off by streams, as along the line of the Manasquan river and its tributaries, it may attain a width of three or four miles, but more often the width does not exceed one or two miles, with frequent variations, as above cited.

Character of Materials.—The deposits of the Manasquan formation consist typically of highly glauconitic greensands of a deep green color. They may at times, by the admixture of argillaceous materials, have a somewhat ashy color, which is characteristic of the beds to which Professor Cook gave the name of "Ash marl." This ash-colored marl is not always confined to the upper portion of the Mana-

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*Journal of Geology, vol. II., 1894, pages 166, 167.

squan formation, however, but more often found there. At the base of the Manasquan formation there is often a layer of fine clay, very light in color, which is commonly referred to under the name of "fuller's earth."

Strike, Dip, Thickness.—The strike and dip of the Manasquan formation conform in general to the strike and dip of the preceding members of the Upper Cretaceous series, so far as can be determined by a study of the sections and of the well-borings. The topographic relations of the strata are such as to preclude satisfactory measurements, such as were possible in the case of the Rancocas and Monmouth formations.

The thickness of the formation diminishes gradually from very nearly fifty feet in the northern portion of its area of occurrence to about forty feet at the eastern border of Burlington county, beyond which it more rapidly declines, reaching thirty feet in the southwestern portion of the county, and entirely disappearing by the overlapping of the Miocene shortly thereafter.

Stratigraphic Relations.—The Manasquan formation rests conformably upon the Rancocas formation, the line of contact being sharply defined in the few places where surface exposures have been found. At these points, namely, upon the Manasquan river to the west of Farmingdale and upon the southwest branch of Rancocas creek to the southwest of Medford, the light-colored clays which form the base of the Manasquan rest conformably upon the Vincentown lime-sands of the Rancocas formation. The Manasquan formation is conformably overlain by the succeding Shark River formation, the line being less sharply defined than in the case of the basal contact.

Fossils.—The fossils of the Manasquan formation are neither numerous in individuals nor in species, except at a few localities. The forms determined are the following:

Textularia agglutinans, d'Orbigny.
Tritaxia tricarinata (Reuss).
Nodosaria spinulosa (Montagu).
Globigerina bulloides, d'Orbigny.
Truncatulina wuellerstorfi (Schwager).
Terebratulina atlantica, Morton.

Ostrea glandiformis, Whitfield.
Gryphæa bryani, Gabb.
Modiola johnsoni, Whit.
Arca quindecemradiata, Gabb.
Cardita, intermedia, Whit.
Crassatella conradi, Whit.
Crassatella delawarensis, Gabb.
Crassatella littoralis, Conrad.
Crassatella rhombea, Whit.
Cardium (*Criocardium*) *nucleolus*, Whit.
Veniella rhomboidea, Conrad
Caryatis (?) *veta*, Whit.
Petricola nova-ægyptica, Whit.
Veleda nasuta, Whit.
Periplomya truncata, Whit.
Panopæa elliptica, Whit.

Shark River Formation.

Name.—The Shark River formation* was earlier so named from its typical occurrence in the upper valley of Shark river, Monmouth county, New Jersey. It includes the upper division of the Upper Marl bed, which was designated as Blue marl by Professor Cook.

Areal Distribution.—The Shark River formation is confined to a very limited district in eastern Monmouth county, New Jersey, being known definitely only to the northwest of Asbury Park and in the valleys of the Shark and Manasquan rivers. Its surface outcrops are confined to the valley sides, being deeply buried in the intervening country by Miocene deposits. To the south of Monmouth county the Shark River formation has been nowhere observed, although it doubtless occurs beneath the Miocene cover.

Character of Materials.—The deposits of the Shark River formation consist of very fine dark-green sands, at times with a bluish tinge, and with a greater or less admixture of argillaceous materials. An indurated stony layer is commonly found at the top of the formation in the limited area where it has been observed.

Strike, Dip, Thickness.—The strike and dip of the Shark River formation are similar to those of the preceding formations, so far as is revealed from the few surface exposures and the records obtained from well-borings.

The thickness of the beds is between ten and fifteen feet, and at points exposed in the Shark river and Manasquan valleys is estimated as pretty constant at about twelve feet. As the Shark River formation has only been observed upon its beveled edges near its contact with the Manasquan formation, it is highly probable that it increases considerably in thickness to the southeastward beneath the Miocene cover.

Stratigraphic Relations.—The Shark River formation rests conformably upon the underlying Manasquan formation, and its deposits are not separated by any sharply-defined lithologic distinction, although the general character of its materials is somewhat different from that of the underlying strata. The Shark River formation is unconformably overlain by the Miocene deposits, and the line of contact is always clearly marked. The Miocene deposits have a con-

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*Journal of Geology, vol. II., 1894, page 167.

siderably smaller angle of dip than the Shark River beds, as shown by the general overlapping of the former upon the subjacent members of the Cretaceous series.

Fossils.—The fossils of the Shark River formation have much interest, since they are supposed to represent a fauna of a later geological period than that to which the previous formations are referred. Among the characteristic and prominent species are the following:

Ostrea glauconoides, Whitfield.
Gryphæa vesicularis, Lamarck.
Pecten kneiskerni, Conrad.
Nucula circe, Whit.
Nuculana albaria, Conrad.
Axinea conradi, Whit.
Astarte castanella, Whit.
Cardita perantiqua, Conrad.
Protocardium curtum, Conrad
Veleda equilatera, Whit.
Corbula (*Neæra*) *nasutoides*, Whit.

Fusus angularis, Whitfield.
Fasciolaria hercules, Whit.
Caricella ponderosa, Whit.
Voluta lelia Whit.
Voluta perelevata, Whit.
Voluta (*Scaphella*) *newcomniana*, Whit.
Volutililhes sayana, Conrad.
Pleurotoma surculitiformis, Whit.
Conus subsauridens, Whit.
Calyptraphorus velatus, Conrad.
Xenophora lapiferens, Whit.
Mesalia elongata, Whit.

Nautilus cookana, Whit.
Aturia vanuxemi, Conrad

INTERPRETATION OF THE SEDIMENTARY RECORD.

General Character of the Deposits.

The Upper Cretaceous deposits described in the preceding pages consist of a great variety of materials, among which sands and clays are the most conspicuous, although these deposits, as well as the calcareous beds of more local development, contain glauconite in greater or less amounts at nearly every horizon. As the materials, however, differ considerably from one another in general aspect in the several formations, the deposits of each horizon will first be briefly characterized and then contrasted with the other members of the series.

The deposits of the Matawan formation consist chiefly of thick-bedded sands and clays in which the glauconite is for the most part developed in seams and pockets, in this particular standing in marked contrast to all the succeeding members of the Upper Cretaceous, where the glauconite is widely, although at times sparingly, disseminated.

The clays of the Matawan formation are also much more homogeneous than in any of the succeeding formations, while the unctuous character of the materials is unknown at later horizons. The rapid alternation of finely-laminated black clays with white, gritty sands, especially well shown in Monmouth county, is very different from anything observed elsewhere in the Upper Cretaceous series.

The deposits of the Monmouth formation consist of a great body of greensand marls and argillaceous beds, more or less highly glauconitic, and situated, where most typically developed, between two horizons of red sands, the latter commonly thick-bedded and often indurated in places. The materials of the Monmouth formation are quite distinct from those of the underlying Matawan in their general aspect. The sandy and more glauconitic marls of the Matawan, particularly in the southern part of New Jersey, show some points of resemblance to the more marly members of the Monmouth, but in general the differences are very marked. On the other hand, a comparison of the materials of the Monmouth with those of the overlying formations shows again a clearly-defined difference in the character of the beds. The greensand marls of the Monmouth formation are in general less-highly glauconitic than the deposits of the higher formations, and can be readily separated both on account of their color and the general composition of the beds. The red sands are quite unknown at later horizons except in certain marginal phases of the Rancocas formation, where even here the weathered glauconite retains enough of its character to reveal the true nature of the strata.

The deposits of the Rancocas formation consist for the most part either of highly-glauconitic greensands or of calcareous beds in which the glauconite is widely disseminated. The thick-bedded greensands, which may at times become chocolate-colored by the admixture of argillaceous materials, can be usually readily distinguished from the glauconitic members of the lower formations, although materials more or less closely similar occur in the overlying Manasquan formation. The calcareous beds, on the other hand, are unique, nothing similar being known in any of the other Cretaceous formations. The persistency and great local thickness reached by these beds render this deposit one of, if not the most striking in the entire Cretaceous series of the northern Atlantic Coastal plain.

The Manasquan formation is typically composed of very pure greensands, which in their upper members particularly may become at times ash-colored by an admixture of argillaceous elements. These ashy and drab-colored marls are thoroughly characteristic of the Manasquan formation, the more argillaceous members of the lower formations possessing rather a chocolate than an ashy color. The pure greensands, too, are generally lighter green than the glauconitic deposits of earlier horizons, their nearest allies being seen in the greensands of the Rancocas formation.

The deposits of the Shark River formation are typically bluish-colored greensands which become at the top often indurated into stony bands. They are more like the greensands of the Manasquan formation than of any of the preceding formations, but nevertheless possess an individuality of their own.

Geographical Variation in the Materials.

Very marked differences are recognized in the materials of the Upper Cretaceous formations in the various parts of the northern Atlantic Coastal plain. With some exceptions the formations are much more fully developed in the north and gradually decline both in thickness and in divisional distinctness toward the south.

The Matawan formation, which has a thickness of fully 275 feet in the northern part of the Cretaceous belt, gradually thins southward until it finally disappears in southern Maryland. The divisions also, which are clearly defined in the north, become gradually obscured in central New Jersey toward the Burlington-Camden county boundary, and farther south are not recognized, the materials becoming practically homogeneous throughout. The well-marked clays and clearly-defined sands of the north gradually give place to micaceous, sandy clays and marls that show in a remarkable degree an admixture of the more characteristic substances found in the New Jersey deposits.

The Monmouth formation changes greatly in character between Monmouth county, New Jersey, and central Maryland, where it finally disappears. In the north the three divisions previously described are clearly defined, while throughout central and southern New Jersey the upper sandy member is either wanting or replaced wholly or in part by fine argillaceous deposits, the lower sandy member at the same time steadily increasing from the north toward the south until it changes from an insignificant bed to the most important member of the formation. Although the triple division again appears in Delaware and upon the eastern shore of Maryland, it is lost upon the western side of the Chesapeake, where the upper and lower sands with their intervening greensand marls, so well developed in the two areas above described, become merged into pinkish and grayish sands which show no persistent divisions, although possessing more or less variability in their different parts. The highly glauconitic character of the deposits in Monmouth county is gradually lost toward the south, the greensand strata becoming at first more or less argillaceous, while, to the south of the Delaware, both upon the eastern and western sides of the Chesapeake, sands with little glauconite largely predominate, and to the west of the Chesapeake alone represent the formation.

The Rancocas formation is much more highly glauconitic in New Jersey than it is south of the Delaware. The lower greensand member gradually decreases south of Monmouth county, while the upper calcareous member increases in thickness, until in the southern portion of New Jersey it far surpasses the lower greensand division in importance. The great thickness of the calcareous beds in Salem county, New Jersey, is one of the most striking things connected with the geographical variation in the materials of the Upper Cretaceous formations. Although the calcareous member is found to the south of the Delaware, it rapidly declines in thickness upon the Delaware peninsula, beyond which it is not known with certainty to occur, the few feet of Rancocas materials found on the western shore being for the most part greatly weathered, so that their original lithologic characters are much obscured.

The Manasquan and Shark River formations show unimportant geographical variations in their materials. Their area of distribution along the strike, as represented by surface outcrops, is far less in extent than is the case with the other members of the Upper Cretaceous series, and even in their area of occurrence they are largely obscured by the overlying Miocene.

The variations thus far described have had to do entirely with geographical variations along the line of strike as shown either in surface exposures or in well-borings near the margin of the several deposits. Some of the deeper well-borings which have been made to the southeast of the Cretaceous belt, down the dip of the beds, show that in general the various members of the Upper Cretaceous series increase in that direction both in thickness and in the amount of glauconitic materials which they contain. The records of the well-borings, on account of the mixture of materials which is liable to result from the methods pursued, do not always afford an accurate account of the beds penetrated; but, so far as can be judged, the broader formational distinctions which prevail at the surface persist. The records are not altogether satisfactory as regards the subdivisions, however, but it seems highly probable that they change materially and often entirely disappear along the line of dip.

Variations of considerable magnitude in the deposits of the Upper Cretaceous of the northern Atlantic Coastal plain are found, as above described, along both the lines of strike and dip, but the chief divisions can everywhere be recognized throughout the area. As they are the only divisions which can be thus employed throughout the region, they have been given formational importance.

Probable Marine Conditions as Revealed by the Deposits.

The descriptions of the formations which have been given in the preceding pages show that the Upper Cretaceous is chiefly composed of deposits in which glauconite is more or less commonly present. A knowledge of the marine conditions can therefore be gained by instituting a comparison between the deposits of the Upper Cretaceous and those in which glauconite is being formed at the present time.

Great light has been thrown upon the origin of greensand deposits as a result of the deep-sea dredgings which have been made in recent years by vessels sent out under national auspices. The most important of these expeditions was that of the "Challenger," sent out by the British government in the years 1872–76. In the report upon the deep-sea dredgings published as a result of that expedition Messrs. Murray and Renard, the authors, present the latest results upon the character and distribution of greensand, and at the same time propose a theory to account for the chemical changes which have taken place to produce the mineral glauconite which characterizes all greensand deposits.

A typical greensand, such as has been described in most of the Upper Cretaceous formations, is composed of glauconite associated with greater or less amounts of land-derived material, composed of the more common rock-building minerals, together with fragments of the rocks themselves, while to these is commonly added a variable amount of calcareous matter derived from the shells of organisms.

The greensand deposits of the present day are estimated to cover a million square miles of the sea-floor and are found limited to those areas adjacent to the coast, and for the most part along the higher portions of the continental slopes, where land-derived materials are deposited in perceptible, yet small amounts. The "Challenger" dredgings show that the production of glauconite seldom reaches to greater depths than 900 fathoms, and most commonly takes place between 100 and 200 fathoms, although under favorable conditions it may be produced at shallower depths. Its formation is interfered with by the entrance of large rivers bearing sediment into the sea and by the prevalence of strong oceanic currents.

It is a remarkable fact that although greensand is not formed except in the presence of land-derived materials its production is accomplished through the intervention of foraminifera, and brought about by chemical changes which take place in the finely-comminuted sediment as the result of the decomposition of the organic matter inclosed in the shells and disseminated in the surrounding mud. Glauconitic casts of foraminifera are of common occurrence in such deposits.

It will be observed, then, that two conditions are requisite for the production of glauconite. First, the deposition of mineral particles of land-derived origin; and, second, the presence of foraminifera. In the absence of either, the production of greensand evidently does not take place, while its formation is retarded and finally ceases altogether as the amount of deposited materials increases adjacent to the coast.

The conditions for the formation of greensand being then as above described, it is probable that the succession of events during the Upper Cretaceous along the northern Atlantic coast was somewhat as follows: With the opening of the Matawan epoch moderately-quiet, deep seas prevailed over most of the area, resulting in a slow accumulation of muddy sediments, in which locally and for brief periods the conditions were favorable for the formation of glauconite. Later in the Matawan epoch the conditions of sedimentation changed in the north, but remained much the same in the south. Thick-bedded sands were laid down over the northern portion of the area, although a return to the muddy sedimentation occurred prior to the close of the epoch throughout a portion of the district, bringing with it locally conditions again favorable to the production of glauconite. The epoch closed in the north with a renewed deposition of sand, at this time, however, highly micaceous, the micaceous materials also characterizing the finer deposits of the south, as they had done to some extent the sediment of that area throughout the epoch.

With the advent of the Monmouth epoch land-derived materials were largely increased in volume in the southern portion of the district, but were only deposited for a short time in the north, where they were shortly succeeded by conditions highly favorable for the production of glauconite, with every indication of quiet and deep seas. These conditions, however, were less pronounced in proceeding southward, and over the area of southern Maryland sedimentation similar to that which had characterized the earlier portion of the epoch was continued. The epoch closed with the deposit of a great volume of sands and clays, sparsely glauconitic, throughout northern New Jersey as well as in Delaware and Maryland, while in the intervening district of central and southern New Jersey the sedimentation was probably of a much finer character, as shown by the chocolate-colored marls of that area, unless, perchance, subsequent erosion had caused the removal of all the sandy sediments.

The succeeding Rancocas epoch was a time of slow accumulation of continental materials throughout the northern Atlantic Coastal plain, so that the production of glauconite went on unhindered. During the later portion of the epoch, however, there must have been a great profusion of bryozoan life, since the deposits show a remarkably large proportion of calcareous materials, largely made up from the shells of these organisms, the percentage of carbonate of lime at times exceeding 80 per cent. of the whole. The conditions most favorable for the production of these deposits were found in central and southern New Jersey, particularly in the region of Salem county.

The Manasquan epoch was characterized throughout by conditions favorable to the formation of highly-glauconitic deposits, but land-derived materials in considerable amounts reached the area just at the opening of the epoch as well as in a less pronounced degree toward its close.

The Shark River epoch succeeded the Manasquan without evidence of any marked change in the physical features of the district, conditions favorable to the production of glauconite still continuing, so that if the Shark River formation is considered of Eocene age, a subject which will be later discussed, then we have no physical break between the Cretaceous and Eocene at this point.

At the close of the Shark River epoch the conditions favorable to the formation of greensand ceased throughout that portion of New Jersey which we have been hitherto considering. To the south, in Delaware and Maryland, the Eocene period was one of greensand production, and the representative of those deposits may to-day exist far to the southward in New Jersey, buried beneath Miocene strata, but its presence has not as yet been definitely shown in the well records.

Probable Continental Relations as Revealed by the Deposits.

The deposits of the Upper Cretaceous afford evidence either that the land of the period was supplying little sediment to the sea or that these Cretaceous materials were laid down so far from the shore-line that but a relatively small amount could reach the area. A brief history of events just prior to the opening of the Upper Cretaceous may aid in the interpretation of the continental relations during that period.

The Lower Cretaceous period is characterized by deposits which give evidence of a gradual submergence of the eastern border of the continent, brought about by seaward tilting and accompanied by landward elevation, which produced increased activity in the streams. The weathered materials of the surface rocks which had become disintegrated to great depths on account of the relatively low elevation of the land in the previous period were carried seaward, thick beds of sands and clays often characterized by large amounts of arkose being formed. Several epochs of elevation and, depression with variations in the angle and direction of tilting doubtless took place during the period, with the result that the land must have been considerably planed down prior to the opening of the Upper Cretaceous.

The Upper Cretaceous was probably ushered in by a general depression of the area draining to the Atlantic border, which must have diminished the power of the streams and at the same time decreased the supply of sediment. This was probably also accompanied by some depression of the sea-floor as well; yet from the descriptions which have been given in the previous pages regarding the character, distribution and relations of the sediments it is evident that the continental conditions could hardly have been constant throughout the period of Upper Cretaceous deposition. Oscillations of greater or less moment, accompanied by increased activity of the streams, must have taken place from time to time, but these changes were not identical or synchronous throughout all portions of the northern Atlantic slope. At the same time many of the minor changes may find their explanation in the direction of transport brought about by variations in the oceanic currents adjacent to the continent border. Such an explanation is, however, wholly inadequate to account for the great deposits of sand in the upper Matawan of northern New Jersey, the lower Monmouth of central and southern New Jersey, Delaware and Maryland, and the upper Monmouth of northern New Jersey and the Delaware peninsula. The largely-increased deposits of coarse materials at these epochs over the wide areas indicated could only have been brought about by changes upon the adjacent land surface.

The close of the Upper Cretaceous witnessed the general elevation of the entire area, the gradual stripping off of the Cretaceous cover, and the superimposition of the consequent streams upon the underlying rocks to which, under varying conditions, they have been continuing to adjust themselves during subsequent periods.

Subsequent Structural and Chemical Changes in the Strata.

The interpretation of the sedimentary record would hardly be complete without reference to the changes, both structural and chemical, which have taken place in the strata subsequent to their deposition. The various oscillations of the northern Atlantic Coastal plain have produced, so far as observed, no marked structural change in the Upper Cretaceous strata, although the beds have been gradually depressed seaward, so that each succeeding group of deposits has come to lie at a slightly lower angle. Slight deformation, both along the strike and dip, has been observed, the explanation for which is sought in movements which have taken place subsequent to the formation of the strata, although no doubt in part explained by the uneven surface upon which the deposits themselves were laid.

Chemical changes of considerable moment have taken place in the beds, often obscuring the original character of the strata. The most conspicuous of these alterations has been the weathering of the glauconite, which has changed the deposits from green or grayish green to brown or reddish brown in color. This is especially marked in the more porous strata or along the thinned-out margins of all the formations. At times the glauconite grains have been entirely destroyed, while at other times the surface only has been weathered, and when crushed the greenish interior is shown. At times induration takes place, producing either shelly layers or thick beds of ironstone. The ironstone deposits have very materially affected the topography of the northern Atlantic Coastal plain, these hard beds protecting the underlying formations from removal. The escarpment in northern New Jersey owes its prominence very largely to the protection thus afforded.

The other deposits have also suffered greater or less change in their surface exposures, the dark clays especially becoming lighter colored as the carbonaceous materials contained in them have been changed or removed by the percolating waters.

INTERPRETATION OF THE FAUNAL RECORD.

Correlation of the Formations Within the Province.

The several formations of the Upper Cretaceous of the northern Atlantic Coastal plain are highly fossiliferous throughout the area of their occurrence, so that, with few exceptions, the paleontological evidence is adequate for the correlation of the strata from their northern to their southern limits.

The Matawan formation is less highly fossiliferous than the other divisions of the Upper Cretaceous. At certain localities, however, the species represented are very numerous, but the fossiliferous bands are less persistent and the individuals seldom so abundant as in the succeeding formation. The several species of ammonites referred to in the list of fossils are especially characteristic of the Matawan formation, *Ammonites delawarensis* and several of the forms of *Scaphites* not having been recognized from the later horizons. Many of the other molluscan types are unknown except in the Matawan, or are found less frequently in the succeeding Monmouth. Other forms, on the other hand, occur with about equal frequency in both the Matawan and the Monmouth. A good many species hitherto recorded from the lower greensand marls are found upon examination of the localities to have come from beds beneath the Monmouth, so that a careful revision of the statements of earlier authors regarding the horizon from which the fossils have been derived is necessary. *Belemnitella americana,* so common in the Monmouth formation, has never been observed in the Matawan, while the shells of *Exogyra costata* and

Gryphæa vesicularis, so common in the Monmouth, although occurring in the lower portion of the Matawan, are not at all frequent until the upper beds are reached.

The Monmouth formation is very rich in organic remains, both in number of species and individuals, the most common and widely distributed forms being *Gryphæa vesicularis*, *Exogyra costata*, and *Belemnitella americana*, which characterize all three divisions of the formation. Large numbers of other molluscan species, as, for example, *Ostrea larva*, *Idonearoa vulgaris*, *Crassatella vadosa*, *Cardium perelongatum*, and *Turritella vertebroides*, are widely distributed, so that the faunal characters of the formation are sufficiently distinctive to establish its occurrence at all points without difficulty.

The Rancocas formation, although highly fossiliferous from the standpoint of individuals, is characterized by very few species. The most typical form is the *Terebratula harlani*, which, throughout New Jersey, is so widely found at the top of the lower greensand member, but which in Delaware and Maryland also occurs within and at the top of the lime-sand division. Among the characteristic forms are *Idonearca medians*, *Gryphæostrea vomer*, and the several types of Echinodermata mentioned above in the list of fossils from the Rancocas formation.

The Manasquan formation is not as rich in organic remains as the Rancocas, but there are several types which are extremely common and characteristic, among them being *Ostrea glandiformis*, *Gryphæa bryani*, *Crassatella conradi*, and *Caryatis* (?) *veta*. With few exceptions, the species are quite distinct from those of the preceding and succeeding formations.

The Shark River formation is characterized by an abundant fauna within the limited area in which it has been observed. With one or two exceptions, the forms are quite distinct from those of the preceding formations, and the genera represented point to a more recent fauna.

An examination of the faunal zones shows that some are much more sharply delimited than others. The Matawan and Monmouth faunas, for example, are much more closely connected with one another than are any of the others, and although they are really but little more than subdivisions of a general fauna, yet they are sufficiently distinct from one another to be readily followed from the Raritan bay to the eastern shore of the Chesapeake, while beyond the distinctive characters of the Matawan fauna are continued to the Potomac at Fort

Washington. The Rancocas fauna is very distinct both from that above and below it, and is highly characteristic of the formation in which it occurs. Its *Terebratula harlani* zone is the most persistent fossiliferous band in the whole Cretaceous series. The Manasquan and Shark River faunas are equally distinctive, although having, so far as can be determined from surface indications, a far less wide geographical distribution. Almost no species common to earlier faunas have been found, and practically no forms continue on from the Manasquan into the Shark River epoch.

Correlation of the Deposits With Those of Other Areas.

The first four formations above described have been, with a single exception, generally recognized as belonging to the Upper Cretaceous, while the fifth or Shark River formation has been assigned to a later date, since Conrad* first in 1848, and again more fully in 1865, maintained the Eocene age of the deposits. More recently Whitfield† has claimed the identity of several of the species with forms found in the Eocene of the Gulf, although they occur there at somewhat widely-separated horizons; but since all of the specimens thus referred are casts, he expresses some doubt as to their identity. So far as the generic relations of the molluscan types are concerned, most of them certainly have a more Eocene than Cretaceous aspect, yet many could as well be referred to the one as the other. With one or two exceptions, all have been found as early as the Cretaceous in some portions of the world. There are, it is true, no distinctively Cretaceous types, while the genus *Aturia* and one or two vertebrate types are not known earlier than the Eocene, yet it has been hitherto impossible to satisfactorily correlate the Shark River formation with any known Eocene deposits. It is, of course, readily conceivable that deposition went on in the moderately-deep waters which prevailed in this region continuously during late Cretaceous and early Eocene time. Elsewhere upon the Atlantic and Gulf coasts, however, a marked stratigraphic break occurs at or near the top of the Cretaceous, and sediments of a different type characterize the oldest of the known Eocene strata.

Some light may perhaps be thrown upon the subject by indicating the equivalents of some of the other Coastal Plain formations where the

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*Jour. Acad. Nat. Sci. Philadelphia, U. S., vol. I., 1848, page 129. Proc. Acad. Nat. Sci. Philadelphia, 1865, pages 71, 72

†Monograph U. S. Geol. Survey, vol. IX., 1884. Ibid., vol. XXI., 1890.

criteria for correlation are more complete. The physical characteristics and organic remains of the Potomac formation of the Atlantic border have generally led to its correlation with the Tuscaloosa of the eastern Gulf, which occupies a similar position at the base of the Coastal Plain series. These basal deposits are generally regarded to be of Lower Cretaceous age and to be the sole representatives of it east of the Mississippi river.

It is highly probable that the more distinctly marine beds of the Upper Cretaceous rest throughout this portion of the continental border unconformably upon the older deposits, but whether their basal strata are synchronous everywhere has not as yet been definitely proven. Enough has been learned, however, from a comparison of the species of the Matawan-Monmouth groups with the Eutaw-Rotten Limestone-Ripley groups to show that they have a common fauna. This is very clear as regards the Ripley and Rotten Limestone groups, while there is nothing in the meager assemblage of forms from the Eutaw group to debar it from being included also. Stanton has found that these Upper Cretaceous deposits in Mississippi have 86 species in common with the New Jersey strata, while in Alabama 35 have been found, all of which are also included in the list from Mississippi. At the same time 54 continue on into Texas. It is highly probable, then, that the Matawan-Monmouth formations stand as the representative of the Upper Cretaceous of the eastern Gulf region.

Before considering the succeeding group of formations (Rancocas-Manasquan-Shark River), all of which contain faunas of post-Ripley age, let us examine the typical Eocene fauna of the Pamunkey formation of Delaware, Maryland and Virginia, which is the next succeeding member of the Coastal Plain series. A critical examination of the fossils from this formation shows two quite distinct faunal zones. The lower, about 60 feet from the bottom of the formation in the Potomac valley, has been designated the Aquia Creek fauna, and shows many points of similarity to the middle Lignitic of the Gulf, while the upper or Woodstock fauna, containing *Ostrea sellæformis* and other types, finds its approximate equivalent in the Claiborne, or rather that zone represented below the fossiliferous sands. With proper allowance for differences in physical conditions and the consequent effect upon geological range of species, for time occupied in migration, and for the lack of typical forms in the highest and lowest strata, the Pamunkey may be regarded as the equivalent of all or the major part of the Lignitic, Buhrstone and Claiborne of the Gulf, although no assumption is made that deposition began at just the same time in the one region as in the other. Some portions of the basal Lignitic may have antedated the lower bed of the Pamunkey, but that is not at all sure.

Let us now return to a consideration of the Rancocas-Manasquan-Shark River formations. The Rancocas fauna, so far as its generic forms are concerned, as well as in a few instances of specific identity, is clearly Cretaceous, but from its position is later than the Ripley. The Manasquan fauna, which succeeds it in conformable deposits, is far less typically Cretaceous, although it could hardly be associated with the Eocene, while the conformably-succeeding Shark River bed, only twelve feet in thickness, has a fauna which shows unmistakable Tertiary affinities.

It seems highly probable that the conformable Rancocas-Manasquan-Shark River group may occupy a position between the Ripley and the Lignitic of the Gulf, and may be in its two basal members of Cretaceous and in its upper member of Eocene age. Clearly-defined unconformity exists between the Ripley and the Lignitic, and during the interval represented by this physical break deposition must have taken place somewhere along the continental border. It is highly probable that the Rancocas-Manasquan-Shark River group represents the whole or a part of this interval.

To the north of New Jersey there are many indications of the former wide extension of the Upper Cretaceous formations. On both Staten Island and Long Island, fossils belonging to the Matawan-Monmouth fauna have been obtained from the drift, while the deposits are still found in place on Block Island, Martha's Vineyard, and at Marshfield, in Massachusetts. It seems highly probable that the deposits of all these localities belong to the Matawan formation. To the south of Maryland, in eastern Virginia, the Upper Cretaceous has been penetratod in well-borings, but the records are not sufficiently complete to determine the horizons with accuracy. In North and South Carolina the presence of the Upper Cretaceous has been known for a long time. The fossils described from this district show that the Matawan-Monmouth fauna is represented, but it is not certain whether the same divisions exist there as in the northern Atlantic States. Nothing similar to the higher formations of the Upper Cretaceous in New Jersey and Maryland has apparently been observed

Some statements regarding the approximate equivalents of these

American formations among western European deposits may well close this chapter. Any attempt at a detailed correlation of the strata must, from the necessities of the case, be fraught with many difficulties. Almost none of the species are identical, yet the assemblage of forms is such as to warrant the conclusion that we have in the New Jersey formations the representatives of the Cretaceous stages of the Senonian and the Danian as well as the very earliest stage of the Eocene of Europe.

The Matawan-Monmouth fauna has many strong Senonian affinities in its cephalopod and pelecypod forms, while the Rancocas and less distinctly the Manasquan point to the Danian. It is interesting to note that the lower Danian, known as the Maestrichtian or Maestricht chalk, also has an extensive development of Bryozoan marls very similar in character to the Vincentown lime-sands, while its paleontological affinities are much the same.

Regarding the equivalents of the Shark River fauna, there is much greater obscurity. In its paleontological relations to the underlying formations it is not unlike the *Calcaire pisolitique* of France, in which the general aspect of the fauna resembles the oldest Tertiary, although a number of undoubted Cretaceous species still persist. These deposits have been placed in the substage Garumnian as the upper member of the Danian by many European geologists, although more recently there has been a tendency to regard them as oldest Eocene (Paleocene of von Koenen). Whatever may be the view regarding the age of the *Calcaire pisolitique*, it is evident that the Shark River fauna must be regarded as very old Eocene, although containing a few Cretaceous representatives, since the assemblage of forms points so strongly to their Tertiary affinities. The correlation of the American Coastal Plain formations with European must at best be of the most general character, in which only the broader affinities of the faunas are indicated. The wide difference in condition is such as to preclude detailed comparisons between the American and European deposits.

ECONOMIC PRODUCTS.

The most valuable of the economic products of the Upper Cretaceous formations are the sands and clays which have been extensively worked for brick-making and the greensand marls, which for over a century have been used as fertilizers.

The workable sands and clays come entirely from the Matawan formation, and mainly from its lowest member, the Crosswicks clays. These deposits are extensively worked in New Jersey at the present time, along the banks and in the vicinity of Matawan creek, in Monmouth county; upon Crosswick creek and near Bordentown and Kinkora, in northern Burlington county, as well as upon the Pensauken creek, near Lenola, in its southern part; a few miles to the east of Camden, in Camden county, and at Woodbury, in Gloucester county. Many millions of brick are annually produced at these places.

The Matawan formation in New Jersey has also been worked in its more glauconitic layers, both in the Crosswick clays and Hazlet sands, for greensand marl, but very little is being done at the present time.

The workable marls come chiefly from the succeeding formations, all of which, from the Monmouth to the Shark river, have produced valuable fertilizers throughout the area of their occurrence. The Monmouth formation was the earliest worked, and extensive pits were opened in Monmouth county, New Jersey, where it is most highly glauconitic. Throughout central and southern New Jersey little digging has been done at this horizon, as the deposits become too argillaceous; but in Delaware, especially in the vicinity of the Chesapeake and Delaware canal, the thin but very marly layers have yielded thousands of tons in quite recent years.

The Rancocas formation, more particularly in its lower division, has been worked for marl at several points in Monmouth county, especially in the southwestern part, at and near Hornerstown. It has been most largely developed for this purpose in recent years, however, in the more southern counties of the State, at Blackwood, in Camden county; at Sewell and Mullica Hill, in Gloucester county, and about Woodstown, in Salem county. The same beds have been worked to some extent in Delaware and on the eastern shore of Maryland, particularly in the valley of the Sassafras river.

The marl richest in fertilizing ingredients belongs to the Manasquan formation, which, with the Shark River formation, which overlies it, has been worked largely in eastern Monmouth county. The Squankum marl, so called, obtained near Farmingdale, has been extensively exported and is in high repute. Very large pits were also opened at Vincentown, Burlington county, and are still worked to some extent.

The greensand marls were first used as fertilizers in 1768, the first recorded pit being opened near Marlboro, Monmouth county, New Jersey. It was not, however, until 1820 that the marl came into general use, and for the next half century millions of tons of it were employed for agricultural purposes. Much of it was dug from small openings for local consumption by the landowners whose farms were in the marl district, or was hauled by wagons into the neighboring county. A great number of larger pits were opened by companies engaged in the marl trade, the railroads oftentimes building branch tracks into the excavations. Thousands of carloads were thus removed directly from the pits and shipped to distant points. During the last twenty-five or thirty years, since the commercial fertilizers have come into such general favor, the marl industry has waned, to the great disadvantage of the Jersey farmer. Recently something of a revival has taken place, and the local use of the marl seems to be increasing annually.

Another economic product of some importance is the calcareous deposit which characterizes the Vincentown lime-sand of the Rancocas formation, and which has been burned for lime at several points in South Jersey. It is largely consumed locally.

The indurated ferruginous layers of the Matawan and Monmouth formations are also used locally for building purposes, in the absence of more suitable materials. The more highly calcareous and ferruginous materials of all the formations are also employed to some extent for road construction, although the superficial Pensauken gravels are better suited and are more extensively used.

SUMMARY.

A summary of the conclusions contained in this paper is as follows:

a. A marked westerly-facing escarpment, called "the Cretaceous escarpment," accompanies and characterizes the Upper Cretaceous formations.

b. The several formations show sufficiently marked differences in the character of their materials throughout the entire distance from northern New Jersey to southern Maryland, to readily distinguish them.

c. The formations, with some local exceptions, thin toward the south, and at the same time change considerably in their lithologic characters.

d. The subdivisions of the different formations, clearly defined at certain points, are unrecognizable at others. In general they grow less distinct toward the south.

e. The formations are gradually overlapped, one after another, toward the south, until in the Potomac valley the Tertiary deposits rest directly upon the Lower Cretaceous.

f. An unconformity is found between the Raritan and Matawan formations, a probable one between the Monmouth and Rancocas formations, and a clearly-marked one between the Shark river and later deposits.

g. The faunal characteristics of the formations are clearly defined throughout the region, the Matawan-Monmouth faunas being more closely related to one another than the Rancocas-Manasquan-Shark River faunas, while the latter, as a whole, are sharply defined from the former.

h. The Matawan-Monmouth faunas, which range through a conformable group of deposits 400 feet in thickness, are the equivalent of the Eutaw-Rotten Limestone-Ripley faunas of the gulf, which occupy strata aggregating 1,600 feet in thickness, and which rest probably unconformably upon the Tuscaloosa formation, the southern representative of the Potomac.

i. The Rancocas-Manasquan-Shark River faunas, occupying a conformable series of beds less than 200 feet in thickness, are absent in the Gulf, and probably represent the time-break between the Upper Cretaceous and Eocene in that region, since the Pamunkey fauna has already been shown to represent approximately the Lignitic-Buhrstone-Claiborne (Lower and Middle Eocene) of the same district.

j. When compared with European horizons the Matawan-Monmouth fauna is probably Senonian and the Rancocas-Manasquan is Danian in age, while the Shark River fauna must be regarded as lowest Eocene, although showing some affinities to the *Calcaire pisolitique* of France, which has been regarded by many authorities as representing the Upper Danian.

k. The economic products are confined largely to the Matawan sands and clays, which have been extensively worked for brickmaking, and to Monmouth-Rancocas-Manasquan-Shark River greensand marls, which have for over a century been used as fertilizers.

PART IV.

Artesian Wells in New Jersey.

BY

LEWIS WOOLMAN.

OUTLINE.

I.

ARTESIAN AND OTHER BORED WELLS, AND ALSO DUG WELLS, IN SOUTHERN NEW JERSEY, &c.

INTRODUCTION.

Principal Water Horizons and their nomenclature.
List of wells in each of the Cretaceous Water Horizons.

Sec. 1.—Well Records in Miocene Strata.

- At Egg Harbor City.
- At Atlantic City.
  - Garden House.
- At Atlantic City.
  - Windsor House.
- At Ventnor.

Sec. 2a.—Well Records in Cretaceous Strata in the Northern Part of Southern New Jersey.

- At Spring Lake.
- At Poplar.
- At Belmar.
- Near Belmar.
- At Allenhurst.
- At Loch Arbor.
- At Darlington.
- At Little Silver.
- At Red Bank and opposite.
- At Brookdale, southwest of Red Bank.
- At Shrewsbury.
- At Seabright and near. Nine wells.
- At Black Point and near. Two wells.
- On Rumson Neck. Five wells.
- On Rumson Bluff. Four wells.
- At Oceanic. Also opposite and near. Five wells.
- At Normandie.
- At Shrewsbury river (mouth).
- At Elberon.
- At Waterwitch.
- At Atlantic Highlands. Two wells
- At Keyport, and east of.
- At Runyon.
- At Matawan.
- On Telegraph Hill.

Sec. 2b.—Well Records in Cretaceous Strata in the Southern Part of Southern New Jersey.

- At Reedy Island.
- At Salem.
- At Alloway Station.
- Near Daretown.
- At Atco. Three locations.
- At Williamstown.
- At Kirkwood.
- At Barnsboro, north of.

At Paulsboro.
At Marlton. Three locations.
At Jenning's Mills.
At Mount Laurel.
    Lenola Molluscan Fossils.
    Ripley Beds.
At North Woodbury.
At National Park.
Southwest of Westville. Three wells.
At Newbold.
At Westville (water works). Two wells.
At Camden. Tenth and Pine streets.
At Merchantville.
In Philadelphia, Pa.
    At Point Breeze.
    At Spreckels' sugar-house, Reed street wharf.
In Philadelphia, Pa.
    At United States Navy Yard.
    At Webster's brickyard, near Gray's Ferry.
    At Fifteenth and Callowhill streets, Reading Railroad subway.
At Pavonia. Two locations.
At Bristol, Pa.
Near Morris Station. Ninety-eight wells.
    Camden Water-Supply.
At West Palmyra.
    Filtrated Water Company.
At Smithville.
Near Vincentown.
At Jobstown.
Near Yardville.

II.

BORED WELLS, MOSTLY IN NORTHERN NEW JERSEY, IN RED SANDSTONE, GNEISS, AND OTHER ROCKS, AND IN THE GLACIAL MORAINE, MAINLY IN ESSEX, HUDSON, SOMERSET AND MIDDLESEX COUNTIES ALSO ON STATEN ISLAND AND LONG ISLAND, N. Y., AND ALONG THE DELAWARE RIVER IN PENNSYLVANIA.

Sec. 1.—Wells Reported by P. H. & J. Conlan.

At Newark. Two locations.
At Arlington.
At Soho.
At Jersey City.
At Jersey City Heights.
At Bayonne.
At Fort Lee.
At Long Island City, N. Y.
At Bridgeport, Conn.
At Dunwoodie, N. Y.
At Arbutus, Md.

Sec 2.—Wells Reported by W. R. Osborne.

At New Brunswick.
At Woodbridge.
At Valentine Station.
At Sand Hills.
At Tottenville, Staten Island, N. Y.
At Pleasant Plains, Staten Island, N. Y.

Sec. 3.—Wells Reported by Stotthoff Bros.

At Lafayette
At Andover.
At Allamuchy. Two wells.
At Hughesville.
At Flanders.
At Lake View.

At Clifton Two wells.
At Passaic. Four wells
At Fort Lee.
At Afton, near Madison.
At Basking Ridge. Two wells.
At Millington.
At Bayway Two wells
At Castleton Corners, Staten Island, N. Y.
At Bound Brook.
At Neshanic Station.
At Three Bridges.
At Flemington. Two wells.
At Princeton.
At Yardville.
At Morrisville, Pa
At Bristol, Pa.
At Croydon, Pa.
At Cornwells, Pa.
At Torresdale, Pa.

Sec. 4.—Wells Communicated by George E. Jenkins and Others.

At Dover and vicinity. Seven wells.
At Arlington and Danville.
At Union, northwest of Elizabeth. Forty-five wells.

I.

ARTESIAN AND OTHER BORED WELLS, AND ALSO DUG WELLS, IN SOUTHERN NEW JERSEY.

INTRODUCTION.

As in past years, so during the present one (1897), the writer has carefully collected data respecting artesian and other bored wells, but before noting the details respecting such wells, the various water horizons which the investigations of the survey have demonstrated to exist will be described, and to each will be assigned a definite name by which it may become known.

PRINCIPAL WATER HORIZONS.

In last year's annual report we noted six principal water horizons between the Delaware river and the Atlantic ocean, the three lowest of which were in the Cretaceous. The developments of the past year have enabled us to indicate three additional horizons. These are interbedded within the various intervals between the lowermost four horizons of last year's report, or the first four, as then enumerated, counting from the base upward.

We therefore now re-enumerate the various horizons in the same order, *i. e.*, from the base upward, or in the order that their upturned and beveled edges would be crossed in passing from the river to the ocean.

For convenience in designating these we now also assign to each a definite name. They are as follows, commencing at the base along the Delaware river and passing eastward to higher horizons:

First Horizon—A Group—The Raritan Group.—This may be defined as a group of *two or three horizons* in heavy gravel and cobble strata near the base of the plastic clays, which clays are variously colored white, yellow and red, or they are mottled in all these colors. The color of the water-yielding gravels may be defined as a *yellowish white* in *contrast* with those of the next higher horizon, which are of a *bluish white.*

Second—The Sewell Horizon.—At the top of the plastic clays and base of the clay marls. The water-bearing gravels are often very coarse. Their color is a *bluish white* in *contrast* with those of the first group. This we designate as the *Sewell water horizon*, because it was first opened and studied in M. J. Anspach's well at that point.

Third—The Woodbury-Wenonah Horizon.—This horizon is near the base of the clay marls. In the region about Woodbury the depths of the various wells seem somewhat too irregular to indicate a well-defined water-bearing sand, and this horizon is there probably distributed through a considerable thickness of laminated sands, while in the neighborhood of Wenonah the horizon, according to our present information, is not so thick, and yet appears to be more decidedly a single sand bed. We name this the *Woodbury-Wenonah horizon.* It was developed by wells at and near Woodbury many years since, and more recently by wells at the *water works* at Wenonah. (The well at the *hotel* at Wenonah goes deeper, to the Sewell horizon.)

Fourth—The Cropwell Horizon.—This horizon is midway in the clay marl or Matawan formation. It is not so far as yet known more than a few feet thick, but yields mostly a satisfactory quality of water, often doing so at points where the water from the next higher horizon, as is occasionally the case, proves somewhat too irony. We designate this the *Cropwell horizon,* since we were first able to define it by a well at that point, though other wells in the region to the eastward had previously developed it.

Fifth—The Marlton Horizon.—At the top of the clay marls and base of the true greensand marl series, which consist of the upper, middle and lower marl beds. Last year we designated this the *Marlton-Medford horizon,* but think it better in future to term it simply the *Marlton horizon.* The water-yielding strata are also bluish white in color.

When boring wells to this horizon its approach is often indicated by the occurrence, first, of the *bryozoa* in the limesand and lime-rock alternations over the Middle Marl, and next by the shell bed in the Middle Marl, of which the two characteristic associated fossils are a *terebratula,* and an ancient oyster, called a *gryphea.* After these, sometimes quite closely after them, and at other times some fifty feet below, there is usually found a hard crust, containing certain straight cigar-shaped fossils, called *belemnites*, and also an oyster (Exogyra) with a twisted or curved beak, which do not occur in any higher stratigraphical position.

Sixth—The Lindenwold Horizon.—A few wells have been developed in this horizon, which is within the Bryozoan limesands next above the Middle Marl bed. We do not yet know how extensive it may be. We designate it the *Lindenwold horizon*, since there are quite a number of wells drawing from it at that place and within a few miles thereof.

Seventh—The 950-foot Atlantic City Horizon.—This horizon may be regarded as one not yet thoroughly defined. The only wells so far known that can draw from it are one each at Winslow and Berkeley, and one to the 950-foot horizon at Atlantic City. The last well is the same that, through misinformation, was erroneously stated in the report for 1889 to have a depth of 1,100 feet. We designate this the *950-foot Atlantic City horizon.* This horizon is *probably* at the base of the Miocene and top of the Eocene beds.

Eighth—The 800-foot Atlantic City Horizon.—About 150 feet higher than the preceding one, and about 125 feet below the base of the great 300 to 400-foot diatom bed. This we designate as the *800-foot Atlantic City horizon.*

Ninth—The 700-foot Atlantic City Horizon.—About 100 feet or more higher than the fifth, and a little below the base of the great diatom bed. This we designate as the *700-foot Atlantic City horizon.*

The finding of diatomaceous clays in the boring of any well in southern New Jersey is positive evidence that sooner or later, as the drilling proceeds, one or both of the two horizons last named will be found. Unfortunately, diatoms can only be seen with a microscope, and they are therefore not so convenient an indication of their underlying water horizons as the readily-visible shells and *belemnites* before noted are of their underlying Marlton water horizon.

Minor horizons yielding much less water than those above listed occur above the ninth or 700-foot Atlantic City horizon, four of which, in Miocene strata, were noted in the annual report for 1894, page 155. Particularity, however, as to all these minor horizons is for the present year omitted.

Of the water horizons now defined, the Raritan, the Sewell, the Woodbury-Wenonah, the Cropwell, the Marlton and the Lindenwold are all in Cretaceous strata. The 950-foot Atlantic City horizon we are not yet prepared to precisely and certainly locate in the geological column, but the 800 and the 700-foot Atlantic City horizons have been clearly demonstrated to be within Miocene strata.

Passing along the coast northward from Barnegat some of the upper of these horizons would not be met with at all points, but southward from Barnegat if a well were drilled anywhere sufficiently deep it would probably find all of them, unless perhaps a few of the thinner ones which have as yet only been developed in the central and western side of the coastal plain, might not continue as open sands so far seaward. Below we re-name these horizons in the reverse order of that followed in the preceding description, or, in other words, we now name them from the top downwards. We also note, where known, the approximate interval in feet from the top of one horizon to the top of the next.

WATER HORIZONS IN STRATIGRAPHICAL ORDER, COMMENCING AT THE TOP.

700-foot Atlantic City horizon.		Miocene.
	Interval about 100 feet.	
800-foot Atlantic City horizon.		
	Interval about 150 feet.	
950-foot Atlantic City horizon.		Age?
	Interval not yet known.	
Lindenwold horizon.		Cretaceous.
	Interval about 50 feet.	
Marlton horizon.		
	Interval about 115 feet.	
Cropwell horizon.		
	Interval 125 to 150 feet.	
Woodbury-Wenonah horizon.		
	Interval about 70 feet.	
Sewell horizon.		
	Interval not yet determined	
Raritan horizons. A group.		

We now classify and refer to their appropriate water horizons a considerable number of Cretaceous wells whose records either appear in this report or have appeared in previous annual reports.

LISTS OF WELLS IN THE SOUTHERN PART OF SOUTHERN NEW JERSEY TO THE VARIOUS CRETACEOUS HORIZONS.

Wells to the Lindenwold Horizon.

Laurel Springs.
Gibbsboro.
Lindenwold, several wells.
Jenning's Mills.
Alloway (probably).
Harrisonville, Jos. Cheeseman's.

Wells to the Marlton Water Horizon.

Magnolia, north of.
Locust Grove, School-house.
" " Ellwood Evans.
Marlton, C B. Chew.
" Samuel Lippincott.
" Henry Brick.
" Amos Wills. Well No. 1.
Mullica Hill, Thomas Borton.
Marlton, Samuel J. Eves.
" S. C. Gardiner (near Milford).
Barnsboro, 110-foot horizon.
Marlton, J. W. Barr.
Kirkwood, Stratford House.
Sewell, 72-foot horizon.
Marlton, Josiah Ballenger.
Medford, I. W. Stokes, Reeves' Station. 70-foot horizon.
Vincentown, Jos. A. Jones.
Marlton, Benjamin Cooper.
Marlton, Amos Evans.
" Wm. B. Cooper.
" Thomas C. Hammitt.
" Wm. J. Evans.
" Bowman S. Lippincott.
" Levi T. Ballenger.
" Joseph Evans.
" Jacob L. Evans.
" A. W. Lofland.
Middletown, Del., 88-foot horizon.
Woodstown.
Salem.
Medford, Joshua S. Wills.
" Joseph Hinchman.
Pitman Grove.
Buddtown.
Clementon, unsuccessful well, abandoned about 30 feet above this horizon.
Daretown.

Wells to the Cropwell Water Horizon.

Cropwell.
Smithville.
Marlton, H. B. Dunphey.
" T. R. Wills & Co. Well No. 2.
" "Town Well" (Water Works Well).
Reeves Station, 183 feet—Isaac W. Stokes, Medford.
Middletown, Del. (Horizon at 204 feet. ?)
Glassboro. (Horizon at 395 to 405 feet. ?)

Wells to the Woodbury-Wenonah Horizon.

Woodbury, D. Cooper.
Mount Ephraim.
Paulsboro, W. Mills.
Woodbury, Well No. 1 at creek.
" Skating Rink.
" C. C. Green's farm.
" L. M. Green's residence.
Woodbury, C. C. Green's residence.
" Glassworks.
" Tollgate, south of.
Mantua.
Wenonah Water Works.
Auburn.
Harrisonville, George Horner's.

Wells to the Sewell Horizon.

Maple Shade, 130 feet.
Gloucester, 85 to 113 feet.
Moorestown, 136 feet.
Mickleton.
Magnolia.
Mount Laurel.
Wenonah Hotel.
Sewell.
Woodstown test-boring 339 feet (?), possibly however, this may be the Wenonah horizon.

Wells in the Raritan Group.

Philadelphia, southern part. Numerous wells.
Delair.
Cramer Hill.
Morris Station, ninety-eight wells for Camden Water Works Supply.
Pavonia, several wells.
Camden, numerous wells.
Burlington, several wells.
Billingsport.
Jordantown.
Maple Shade, 190 to 205 feet.
Gloucester, 169 feet.
Collingswood.
Colestown, 251 feet.
Moorestown, 212 to 250 feet.
Mount Holly.
Jobstown.
Yardville.
Middletown, Del., either 475 to 495 feet, or 517 to 534 feet.
Woodstown, test-boring 776 feet.
Reedy Island.

DETAILED RECORDS OF WELLS.

We now present detailed reports of the wells in New Jersey of which data have been collected during the year. These are classified in the following order:

I.

Sec. 1. Wells in Miocene strata.
Sec. 2a. Wells in the northern part of the Cretaceous belt.
Sec. 2b. Wells in the southern part of the Cretaceous belt.

II.

Wells in Red Sandstone, Gneiss, &c.

Sec. 1. Wells reported by P. H. & J. Conlan.
Sec. 2. Wells reported by W. R. Osborne.
Sec. 3. Wells reported by Stotthoff Bros.
Sec. 4. Wells communicated by George E. Jenkins and others.

I.

Sec. 1. Wells in Miocene Strata.

TWO ARTESIAN WELLS AT EGG HARBOR CITY.

Elevation, 50 feet; diameter of each, 6 inches; depths, 369 and 371 feet. Water rises in one of the wells to the surface and overflows at high tide.

Early in the year two wells were bored by Kisner & Bennett, at Egg Harbor City, to supply that place with water. The contractors courteously saved and furnished specimens of the borings, from which we make the following record. This well passes through the lower 146 feet of the great 300-foot diatomaceous clay bed of the Atlantic coastal plain, and obtained water in brownish and gray sands immediately beneath. There is a slight difference in the elevation of the two wells, say two feet. From the lowest one, at high tide, the water flowed over the surface:

Swamp muck from surface		to 7 feet.		
Yellow sand, *some water* at 75 feet	7 feet	" 87 "		
Yellow sandy clay	87 "	" 124 "		
Gray sandy clay	124 "	" 146 "		?
Yellowish sandy clay	146 "	" 164 "		
Dark clayey sand	164 "	" 183 "	Diatomaceous.	Miocene.
Dark clayey sand	183 "	" 199 "		
Dark sand with a little clay	199 "	" 216 "		
Dark sand and clay	216 "	" 234 "		
Clayey sand, slightly yellow	234 "	" 251 "		
Dark sandy clay	251 "	" 270 "		
Sandy clay, lighter shade	270 "	" 290 "		
Sand and clay with *coniferous wood*	290 "	" 310 "		
Sand, brownish	310 "	" 328 "		
Sand, gray	328 "	" 346 "		
Sand, gray, *water*	346 "	" 371 "		

Every specimen from the depth of 164 feet to that of 310 feet, when examined under the microscope, showed sponge spicules and diatoms; among the latter were the characteristic specific forms only occurring in the Chesapeake Miocene clays of the Atlantic coast deposits. We, however, regard all the beds below the depth of 124 feet as of Miocene age.

ARTESIAN WELL AT ATLANTIC CITY, AT THE GARDEN HOUSE.

Elevation, 10 feet; diameter, 6 inches; depth, 847 feet.

Late in the year 1896, Uriah White finished the boring of a well at the Garden House. An 8-inch casing was sunk to the depth of 408 feet, or to just within the top of the great diatomaceous clay bed, and a 6-inch casing the rest of the depth, except the last 50 feet, which was occupied by that length of strainer. The salient features of this boring are briefly as follows:

To the top of the great diatom bed	400 feet.
Clay	400 feet to 540 "
Sand, *water-bearing*	540 " " 550 "
Clay	550 " " 560 "
Sand	560 " " 562 "
Clay	562 " " 696 "
Clay, brownish	696 " " 775 "
Brownish sand, with *abundance of water*	775 " " 847 "

It should be noted that at the depth of about 100 feet there occurred a bed of *coarse white sand and heavy gravel about twenty feet thick.*

The water horizon reached is that which we have designated as the 800-foot Atlantic City water horizon, that being proved to be the average or approximate depth to its top along the *beach fronts* from Brigantine to Ocean City. The depth thereto, north of Brigantine, becomes gradually less, and south of Ocean City gradually somewhat greater, while at Atlantic City, back on the meadows, it is also somewhat less.

ARTESIAN WELL AT ATLANTIC CITY, AT THE WINDSOR HOUSE.

Elevation, 10 feet; diameter, 6 inches; depth, 835 feet.

With the close of the year, Uriah White informs us that he has completed the boring of a well at the Windsor House, with a depth of 835 feet. This horizon is the same as that supplying the well at the Garden House, as noted in the preceding record, and also the wells at the Dennis, the St. Charles, the Rudolph, the Haddon and the Brighton Hotels, as reported last year and the previous year.

ARTESIAN WELL AT VENTNOR, SOUTH OF ATLANTIC CITY.

Depth attained, 813 feet, but the well not yet completed.

As we conclude this report, Uriah White informs us that he is boring a well at Ventnor, south of Atlantic City, and has reached a depth of 813 feet with the drill, but had not yet driven the casing so far or finished the well. As, however, the 800-foot water horizon had been opened, the well would probably not be prospected farther. Particulars respecting this well will be deferred for next year.

I.

Sec. 2a Wells in the Northern Part of the Cretaceous Belt.

ARTESIAN WELL AT SPRING LAKE.

Elevation, 10 feet; depth, 730 feet. Water rises within — feet of the surface.

Kisner & Bennett inform that they have bored a well at Spring Lake, for Dr. Krout, to the depth of 730 feet. This well is finished with a 60-foot strainer, so as to draw water from the interval between the depths of 670 and 730 feet.

ARTESIAN WELL AT POPLAR.

Elevation, 50 feet; depth, 520 feet. Water rises to within 30 feet of the surface.

During the year 1896, a well was put down by Uriah White, at Poplar, on the Williams farm, near the Eden Wooley farm. The well has a depth of 520 feet, and is said to be "a very good well." The water rises to within 30 feet of the surface. This well reaches the 525-foot Asbury Park water horizon, which is probably the same as has been named the Marlton horizon in the section from the Delaware river to the ocean. (See page 217.)

THREE ARTESIAN WELLS AT BELMAR, AT THE WATER WORKS PLANT.

Elevation, 15 feet; depth of each, 640 feet.

Kisner & Bennett have bored three wells at the water works plant at Belmar, the location being west of the railroad, and a short distance south of the station. Each well has a depth of 640 feet, and each is finished at the bottom with a strainer 60 feet in length, thus drawing water from the interval between 580 and 640 feet. This water horizon is the equivalent of that at the depth of 525 feet at Asbury Park.

ARTESIAN WELL ONE MILE WEST OF BELMAR STATION.

Elevation, 10 feet; depth, 445 feet.

Kisner & Bennett have sunk a well for Mrs. Hannah Truax on the south side of Shark river, about one mile west of the railroad station, at Belmar. This well has a depth of 445 feet, which corresponds stratigraphically with a depth of 480 feet on the beach front. It taps the first Cretaceous water horizon of this region, the equivalent of the 400-foot horizon at Asbury Park.

THREE ARTESIAN WELLS AT ALLENHURST, AT ALLENHURST WATER WORKS.

Wells overflow 9 months in the year. Do not overflow in the summer when the wells at Asbury Park are being heavily pumped.

No. 1	Elevation, 10 feet;	diameter, 4½ inches;	depth, 548 feet.
No. 2	" 10 "	" 4½ "	" 545 "
No. 3	" 10 "	" 4½ "	" 530 "

From Bartine Green, engineer of the water works plant at Allenhurst, on the north side of Deal lake, we have been furnished with the above data respecting wells put down by Uriah White at that point in 1896, and which have not been previously noted.

These wells draw from the 525 to 550-foot Asbury Park water horizon.

ARTESIAN WELL AT LOCH ARBOR.

Elevation, 10 feet; depth, 562 feet.

Uriah White informs of a well with a depth of 562 feet at Loch Arbor. The water horizon is the equivalent of the 525 to 550-foot horizon at Asbury Park, *i. e.*, the Marlton horizon.

TWO WELLS AT DARLINGTON STATION (DEAL BEACH).

Elevation, 20 feet; depth of each, 500 feet.

We are informed that a 6-inch well was drilled near Darlington (formerly Deal Beach) station, on the east of the railroad, by Uriah White, in the year 1895, to the depth of 500 feet, and a 4½-inch well west of the railroad to the same depth (500 feet).

These wells draw from the same horizon as the Allenhurst wells just above noted, viz., from the 525-foot Asbury Park horizon.

WELL AT DARLINGTON, NEAR THE BEACH.

Elevation, 20 feet; depth, 525 feet.

We learn that a well has been put down nearer the beach at Darlington, to the depth of 525 feet, the water horizon reached being the 525-foot horizon at Asbury Park. The well was drilled by Uriah White.

ARTESIAN WELL ONE-HALF MILE WEST OF LITTLE SILVER STATION.

Elevation, 30 feet; drilled to the depth of 310 feet; finished to draw water from between the depths of 180 and 230 feet. Water rises within 8 feet of the surface.

Through the courtesy of Uriah White, we have been furnished with a full series of the borings of a well put down by him about one-half mile west of the railroad station, at Little Silver.

The well was bored to the depth of 310 feet, where something hard, supposed to be rock, was encountered. It was afterward finished with a depth of 230 feet, and draws water from the sands occurring between the depths of 180 and 230 feet. This water horizon is the equivalent of the first, or 400-foot horizon at Asbury Park.

From an examination of the specimens, we present the following, each separate specimen being noted:

Surface deposits		14 feet.		
Greenish yellow clay and sand	14 feet to	20 "		
Greenish yellow sand and clay	20 " "	40 "	Red sand bed.	Cretaceous.
Greenish yellow sand	40 " "	60 "		
Greenish gray sand.	60 " "	80 "		
Greenish gray sand	80 " "	100 "		
Greensand marl	100 " "	120 "	Lower marl bed.	
Greensand marl	120 " "	140 "		
Greenish sand	140 " "	163 "	Matawan clay marls.	
Greenish sand	163 " "	180 "		
Fine gray sand, with water.	180 " "	197 "		
Fine gray sand, slightly darker.	197 " "	216 "		
Black micaceous clayey sand	216 " "	225 "		
Gray sand	225 " "	251 "		
Dark pure clay streak at		251 "		
Sandy clay, dark.	251 " "	271 "		
Dark clayey sand	271 " "	290 "		
Gray sand.	290 " "	310 "		

THREE ARTESIAN WELLS AT RED BANK.

One well, depth, 197 feet; one well, diameter, 4 inches; depth, 209 feet; one well, depth, 214 feet. Elevation of each, about 30 feet.
Water rises to within 8 feet of the surface.

Kisner & Bennett inform us of three wells at Red Bank, with depths as noted above. The one with the depth of 214 feet was put down by them for the railroad company, and is located near the station. They state that the water rises therein to within 8 feet of the surface under natural conditions; that is, when wells adjacent are not pumped. The water is said to be of good quality. The horizon is the equivalent of that at the depth of 640 feet at Belmar, or 525 to 550 feet at Asbury Park.

ARTESIAN WELL OPPOSITE RED BANK, ON THE NORTH BANK OF THE NAVESINK RIVER.

Elevation about 17 feet; diameter, 3 inches; depth, 217 feet.
Water rises within 14 feet of the surface.

Matthews Bros. write: "In 1895 we drilled a 3-inch well for Sheriff Patterson, whose cottage is situated on the north bank of the Shrewsbury river, directly opposite Red Bank, N. J. The elevation above tide-level is about 17 feet. The depth of the well is 217 feet, and the water arose to within 14 feet of the surface, and the supply of water large and good.

"The strata passed through were:

" Brown sand	9 feet	= 9 feet.
White sand	2 "	= 11 "
Marl	27 "	= 38 "
Pebbles and sand	6 "	= 44 "
Clay and sand	40 "	= 84 "
Dark-colored sand	48 "	= 132 "
Black marl	43 "	= 175 "
Sand and wood, *water-bearing stratum*	42 "	= 217 " "

This horizon is the equivalent of that at 525 to 550 feet at Asbury Park.

ARTESIAN WELL AT BROOKDALE.

Elevation, 28 feet; diameter, 4½ inches; depth, 712 feet. Water rises within 18 feet of the surface. Pumping capacity, 174 gallons per minute.

Matthews Bros. write: "In 1896 we drilled a 4½-inch well for Mr. William Thompson, owner of Brookdale Stock Farm, southwest of Red Bank, Monmouth county. The elevation is about 28 feet above tide-level. The depth of this well is 712 feet. The water rises to within 18 feet of the surface.

"The strata passed through were:

"Sand	3 feet	= 3 feet.	
Clay	5 "	= 8 "	
Brown sand	5 "	= 13 "	Lower marl.
Marl	17 "	= 30 "	
Pebbles and sand	9 "	= 39 "	
Clay and sand	40 "	= 79 "	?
Dark-colored sand	52 "	= 131 "	
Black marl	49 "	= 180 "	
Black marl rock	14 "	= 194 "	
Sand, *water-bearing*, but supply not sufficient	22 "	= 216 "	
Clay and greensand	73 "	= 289 "	
Sticky clay	35 "	= 324 "	Matawan clay marls.
Black sand	64 "	= 388 "	
Quicksand	14 "	= 402 "	
Marl and clay	64 "	= 466 "	
Rock	6 "	= 472 "	
Cemented shells	9 "	= 481 "	
Greensand and clay	32 "	= 513 "	
Brown sand and wood	87 "	= 600 "	?
Blue clay	44 "	= 644 "	
White sand, *water-bearing*	68 "	= 712 "	Raritan. (?)

"We could pump from this well 174 gallons per minute."

Notes furnished us in connection with an analysis of this water state that it contains "very little organic matter" and is "in every way suitable for drinking and household purposes."

The water horizon opened by this well is *probably* the equivalent of that at 690 to 740 feet at Barren Island, Jamaica Bay, L. I., N. Y., as noted in last year's report. It is also probably the same as that at the depth of 540 to 575 feet at a point about three miles to the westward and near Holmdel, as was also noted in last year's report.

The horizon at the depth of 465 feet at the base of the bluff at Matawan (see page 465) is also probably identical with that developed by this well.

The records of this well and of those at Holmdel * and Asbury Park † [1,321-foot well] are especially interesting, since they indicate that the Matawan or Clay Marl formation increases notably in thickness as it dips southeastwardly beneath the coastal plain and toward the ocean from its outcrop along and near the boundary line between Middlesex and Monmouth counties.

ARTESIAN WELL AT SHREWSBURY, N. J.

Elevation, 26 feet; diameter, 6 inches; depth, 264 feet.

This well was put down by Matthews Bros., who write as follows: "In 1897 we drilled a 6-inch well for Mr. W. P. Brown, at his summer residence at Shrewsbury, N. J. The elevation is about 26 feet above tide-level. The depth of the well is 264 feet.

"The strata were:

"Red clay	7 feet	=	7	feet.
Sticky blue clay.	4 "	=	11	"
Red clay and iron ore	14 "	=	25	"
Brown sand	5 "	=	30	"
Red clay and iron ore	12 "	=	42	"
Marl	16 "	=	58	"
Dark sand	81 "	=	139	"
White clay	15 "	=	154	"
Black marl	42 "	=	196	"
White sand (*water-bearing stratum*)	68 "	=	264	" "

ARTESIAN WELL ON THE NAVESINK RIVER, BETWEEN FAIRHAVEN AND OCEANIC.

Elevation about 24 feet; diameter, 3 inches; depth, 214 feet.
Water rises to within 22 feet of the surface.

Matthews Bros. report as follows: "Later in 1895 we drilled a 3-inch well for Mr. John J. Gillicks. Cottage situated on the south bank of the North Shrewsbury river, between Fairhaven and Oceanic,

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* Annual Report 1896, page 147.

† Annual Report 1895, page 72.

N. J. The elevation above tide-level is about 24 feet. The depth of the well was 214 feet, and the water arose to within 22 feet of the surface.

"The strata passed through were:

"Clay	4 feet	=	4 feet.
Brown sand	16 "	=	20 "
Heavy gravel	4 "	=	24 "
Sand and clay	24 "	=	48 "
Marl	41 "	=	89 "
Shells	4 "	=	93 "
Pebbles of different colors	7 "	=	100 "
Dark-colored sand	36 "	=	136 "
White clay	7 "	=	143 "
Black marl	28 "	=	171 "
White sand and wood (*water-bearing stratum*)	43 "	=	214 " "

ARTESIAN WELLS AT SEABRIGHT.

Elevation, 10 feet; depth, 240 feet; first water horizon at the depth of 70 to 90 feet; second water horizon at the depth of 175 to 240 feet.

Kisner & Bennett inform us of three or four wells that have been put down in past years at Seabright to the depth of 240 feet, finding a water-bearing sand between the interval of 175 and 240 feet. This represents the second Cretaceous water horizon, occurring at Belmar, or that at the depth of 600 to 640 feet. In drilling, a higher horizon was passed between the depths of 70 and 90 feet, which horizon is the equivalent of the first horizon at Belmar, the top of which is found there at the depth of 475 feet. This horizon rises above sea-level before reaching Atlantic Highlands, and consequently is not found at the latter place. The higher of these horizons is the equivalent of the 400-foot horizon at Asbury Park, and the lower of them equals that at 525 to 575 feet at Asbury Park.

TWO ARTESIAN WELLS AT SEABRIGHT AT THE "HOTEL PANACCI."

Elevation, 4 feet; diameter of each, 4½ inches.
Well No. 1, depth, 272 feet; yield, 84 gallons a minute.
Well No. 2, depth, 286 feet; yield, 294 gallons a minute.

These wells were bored in 1897 by Matthews Bros., who write: "We have drilled two 4½-inch wells for Mr. Edward Panacci, of the 'Hotel Panacci,' Seabright, N. J. The elevation is about 4 feet above tide-level. The depths of the wells were, first, 272 feet, and second, 286 feet. The first well yielded 84 gallons per minute; the second well yielded the enormous supply of 294 gallons per minute. This second well was considered the most successful of any along the coast.

"The strata penetrated were:

"Coal and beach sand (made ground)	3 feet	= 3 feet.
Beach sand	40 "	= 43 "
Marl	43 "	= 86 "
Cemented shells	4 "	= 90 "
Colored pebbles	6 "	= 96 "
Dark-colored sand	76 "	= 172 "
White clay	17 "	= 189 "
Black marl	44 "	= 233 "
White sand and wood (*water-bearing*), first well	39 "	= 272 "
White sand and wood (*water-bearing*), second well	53 "	= 286 " "

ARTESIAN WELL ONE-QUARTER MILE WEST OF SEABRIGHT.

Elevation, 14 feet; diameter, 3 inches; depth, 297 feet. Water rises within 12 feet of the surface. Pumped 71 gallons per minute.

Matthews Bros. inform as follows:

"In 1897 we drilled a 3-inch well for Mrs. Hadden, whose summer residence is on the Rumson road, one-quarter mile west of Seabright, N. J. The elevation is about 14 feet above tide-level. The depth of the well is 297 feet, and the water rises to within 12 feet of the surface. A supply of 71 gallons per minute was obtained from this well.

"The strata drilled were:

"Sand	4 feet	= 4 feet.
Clay and brown sand	1 "	= 5 "
Black sand and clay	11 "	= 16 "
Marl	39 "	= 55 "
Cemented shells	41 "	= 96 "
Colored pebbles	3 "	= 99 "
Dark-colored sand	77 "	= 176 "
White clay	15 "	= 191 "
Marl	40 "	= 231 "
White sand and wood (*water-bearing stratum*)	68 "	= 297 " "

ARTESIAN WELL ONE MILE FROM SEABRIGHT, ON RUMSON ROAD.

Elevation, 14 feet; diameter, 4½ inches; depth, 393 feet. Water rises within 12 feet of the surface; yields 103 gallons per minute.

This well was put down by Matthews Bros., who write as follows:

"In 1897 we drilled a 4½-inch well for Mrs. Dermott. Location near the Rumson road, about one mile from Seabright. The elevation above tide-level is about 14 feet. The depth of the well is 393 feet. The water rises to within 12 feet of the surface, and the well yields 103 gallons per minute.

"The strata were:

"Heavy sand	3 feet	= 3 feet.
Clay	4 "	= 7 "
Brown sand	14 "	= 21 "
Black sand	36 "	= 57 "
Marl	42 "	= 99 "
Cemented shells	5 "	= 104 "
Colored pebbles	4 "	= 108 "
Dark sand	73 "	= "
White clay	15 "	= 196 "
Black marl	47 "	= 243 "
White sand and wood (*water-bearing*)	79 "	= 322 "
Blue clay	18 "	= 340 "
White sand and wood (*water-bearing*)	53 "	= 393 " "

ARTESIAN WELL ONE-HALF MILE WEST OF SEABRIGHT, NEAR THE RUMSON ROAD.

Elevation, about tide-level; diameter, 3 inches; depth, 292 feet.

Matthews Bros. write: "In 1895 we drilled 3-inch well for Mr. Palmer, cottage situated near the Rumson road, one-half mile west of Seabright. The elevation of ground above tide-level is about 14 feet. The depth of the well is 292 feet.

"The strata passed through were:

"Sand	4 feet	= 4 feet.
Clay	1 "	= 5 "
Brown sand	10 "	= 15 "
Black sand	31 "	= 46 "
Marl	46 "	= 92 "
Shells, cemented	4 "	= 96 "
Pebbles, different colored	2 "	= 98 "
Dark-colored sand	66 "	= 164 "
White clay	19 "	= 183 "
Black marl	47 "	= 230 "
White sand and wood (*water-bearing*)	62 "	= 292 " "

ARTESIAN WELL ON RUMSON BLUFF.

Elevation, 12 feet; diameter, 3 inches; depth, 367 feet.

Matthews Bros. write: "In 1895 we drilled a 3-inch well for Mrs. Ralli, cottage situated on the Rumson Bluff, about 12 feet above tide-level. The well is 367 feet deep, and the water rises to within 9 feet of the surface.

"The strata passed through were:

"Sand	2 feet	=	2 feet.
Clay	3 "	=	5 "
Brown sand	9 "	=	14 "
Black sand	30 "	=	44 "
Marl	40 "	=	84 "
Shells	6 "	=	90 "
Pebbles, different colors	3 "	=	93 "
Dark-colored sand	68 "	=	161 "
White clay	23 "	=	184 "
Marl	45 "	=	229 "
White sand	74 "	=	303 "
Blue clay	16 "	=	319 "
White sand and wood (*water-bearing*)	48 "	=	367 " "

ARTESIAN WELL NEAR SEABRIGHT, ON THE RUMSON ROAD.

Elevation, 1 foot; diameter, 3 inches; depth, 274 feet; natural flow, 18 gallons per minute.

Matthews Bros. write:

"In 1895 we drilled a 3-inch well for Mr. John Bryan, whose cottage is situated along the Rumson road, near Seabright, N. J. The well has a natural flow of 18 gallons per minute, and is 274 feet deep.

"The strata penetrated were:

"Sand	2 feet	=	2 feet.
Clay	3 "	=	5 "
Black sand	30 "	=	35 "
Marl	43 "	=	78 "
Shells	4 "	=	82 "
Pebbles, different colors	2 "	=	84 "
Dark-colored sand	74 "	=	158 "
White clay	24 "	=	182 "
Marl	47 "	=	229 "
White sand and wood (*water-bearing stratum*)	45 "	=	274 " "

ARTESIAN WELL TWO MILES WEST OF SEABRIGHT, ON RUMSON ROAD.

Elevation between 40 and 60 feet; diameter, 3 inches; depth, 396 feet.

Matthews Bros. also write:

"Later in 1895 we drilled a 3-inch well for Mrs. Gen. C. B. Fiske, whose cottage is situated on an elevation along the Rumson road, about two miles west of Seabright, N. J. The elevation above tide-level is between 40 and 60 feet. The depth of the well was 396 feet, and in drilling this well we penetrated an *exceptionally-thick* marl stratum.

"The strata passed through were:

"Sand	2 feet	= 2 feet.
Clay	8 "	= 10 "
Red sand	45 "	= 55 "
Fine brown sand	7 "	= 62 "
Coarse sand	47 "	= 109 "
Sticky marl	96 "	= 205 "
White clay	24 "	= 229 "
Black marl	112 "	= 341 "
White sand (*water-bearing stratum*)	55 "	= 396 " "

ARTESIAN WELL ONE-HALF MILE WEST OF SEABRIGHT, ON THE RUMSON ROAD.

Elevation, 5 feet; diameter, 4½ inches; depth, 347 feet. Water rises within 1 foot of the surface.

Matthews Bros. report:

"In 1897 we drilled a 4½-inch well for Mr. E. G. Woerz; location is on the Rumson road, one-half mile west of Seabright. The elevation above tide-level is about 5 feet. The depth is 347 feet. The water rises in the well to within 1 foot of the surface.

"The strata were:

"Brown sand	20 feet	= 20 feet.
Black sand	37 "	= 57 "
Marl	44 "	= 101 "
Cemented shells	4 "	= 105 "
Colored pebbles	5 "	= 110 "
Dark sand	71 "	= 181 "
White clay	16 "	= 197 "
Black marl	37 "	= 234 "
White sand and wood (*water-bearing*)	58 "	= 292 "
Blue clay	15 "	= 307 "
White sand and wood (*water-bearing*)	40 "	= 347 " "

ARTESIAN WELL AT BLACK POINT, OPPOSITE ROCKY POINT, NAVESINK HIGHLANDS.

Elevation, 17 feet; diameter, 4½ inches; depth, 279 feet.
Water rises within 15 feet of the surface.

This well was put down by Matthews Bros., who write:

“In 1897 we drilled a 4½-inch well for Mr. R. Romaine; location, Black Point, opposite Rocky Point of the Highlands, N. J. The elevation above tide-level is about 17 feet. The depth of the well is 279 feet, and the water rises to within 15 feet of the surface.

“The strata were:

“Made ground	9 feet	= 9 feet.
Sand	3 “	= 12 “
Clay	2 “	= 14 “
Brown sand	7 “	= 21 “
Black sand and clay	37 “	= 58 “
Marl	41 “	= 99 “
Cemented shells	6 “	= 105 “
Colored pebbles	3 “	= 108 “
Dark sand	74 “	= 182 “
White clay	15 “	= 197 “
Black marl	44 “	= 241 “
White sand and wood (*water-bearing*)	38 “	= 279 “ ”

ARTESIAN WELL NEAR BLACK POINT, ABOUT ONE MILE WEST OF SEABRIGHT.

Elevation, 12 feet; diameter, 3 inches; depth, 296 feet. Water rises within 9 feet of the surface. Yield, 54 gallons a minute.

Matthews Bros. state: “In 1897 we drilled a 3-inch well for Dr. Kimball; location near Black Point, about 1 mile west of Seabright. The elevation above tide-level is about 12 feet. The depth of the well is 296 feet, and the water rises to within 9 feet of the surface. The yield of this well was 54 gallons per minute. The strata were:

“Sand	3 feet	= 3 feet.
Clay	2 “	= 5 “
Brown sand	9 “	= 14 “
Black sand and clay	40 “	= 54 “
Marl	39 “	= 93 “
Cemented shells	6 “	= 99 “
Colored pebbles	4 “	= 103 “
Dark sand	76 “	= 179 “
White clay	17 “	= 196 “
Black marl	40 “	= 236 “
Black marl *rock*	4 “	= 240 “
White sand and wood (*water-bearing stratum*)	56 “	= 296 “ ”

ARTESIAN WELL ON RUMSON'S NECK, OPPOSITE SEABRIGHT.

Elevation, 4 feet; diameter; 4½ inches; depth, 267 feet.
Natural flow, 23 gallons per minute.

This well was put down in 1897 by Matthews Bros., who write: "We drilled a 4½-inch well for Mr. George O. Waterman. Cottage situated on the Rumson Neck, on the opposite side of the river from Seabright. The elevation above tide-level is about 4 feet. The depth of the well is 267 feet, and it has a natural flow of 23 gallons per minute.

"The strata penetrated were:

"Red clay, partly made ground	17 feet	= 17 feet.
Black sand	24 "	= 41 "
Marl	47 "	= 88 "
Cemented shells.	7 "	= 95 "
Different-colored pebbles	5 "	= 100 "
Dark-colored sand	69 "	= 169 "
White clay	17 "	= 186 "
Black marl	41 "	= 227 "
White sand and wood (*water-bearing*)	40 "	= 267 " "

ARTESIAN WELL ON RUMSON'S NECK.

Elevation, 7 feet; diameter, 3 inches; depth, 277 feet. Water rises within 6 inches of the surface

This well was put down by Matthews Bros., who write as follows: "In 1897 we drilled a 3-inch well for Mrs. Kellogg; location, Rumson's Neck. Elevation is about 7 feet above tide-level. The depth of this well is 277 feet, and the water rises to within 6 inches of the top of the well.

"The strata penetrated were:

"Clay	4 feet	= 4 feet.
Black sand	47 "	= 51 "
Marl	46 "	= 97 "
Cemented shells	3 "	= 100 "
Pebbles, colors	4 "	= 104 "
Dark-colored sand	72 "	= 176 "
White clay	14 "	= 190 "
Black marl	46 "	= 236 "
White sand (*water-bearing*)	41 "	= 277 " "

ARTESIAN WELL ON RUMSON'S NECK.

Elevation, 4 feet; diameter, 3 inches; depth, 284 feet; natural flow, 26 gallons per minute; pumping yield, 73 gallons per minute.

Matthews Bros. write: "In 1897 we drilled a 3-inch well for Mr. Minugh; location, Rumson's Neck, about 4 feet above tide-level. The depth of the well is 284 feet, and it has a natural flow of 26 gallons per minute, and yields 73 gallons per minute when pumped.

"The strata penetrated were:

"Clay	4 feet	= 4 feet.
Black sand	49 "	= 53 "
Marl	46 "	= 99 "
Cemented shells	4 "	= 103 "
Different-colored pebbles	3 "	= 106 "
Dark-colored sand	74 "	= 180 "
White clay	16 "	= 196 "
Black marl	45 "	= 241 "
White sand and wood (*water-bearing*)	43 "	= 284 " "

ARTESIAN WELL ON RUMSON'S NECK.

Elevation, 3 feet; diameter, 3 inches; depth, 284 feet; natural flow, 32 gallons per minute; pumping capacity, 93 gallons per minute.

Matthews Bros. write: "In 1897 we drilled a 3-inch well for Mr. Peter White; location, Rumson's Neck, and the elevation is about 3 feet above tide-level. The depth of this well is 284 feet, and it has a natural flow of 32 gallons per minute, and when pumped 93 gallons per minute was obtained.

"The strata penetrated were:

"Clay	5 feet	= 5 feet.
Black sand	47 "	= 52 "
Marl	44 "	= 96 "
Cemented shells	5 "	= 101 "
Different-colored pebbles	3 "	= 104 "
Dark sand	73 "	= 177 "
White clay	16 "	= 193 "
Black marl	45 "	= 238 "
White sand and wood (*water-bearing*)	46 "	= 284 " "

ARTESIAN WELL ON RUMSON'S NECK, NEAR THE SHREWSBURY RIVER.

Elevation, 4 feet; diameter, 3 inches; depth, 369 feet.
Natural flow, 65 gallons per minute.

From Matthews Bros. we have received the following: "In 1895 we drilled a 3-inch well for Mr. Strong, whose cottage is situated on the Rumson Neck, near the Shrewsbury river. The depth of the well is 369 feet, and has a natural flow of 65 gallons per minute.

"The strata passed through were:

" Black sand	48 feet	= 48 feet.
Marl	42 "	= 90 "
Shells	5 "	= 95 "
Pebbles	4 "	= 99 "
Dark-colored sand	63 "	= 162 "
White clay	17 "	= 179 "
Black marl	44 "	= 223 "
White sand and wood (*water-bearing*)	72 "	= 295 "
Blue clay	17 "	= 312 "
White sand and wood (*water-bearing*)	57 "	= 369 " "

ARTESIAN WELL ON RUMSON'S BLUFF.

Elevation, 18 feet; diameter, 3 inches; depth, 376 feet.

Matthews Bros. write as follows respecting the above: "In 1896 we drilled a 3-inch well for Mr. S. W. Alexander, whose summer residence is on the Rumson Bluff. The elevation is about 18 feet above tide-level. The depth of the well is 376 feet.

"The strata passed through were:

" Sand	6 feet	= 6 feet.
Clay	4 "	= 10 "
Brown sand	9 "	= 19. "
Black sand	34 "	= 53 "
Marl	43 "	= 96 "
Cemented shells	5 "	= 101 "
Different-colored pebbles	4 "	= 105 "
Dark-colored sand	72 "	= 177 "
White clay	19 "	= 196 "
Black marl	47 "	= 243 "
White sand and wood (*water-bearing*)	67 "	= 310 "
Blue clay	19 "	= 329 "
White sand and wood (*water-bearing*)	47 "	= 376 " "

ARTESIAN WELL ON RUMSON'S BLUFF, THREE-FOURTHS OF A MILE NORTHWEST OF SEABRIGHT.

Elevation, 12 feet; diameter, 3 inches; depth, 367 feet.
Water rises within 9 feet of the surface.

This well was put down by Matthews Bros., who state: "In 1897 we drilled a 3-inch well for Mr. Peabody, whose cottage is situated on the Rumson Bluff, three-quarters of a mile northwest of Seabright. The elevation above tide-level is about 12 feet. The depth of this well is 367 feet, and the water rises to within 9 feet of the surface.

"The strata penetrated were:

"Sand	5	feet	= 5	feet.
Clay	2	"	= 7	"
Brown sand	9	"	= 16	"
Black sand	38	"	= 54	"
Marl	43	"	= 97	"
Cemented shells	4	"	= 101	"
Colored pebbles	3	"	= 104	"
Dark sand	77	"	= 181	"
White clay	19	"	= 200	"
Black marl	42	"	= 242	"
Black marl *rock*	2	"	= 244	"
White sand and wood (*water-bearing*)	69	"	= 313	"
Blue clay	14	"	= 327	"
White sand and wood (*water-bearing*)	40	"	= 367	" "

ARTESIAN WELL ON RUMSON'S BLUFF ALONG THE SHREWSBURY RIVER.

Elevation, 29 feet; diameter, 3 inches; depth, 395 feet. Water rises within 26 feet of the surface.

Matthews Bros. write as follows respecting this well: "In 1897 we drilled a 3-inch well for Mr. John T. Fralley, cottage on the Rumson Bluff, along the Shrewsbury river, nearly opposite Seabright. The elevation above tide-level is about 29 feet. The depth of the well is 395 feet, and the water rises to within 26 feet of the surface.

"The strata penetrated were:

"Irony clay	7 feet =	7 feet.
Red sand	10 " =	17 "
Clay	3 " =	20 "
Brown sand	11 " =	31 "
Black sand	43 " =	74 "
Marl	47 " =	121 "
Cemented shells	7 " =	128 "
Colored pebbles	3 " =	131 "
Dark sand	69 " =	200 "
White clay	18 " =	218 "
Black marl	44 " =	262 "
White sand and wood (*water-bearing*)	71 " =	333 "
Blue clay	19 " =	352 "
White sand and wood (*water-bearing*)	43 " =	395 " "

ANOTHER ARTESIAN WELL ON RUMSON'S BLUFF.

Elevation, 15 feet; diameter, 3 inches; depth, 374 feet. Pumping capacity, 162 gallons per minute.

Matthews Bros. also write: "In 1895 we drilled a 3-inch well for Mr. Harriot. Cottage situated on the Rumson Bluff, about 15 feet above tide-level. The depth of the well is 374 feet. We could pump from this well, constantly, 162 gallons per minute.

"The strata penetrated were:

"Sand	8 feet =	8 feet.
Clay	4 " =	12 "
Brown sand	9 " =	21 "
Black sand	30 " =	51 "
Marl	43 " =	94 "
Shells	4 " =	98 "
Pebbles, different colors	3 " =	101 "
Dark-colored sand	65 " =	166 "
White clay	25 " =	191 "
Marl	42 " =	233 "
White sand and wood (*water-bearing*)	72 " =	305 "
Blue clay	14 " =	319 "
White sand and wood (*water-bearing stratum*)	55 " =	374 " "

ARTESIAN WELL AT OCEANIC.

Elevation, 16 feet; diameter, 6 inches; depth, 372 feet. Water rises within 12 feet of the surface. Pumping yields 210 gallons per minute.

Matthews Bros. inform that in 1897 they put down "a 6-inch well for M. C. D. Borden, of Oceanic, N. J. The elevation is about 16 feet above tide-level. The depth of the well is 372 feet, and the water rises to within 12 feet of the surface. This well yields 210 gallons per minute.

"The strata were:

"Brown sand	9 feet	= 9 feet.
White sand	8 "	= 17 "
Gravel	3 "	= 20 "
Black sand and clay	36 "	= 56 "
Marl	47 "	=103 "
Cemented shells	7 "	=110 "
Colored pebbles	3 "	=113 "
Dark sand	77 "	=190 "
White clay	17 "	=207 "
Black marl	53 "	=260 "
White sand and wood (*water-bearing*)	44 "	=304 "
Blue clay	15 "	=319 "
White sand and wood (*water-bearing stratum*)	53 "	=372 " "

ARTESIAN WELL OPPOSITE OCEANIC, ON THE NORTH BANK OF THE NAVESINK RIVER.

Elevation, 16 feet; diameter, 4½ inches; depth, 297 feet. Water rises to within 14 feet of the surface. Pumping capacity, 187 gallons per minute.

Matthews Bros. inform as follows: "In 1897 we drilled a 4½-inch well for Paul Lamarche. Cottage situated opposite Oceanic, on the north bank of the Shrewsbury river. The elevation is about 16 feet above tide-level. The depth of this well is 297 feet. The water rises to within 14 feet of the surface. We could pump from this well, continually, 187 gallons per minute.

"The strata passed through were:

"Sand	2 feet	= 2 feet.
Marl	37 "	= 39 "
Quicksand	9 "	= 48 "
Marl and sand	49 "	= 97 "
Different-colored gravel	5 "	=102 "
Dark-colored sand	64 "	=166 "
White clay	27 "	=193 "
Marl	59 "	=252 "
White sand and wood (*water-bearing*)	45 "	=297 " "

ARTESIAN WELL OPPOSITE OCEANIC, ON THE NORTH BANK OF THE NAVESINK RIVER.

Elevation, about 34 feet; diameter, 4½ inches; depth, 357 feet.
Water rises within 31 feet of the surface.

Matthews Bros. write: "In 1895 we drilled a 4½-inch well for Henry Lamarche, whose cottage is situated on the north bank of the Shrewsbury river, opposite Oceanic, N. J. The elevation above tide-level is about 34 feet. The depth of the well is 357 feet, and the water arose to within 31 feet of the surface.

"The strata drilled through were:

"Red sand	20 feet	= 20 feet.
Clay	3 "	= 23 "
Brown sand	8 "	= 31 "
Marl	33 "	= 64 "
Quicksand	7 "	= 71 "
Marl and sand	46 "	=117 "
Different-colored gravel	6 "	=123 "
Dark-colored sand	58 "	=181 "
White clay	29 "	=210 "
Black marl	57 "	=267 "
White sand and wood (*water-bearing stratum*)	90 "	=357 " "

ARTESIAN WELL OPPOSITE OCEANIC AND NEXT THE ABOVE WELL.

Elevation, about 30 feet; diameter, 3 inches; depth, 353 feet.
Water rises within 28 feet of the surface.

Matthews Bros. also write: "In 1895 we drilled a 3-inch well for Mr. John Lamarche, location next to Henry Lamarche. The depth of the well is 353 feet, and the water arose to within 28 feet of the surface. The strata penetrated were about the same as the well drilled for Mr. Henry Lamarche."

ARTESIAN WELL OPPOSITE OCEANIC, ON THE NAVESINK RIVER.

Elevation, about 80 or 90 feet; diameter, 4½ inches; depth, 365 feet.
Water rises within 80 feet of the surface.

Matthews Bros. write as follows: "In the summer of 1895 we drilled a 4½ inch well for Mr. Matthew Lamarche, whose cottage is situated on the banks of the North Shrewsbury river, opposite Oceanic,

N. J. The elevation above tide-level is about 80 or 90 feet. The water came up to within 80 feet of the surface. The depth of the well was 365 feet.

"The strata passed through were:

"Red clay	20 feet	= 20 feet.
Iron ore	2 "	= 22 "
Peanut stone	2 "	= 24 "
Red clay	20 "	= 44 "
Red sand	30 "	= 74 "
Red clay	4 "	= 78 "
Brown sand	7 "	= 85 "
Black marl	30 "	=115 "
Quicksand	10 "	=125 "
Marl and sand	40 "	=165 "
Heavy gravel, various colors	6 "	=171 "
Dark-colored sand	60 "	=231 "
White clay	26 "	=257 "
Black marl	50 "	=307 "
White sand and wood (*water-bearing stratum*)	58 "	=365 " "

TWO ARTESIAN WELLS AT NORMANDIE.

No. 1..........Elevation, 10 feet; diameter, 3 inches; depth, 200 feet.
No. 2.......... " 10 " " 4½ " " 200 "

Kisner & Bennett inform us of two wells put down at Normandie for F. P. Earl, each having a depth of 200 feet. One of these is a 3-inch well, drilled some eight years since, and the other a 4½-inch well, put down some three years since. The water is of good quality. The horizon is the equivalent of the Asbury Park 525-foot horizon.

ARTESIAN WELL AT NORMANDIE, AT THE OUTLET OF THE SHREWSBURY RIVER.

Elevation, 10 feet; depth, 200 feet.

Kisner & Bennett furnish the following generalized record of another well put down by them to the depth of 200 feet at Normandie, at the outlet of the Shrewsbury river:

Beach sand to		150 feet.
Green marl	15 feet	=165 "
White sand (*water-bearing*)	35 "	=200 "

This water-bearing sand is the equivalent of that at 525 feet at Asbury Park.

ARTESIAN WELL AT ELBERON.

Elevation, 25 feet (?); depth, 375 feet.

Kisner & Bennett state that a well has been drilled at Elberon, northwest of the railroad depot, to the depth of 375 feet to the first or 400-foot Asbury Park water horizon, viz., the one next below the marl series.

ARTESIAN WELL AT WATERWITCH, AT THE BASE OF THE HIGHLANDS OF THE NAVESINK.

Elevation, 10 feet; depth, 142 feet. Water overflows.

During the early summer a well was put down near Waterwitch station, at the base of the Highlands of the Navesink, on the beach upon the south side of Sandy Hook bay. Kisner & Bennett, who drilled the same, state that it has a depth of 142 feet, and has a 40-foot strainer at the bottom. The water horizon is the second one beneath the marls, or the 525-foot horizon of Asbury Park. The well overflows at the surface.

ARTESIAN WELLS AT ATLANTIC HIGHLANDS.

Elevation, 5 feet. Seven wells, diameter of each, 4½ inches; depth, 114 feet.
Water horizon near the top of the clay marls.
One well, diameter, 6 inches; depth, 465 feet.
Water horizon at the base of the clay marls.

Kisner & Bennett inform that they have drilled seven wells at Atlantic Highlands to the depth of 114 feet, and one well to the depth of 465 feet. These wells are situated at the base of the bluff, on the margin of Raritan bay, and are but a few feet above tide. They all overflow. The wells with a depth of 114 feet draw from the water horizon that is found at Asbury Park at the depth of 600 feet, and but a short distance below the base of the marl series, while the well that draws from the depth of 465 feet is supplied from the same horizon that furnishes the wells noted in this report at Keyport and Matawan,* viz., at the base of the clay marls and top of the plastic clays.

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*See pages 245 and 246.

ARTESIAN WELL NEAR ATLANTIC HIGHLANDS.

Elevation, about 30 feet; diameter, 6 inches; depth, 167 feet.
Water rose to within 28 feet of the surface.

Matthews Bros. inform as follows: "Late in the fall of 1895 we drilled a 6-inch well for Mr. Charles Leonard, Leonard avenue, near Atlantic Highlands, N. J. The elevation above tide-level was about 30 feet. The depth of the well was 167 feet, and yielded a good supply of water, and this well now supplies the village with plenty of water. The water arose to within 28 feet of the surface.

"The strata drilled through were:

" Red clay and peanut stone	8 feet	= 8 feet.
Red clay	12 "	= 20 "
Brown sand	4 "	= 24 "
Marl	16 "	= 40 "
Black sand	38 "	= 78 "
White clay	14 "	= 92 "
White sand and wood (*water-bearing stratum*)	75 "	=167 " "

FOUR ARTESIAN WELLS AT KEYPORT.

Elevation, 2 feet; depth of each, 214 feet. Water overflows.

From Kisner & Bennett we learn that a few years since they drilled four wells at Keyport for the water-supply of the town. These wells are located on ground only about two feet above tide and overflow. They have a depth of 214 feet, and draw from the same horizon as the wells noted at Matawan (see pages 246 and 247), *i. e.*, from sands below the clay marls and at the top of the plastic clay or Raritan beds.

ARTESIAN WELL TWO MILES EAST OF KEYPORT PIER, AT LORILLARD'S BRICKYARDS.

Elevation, 10 feet; diameter, — inches; depth, 230 feet.
Water rises within 3 feet of the surface.

This well was put down by Uriah White. It has a depth of 230 feet, and must draw from practically the same water horizon as the wells reported at Keyport and Matawan (see pages 245 and 246). It is finished with a 30-foot strainer at the bottom. There is said to have been a little sand, without much water, at the depth of 175 feet, then there was 20 feet of blue clay at 175 feet to 195 feet. The water-bearing sand above the depth of 230 feet is described as consisting of grains the size of those composing the beach sand at Asbury Park.

ARTESIAN WELL AT RUNYON, FOR PERTH AMBOY WATER-SUPPLY.

Diameter, 4 inches; depth, 185 feet. Water rises 16 feet above the surface. Temperature of the water, 54 degrees Fahrenheit.

During the fall W. R. Osborne completed the boring of a 4-inch well at the Perth Amboy Water Works, which are situated about seven miles southwest of that city, and near Runyon station.

The well has a total depth of 185 feet, but the top of the water-bearing sand was found at the depth of 175 feet. We are informed that the well flows freely at the surface, and "delivers 280,000 gallons per 24 hours." By placing a joint of pipe on the top of the casing the water rose within it to the height of 16 feet above the surface. The temperature of the water, as it flows from the mouth of the well, is 54 degrees.

The diameter of the well is 4 inches. A 6-inch casing was sunk to the depth of 105 feet, and then a 4-inch casing inside the 6-inch to the depth of 180 feet from the surface.

The contractor kindly furnished specimens of the borings, and also a record, which we copy below, noting the specimens in brackets:

Fine white sand, like seashore sand, with *lignite* at 75 feet........ 75 feet = 75 feet.
[Specimens of *lignite* furnished.]
White clay, then red clay, then sandy blue clay, interstratified with rock seams, each a few inches thick........................ 100 feet = 175 feet.
[Specimens furnished of white clay at 75 feet, and of one of the rock seams at 145 feet, and of the "blue clay" at 160 feet.]
Very white sand, with abundance of water, which overflows......... 10 feet = 185 feet.
[Specimen at 185 feet.]

THREE ARTESIAN WELLS AT MATAWAN.

No. 1...........................	Elevation, 1 foot;	depth, 215 feet;	overflows.
No. 2...........................	" 40 feet;	" 260 "	
No. 3...........................	" 30 "	" 230 "	

Water from No. 3 rises within 28 feet of the surface. Well No. 1 bored by Kisner & Bennett. Wells No. 2 and 3 bored by Uriah White.

The first artesian well at Matawan was put down a few years since by Kisner & Bennett. It is located at the wharf landing on Matawan creek, just east of where the railroad crosses that stream. It has a depth of 215 feet, and is allowed to continually overflow from the mouth of the casing, which has an elevation of but about one foot above high tide.

The second and third wells were drilled the present year by Uriah White. No. 2 has an elevation of 40 feet and a depth of 260 feet. It is located east of the railroad and south of the carriage road crossing the railroad near the station. Well No. 3 has an elevation of 30 feet and a depth of 230 feet, the water rising within 28 feet of the surface. It is also located east of the railroad, but north of the carriage road. All of these wells draw from the same water-bearing sand, an horizon located below the clay marls and at the top of the plastic clay or Raritan beds.

Uriah White kindly preserved and furnished a full set of the borings from Well No. 3, from an examination of which we compile the following record:

Alternations of sand and ironstone crusts..	10 feet	= 10 feet.	?	?
Black micaceous sandy clay, with lignite, but no greensand	15 "	= 25 "		
Dark micaceous sandy clay, slightly brown	10 "	= 35 "	Matawan clay marls.	Cretaceous.
Dark micaceous sandy clay, greenish......	50 "	= 85 "		
Black micaceous sandy clay..................	5 "	= 90 "		
Streak of lignite at	.....	= 90 "	?	
Clay, with lignite like peaty marsh.......	5 "	= 95 "		
White sand, with some lignite..............	25 "	= 120 "	Transitional.	
Dark micaceous sandy clay..................	10 "	= 130 "		
Whitish sand, with some lignite throughout	100 "	= 230 "	Probably Raritan	

This well (No. 2) was finished with a strainer 60 feet long at the bottom.

BORED WELL ON TELEGRAPH HILL.

Elevation, 300 feet; depth, 575 feet.

As we close this report a well is being bored by Stotthoff Bros. about two and one-quarter miles southeast of Hazlet station, nearly on the 300-foot elevation contour upon the eastern slope of the 357-foot hill known as Telegraph Hill. The contractors have kindly furnished us with a series of the borings as far as they have so far progressed, to the depth of 575 feet. We have carefully examined the same and have prepared therefrom the following interesting record.

Gravel surface to		25 feet.		
Mixture of gravel and marl at		25 "		Cretaceous.
Light-colored olive green marl	25 feet to	40 "	= Middle marl.	
Reddish-yellow sand with iron stone crust at 65 feet	40 " "	70 "	= Red sand bed.	
Black clay	70 " "	130 "	Lower marl.	
Dark green or black marl	130 " "	160 "		
Black clay	160 " "	185 "	?	
Sand, gray	185 " "	243 "		
Stony crusts, &c	243 " "	255 "		
Clayey sand	255 " "	260 "	Matawan clay marls and sands.	
Black clay	260 " "	278 "		
Black sandy clay	278 " "	294 "		
Sand, with *lignite*	299 " "	303 "		
Clayey sand, with *lignite*	303 " "	310 "		
Sand	310 " "	350 "		
Clay	350 " "	360 "		
Sand, with *lignite*	360 " "	375 "		
Clay	375 " "	428 "		
Greenish clay, some *greensand*	428 " "	435 "		
Clay	435 " "	457 "		
Sand, with considerable *lignite*	457 " "	475 "		
Clay	475 " "	515 "		
Sand, *lignite* and mica	515 " "	545 "		
Clay	545 " "	555 "		
Sand, *lignite* and mica	555 " "	565 "		
Sand, quite white, some mica, *no lignite*, some water	565 " "	575 "	?	

On comparing the specimens from this well with those from one of the wells at Matawan, there appears to be a correspondence lithologically in the peculiar greenish micaceous material at the depth of 435 feet in this well with that at the depth of 80 feet at Matawan. As the thick clay bed of which this is a portion terminates at Matawan 15 feet lower, and as there it is about 150 feet farther to a water horizon, it appears probable that by continuing the Telegraph Hill boring, the water-yielding sand would be reached at about 625 feet.

I.

Sec. 2b. Wells in the Southern Part of the Cretaceous Belt.

ARTESIAN WELL ON REEDY ISLAND.

Elevation, 5 feet; depth, 570 feet.

A well has been bored at the United States Quarantine Station at the northern end of Reedy Island, in the Delaware river, opposite Port Penn, Delaware. This well is nearly on the line of strike with the wells at Salem, noted in this report, pages 249 and 250.

We have been furnished with a series of the borings, from which we compile the following record below the depth of 90 feet, to which depth, we are informed, the material penetrated was "mud:"

Mud (?) to		90 feet.
Coarse gravel	90 feet to	113 "
Still coarser gravel	113 " "	125 "
Gray sand, slightly olive in shade, at		160 "
Dark gray sand at		170 "
Light gray sand at		201 "
Light gray sand at		205 "
Black clay at		240 "
Black clay at		269 "
Greenish clay at		275 "
Dark clay at		283 "
Greenish clay at		295 "
Dark clay, mixed with gravel, at		300 "
Dark clay, slightly greenish, at		304 "
Whitish clay	304 feet to	314 "
Reddish clay	314 " "	318 "
Dark clay	318 " "	323 "
Dark clay, slightly yellow, at		333 "
Black clay at		342 "
Red clay at		370 "
Red clay at		385 "
Red clay at		400 "
Red clay at		570 "
Whitish sand, with *water*		570 " +

THREE ARTESIAN WELLS AT SALEM.

Elevation, 3 feet; depth of each, 130 feet. Water rises within 1 foot of the surface.

Late in the spring J. Haines & Bro. completed the boring near the railroad station, at Salem, of three wells for John Q. Davis, to furnish fresh water to a pond to be used in the winter for the natural freezing of ice.

These wells are located upon the margin of the level flood plain of a small tributary of Fenwick creek. The higher ground immediately adjacant upon the south rises about 10 feet, and is composed of about 3 feet on top of coarse yellow gravel, and 7 feet below of fine yellowish gravel. The first well put down was upon a level 1 or 2 feet less than that of the other two wells. The water rises in this well to within 1 foot of the surface, the elevation being probably about 3 feet above high tide.

J. Haines & Bro. courteously saved a full series of the borings from this well, from an examination of which we make the following record:

Marsh mud, roots, &c.	1 foot =	1 foot.
Yellow sand, with some greensand	19 feet =	20 feet.
Olive green marl	10 " =	30 "
Dark green marl	10 " =	40 "
Green marl, slightly lighter in color	15 " =	55 "
Sand, with *belemnites* and some fragments of *shell*	5 " =	60 "
Sand (*water-bearing*)	70 " =	130 "

The horizon reached is that which we have designated as the Marlton water horizon, and which also supplies the wells at Quinton, three miles slightly south of east, which wells furnish water to the Salem Water Works plant. These wells were cased to the depth of 70 feet, leaving the entire thickness of the water-bearing sand, some 60 feet, open for supply.

BORED WELL AT ALLOWAY STATION.

Elevation, 30 feet; depth, 60 feet.

We are informed that a boring has been made at the above-named station to the depth of 60 feet. On plotting this well upon a vertical section, now being prepared, it seems probable that the water-supply is from the Lindenwold or lime-sand horizon over the Middle Marl bed.

ARTESIAN WELL SOUTH OF DARETOWN, ON THE FARM OF WILLIAM T. RICHMAN.

Elevation, 140 feet; diameter, 3 inches; depth, 405 feet. Water rises to within 100 feet of the surface.

During the spring of the present year a 3-inch well was bored to the depth of 405 feet on the farm of William T. Richman, one mile south of Daretown. This well obtained a supply of excellent water from the Marlton horizon. The contractors, J. Haines & Bro., carefully saved an admirable series of the borings, which they courteously furnished the writer. From an examination of the specimens we make the following record. The boring was commenced at the bottom of a dug well at the depth of 40 feet:

Description of Material.	Depths.		Contained Organisms, &c., Microscopical and otherwise.			
Yellow gravel at the surface underlaid by fine orange-yellow sand to the bottom of the dug well at		40 feet.		Age (?)	80 ft.	
Orange-colored sand	40 feet to	80 "				
Brownish clay	80 "	105 "	No microscopic organisms seen.	Miocene,	25 ft.	
Ash-colored clay, light shade	105 "	200 " *	No microscopic organisms found.	Age (?)	95 ft.	
" " " slightly darker, some stony fragments in the borings	200 "	220 "	No microscopic organisms found.	Probably upper part of upper layer of Upper Marl,	30 ft.	Upper Marl beds, 115 feet. Cretaceous and Eocene.
Ash-colored clay, slightly greenish tinge	220 "	230 "				
" " "	230 "	240 "	*Coccoliths* seen with ⅙-inch objective.			
Greenish clay with marl grains	240 "	250 "	A few *coccoliths* and *globigerina*.	Upper layer, Upper Marl, "Blue marl."	10 ft.	
Ash-colored clay	250 "	260 "	A few *coccoliths*.	Ash-colored clay, "Ash marl."	30 ft.	
" " "	260 "	270 "				
" " "	270 "	280 "				
" " " with a little greensand	280 "	290 "	No micro-organisms observed under a ⅙-inch objective.	Lower layer, Upper Marl, "Green marl,"	10 ft.	
" " "	290 "	295 "	A few *coccoliths* and a few transparent rosettes, globular in shape (probably crystal ?).	Clay,	25 ft.	
" " "	295 "	305 "				
Greenish clay	305 "	315 "				
Greensand marl with *Terebratula harlani*	315 "	325 "	*Terebratula harlani*.	Middle and Lower Marl beds,	60 ft.	Cretaceous.
" "	325 "	335 "				
" " some chocolate-colored marl seen in this specimen	335 "	345 "				
Greensand marl with fragments of molluscs, too much broken for identification	345 "	355 "				
Gray marl with greensand and white rounded quartz grains	355 "	375 "	*Belemnitella mucronata*.			
Interval no specimen	375 "	385 "			30 ft.	
Gray sand, *water-bearing*	385 "	405 "				
				Total,	405 ft.	

The salient features of the preceding record are, the depth and thickness (80 feet) of the Beacon Hill gravel and sand; the occurrence next beneath of a brownish clay, which we take to be the so-called rotten stone noted by well-drillers in Monmouth county, and which probably represents the base of the Miocene; and then most interesting of all is the existence of all three divisions of the Upper Marl bed, as defined by Prof. George H. Cook, viz., naming them in descending order, the blue marl, ash marl and green marl layers, with the addition of a considerable thickness of a similar ash marl above the blue marl. We assign, with considerable certainty to the Upper Marl, as thus divided, the material between the depths of 200 and 315 feet, but still hold in reserve the exact age of the 95 feet of earth next above or between the depths of 105 and 200 feet, since but one specimen was furnished for that interval, which may have come from the base thereof, and we are consequently unable to judge where to place the boundary between undoubted Miocene and the top of the Eocene division of the Upper Marl bed. Respecting this 95-foot interval, however, we are informed by the workmen who actually made the boring that a decided change occurred at the depth of 105 feet from a dark-brown hard clay to a light-colored clay much softer, the borings from which, however, became hard when dried. This light clay was so soft they could often sink 9 feet or so in five minutes without change of tools, the "borings coming out like sausages." The ashy marly clays between 230 and 315 feet are characterized by small calcareous microscopic fossil organisms, known as *coccoliths*, and which may now be dredged from the bottom of the ocean. *Terebratula harlani*, a brachiopod shell which occurs at the top of the Middle Marl bed was found at the depth of 325 feet, and *Belemnitella mucronata*, a cephalopod which occurs at or beneath the base of the Lower Marl bed, was found at the depth of 375 feet. The specimens furnished show the Middle and Lower Marl beds as one continuous stratum, consisting largely of glauconitic greensand marl; the Red-sand bed, which in Monmouth county intervenes between these two marl beds, being here apparently wanting.

The finding in this well, as already noted, of a complete typical section of the Upper Marl bed indicates the continuance of that bed some twenty miles or more southwestwardly from Clementon, which has heretofore been the most southerly point at which it has been known and mapped on the geological map of the State. Near Clementon its basal green marl member is found a few feet below the bed of the northern tributary of the north branch of Timber creek, about one-half mile east of the railroad station, while its upper or blue marl layer and the intermediate peculiar ashy marly clay, 57 feet in thickness, have been revealed in a boring on the line of the 150-foot contour at a point about one and one-half miles east of the same station.

We note in this (Daretown) boring the apparent absence of the upper or bryozoan lime-sand member of the Middle Marl bed. This peculiar lime-sand does not appear in any of the samples furnished of the borings, nor was it seen at all by anyone present during the entire progress of the work. This absence seems to the writer remarkable, in view of its occurrence in outcrops along the strike of the beds to the northwest, where cut across by the streams at Harrisonville, Woodstown and near Penton. This absence is even more remarkably emphasized by the great thickness (about 100 feet) of this bed at Quinton, as revealed in a number of wells put down there, which fact was noted in the Annual Report for 1890, page 136, Quinton being not so far out on the dip of the beds by nearly two miles, and being located but eight miles distant, slightly south of west.

BORED WELLS AT ATCO, ON PROPERTIES BELONGING TO JAMES L. GRIEB.

Wells Nos. 1 and 3, elevation, 150 feet; diameter, 3 inches; depth, 60 feet each.
Well No. 2, elevation, 160 feet; diameter, 3 inches; depth, 65 feet.

During the summer three wells were bored about one-half mile northwest of the railroad station at Atco, on properties belonging to James L. Grieb, who kindly furnished some specimens of the borings, and also some notes respecting the same, from a study of which we are able to present the section noted below.

The first and third of these wells, numbering them in the order in which they were put down, are near to and on the north of the railroad upon ground having an elevation of 150 feet, while the second well is a short distance south of the railroad and nearly, if not exactly, upon the 160-foot contour. We insert the record of well No. 2, only, (the well upon the highest ground), since those of the others are, as should be expected, essentially the same.

This record corresponds and harmonizes with the upper portion of the record on page 255, of the well at Thomas Richards':

Yellow gravel	32 feet	= 32 feet.
Yellow sand	20 "	= 52 "
Yellow clay	4 "	= 56 "
Black clay	8 "	= 64 "
White fine sand	1 "	= 65 "

The black clay stratum is reported as brownish in color from the other two wells, and not quite so thick.

TWO WELLS AT ATCO, NEAR THE RAILROAD STATION.

Elevation, 150 feet; depth of each, 57 feet.

A few years since two wells were put down on the north side of the railroad, near the station at Atco. One of these is at the store at the northeast corner of the cross-roads, and the other on the property immediately adjacent on the south. Each of these wells is 57 feet in depth. Some "putty-like" clay is said to have been taken out. They draw their supply of water from the same stratum as that reached by the wells at James L. Grieb's. See next preceding record.

ARTESIAN WELL AT ATCO, AT THE RESIDENCE OF THOMAS RICHARDS.

Elevation, 170 feet; depth, as finished, 100 feet.
Prospected beyond to the depth of 128 feet.

During the spring a well was bored at Atco, on the property of Thomas Richards. This well is nearly on the 170-foot contour line on the northern side of the 178-foot hill, near to and northeast of the railroad station. The work was done by George Hugg, who furnishes the following generalized memoranda of strata:

Alternations every few feet of sand, gravel, fine quicksand and red, rusty, sandy hardpan, with pebbles ½ to 1 inch in diameter	50 feet	= 50 feet.
Sticky black clay	15 "	= 65 "
Sea sand	35 "	=100 "
Potters' clay (?)	2 "	=102 "
White fine gravel, without clay	26 "	=128 "

BORED WELL AT WILLIAMSTOWN, AT THE GLASSHOUSE, NEAR THE RAILROAD STATION.

Elevation, 150 feet; diameter, 4 inches; depth, 80 feet.
Water rises within 32 feet of the surface.

Joseph W. Pratt, who bored this well, furnishes the following record thereof:

Sand and coarse gravel	4 feet to 26 feet.
Yellow clay	26 " " 31 "
Red and white gravel	31 " " 66 "
Black clay	66 " " 71 "
Reddish brown gravel	71 " " 80 "

The well is finished with a 9-foot length of strainer at the bottom.

ARTESIAN WELL AT KIRKWOOD, AT THE STRATFORD HOUSE.

Elevation, 100 feet; diameter, — inches; depth, 100 feet.
Water rises within 51 feet of the surface.

Through the courtesy of C. S. King, we have been furnished with a series of specimens from a well bored at the Stratford House, located nearly midway between Kirkwood station, on the Camden and Atlantic railroad, and Stratford station, on the Reading railroad route to the shore, and on nearly the highest ground. C. S. King has also handed us a record of the material passed through, this being in the handwriting of W. R. Kelly, the contractor who bored the well.

We append the record verbatim, adding upon the right our interpretation of the geology of the strata:

Specimens.				
No. 0. Dug well		33 feet.	Beacon Hill (?) 48 feet.	Miocene?
" 1. Fine yellow sand	8 feet	= 41 "		
" 2. Coarse yellow sand	2 "	= 43 "		
" 3. Yellowish loamy gravel	3 "	= 46 "		
" 4. Yellowish clayey sand	2 "	= 48 "		
" 5. Green marly clay	7 "	= 55 "	Middle and Lower Marl beds 45 feet.	Cretaceous.
" 6. Black marl sand	3 "	= 58 "		
" 7. Green marly clay, very hard	13 "	= 71 "		
" 8. Black marl sand with water in it,	5 "	= 76 "		
" 9. Green clayey marl, very sticky,	4 "	= 80 "		
" 10. Lime rock (?), very hard	2 "	= 82 "		
" 11. Brown marly clay, soft and sticky	4 "	= 86 "		
" 12. Black sand and gravel, with water in it	3 "	= 89 "		
" 13. Hard stony conglomerate	2 "	= 91 "		
" 14. Light-green marly clay	2 "	= 93 "		
" 15. Sand in layers, softer and harder,	7 "	= 100 "	Water-bearing sand at the top of the clay marls.	

Nos. 5 and 6 of the above record outcrop along the Camden and Atlantic railroad, a short distance north of Kirkwood station, at an elevation of about 50 feet.

The water-supply comes from the Marlton horizon.

BORED WELL ONE MILE NORTHWEST OF BARNSBORO.

Elevation, 70 feet; diameter, 4 inches; depth, 318½ feet.
Water rises within 70 feet of the surface.

This well was bored for James Jessup. Its location is on the road from Barnsboro to Mount Royal station and Berkeley. Joseph W. Pratt, who bored the well, furnishes the following record, which we quote verbatim:

"Surface loam	5 feet	= 5 feet.		
Greenland	30 "	= 35 "	Base of the lower marl.	Cretaceous.
Black mud and marl alternating in 8 to 10-foot layers. A little water at 90 to 100 feet.	80 "	= 115 "	Clay marls and sands, Matawan formation.	
Black mud	183 "	= 298 "		
Fine white sand	5 "	= 303 "		
Coarse white gravel with water	15½ "	= 318½ ""		

Stopped on dark quicksand. Finished with a 9-foot strainer point.

This well is probably supplied from the Sewell water horizon.

That the "greenland" noted above represents the Lower Marl bed is demonstrated by an exposure, on the banks of a small creek but a few hundred feet westward, of a shell bed, some five feet thick, literally packed with such characteristic fossils as *Belemnites*, *Exogyra* and a large *Gryphea*.

BORED WELL ONE-HALF MILE WEST OF PAULSBORO.

Elevation, 10 feet; depth, 66 feet.
Water rises within 16 feet of the surface.

A well has been bored for Joseph L. Locke, about one-half mile west of Paulsboro. It has a depth of 66 feet, and the water rises to within 16 feet of the surface. It was put down by Seth Roberts, who kindly forwarded us some samples of the borings, and also furnished the following record:

Started in the bottom of a dug well at the depth of	15 feet	= 15 feet.
Sand and fine gravel	2 "	= 17 "
Streaks of blue and white clay	8 "	= 25 "
White sand and coarse gravel, water thick and milky	15 "	= 40 "
Black mud or clay	7 "	= 47 "
Dark, tough clay, crumbles when brought to the air	8 "	= 55 "
Black micaceous clay, with considerable *lignite*	9 "	= 64 "
Water-bearing sand	1 "	= 65 "
Water-bearing gravel	1 "	= 66 "

BORED WELL NEAR MARLTON, ON THE FARM OF T. R. WILLS & CO. (formerly Amos B. Wills).

Elevation, 100 feet; diameter, 4 inches; depth, 199 feet.
Water rises to within 31½ feet of the surface.

A 4-inch well has been put down on the farm of Thos. R. Wills & Co., about five-eighths of a mile south of Marlton. This well was bored to the depth of 199 feet, but was cased only to the top of the water-bearing sand at the depth of 196 feet.

In the Annual Report for 1894, page 208, there is note made of a previous well on the same farm, with a depth of only 84 feet. It was because the water in this well proved to be quite *irony* that the well of the present year was put down to a lower horizon, which furnishes water of a satisfactory quality.

The contractor, A. G. Dunphey, preserved from the recent well a full series of specimens of the borings, which he courteously divided with the writer. From an examination of these we compile the following record:

Specimen.

No. 1.	Soil and yellow loam		to 12 feet.			
" 2.	Gravel and greenish-yellow sand	12 feet	" 15 '			
" 3.	Yellowish sand with some greensand grains.............	15 "	" 22 "			
" 4.	Dark or black clay...............	22 "	" 32 "			
" 5.	Sand mixture of greensand and white quartz grains.....	32 "	" 36 "			
" 6.	Greensand marl, somewhat clayey....	36 "	" 50 "	Middle and lower marl beds.		Cretaceous.
" 7.	Pure greensand marl, called powder-grain marl...........	50 "	" 60 "			
" 8.	Chocolate marl....................	60 "	" 68 "			
" 9.	Chocolate marl, darker shade,	68 "	" 82 "			
" 10.	Mixture of greensand and quartz sand, with some thin crusts of irony conglomerate, contains also fossils as follows: *Grypheaostrea vomer* Morton and a more ponderous *Gryphea* or oyster, too fragmentary for specific identification, also the mineral Vivianite, replacing the lime of some of the shells ..	82 "	" 87 "			
" 11.	Medium-coarse sand, slightly greenish-yellow..........	87 "	" 96 "	Marlton water horizon.	Matawan clay marls.	
" 12.	Medium-coarse sand, greenish-yellow, but darker.	96 "	" 98 "			
" 13.	Finer sand, similar in color, but containing numerous pale yellowish-green casts of *foraminifera*..................	98 "	" 118 "			
" 14.	Sand slightly clayey...........	118 "	" 130 "			
" 15.	Sand mainly quartz grains...	130 "	" 143 "			
" 16.	Black, sandy clay, 52 feet in thickness........	143 "	" 195 "			
" 17.	Hard crust, consisting of sand conglomerate, *shells* and other *fossils* In this stratum were found the cusp of a tooth of *Thoracosaurus neocesariensis* Leidy, a gavial related to the crocodile, and also the molluscan genera *Cardium*, *Gryphea* and *Pecten*...	195 "	" 196 "			
" 18.	Clean, clear yellowish quartzose sand, without greensand grains, *water-bearing*.	196 "	" 199 "	Cropwell water horizon.		
19.	Sandy clay, with greensand, at		199+"			

Numbers 11, 12, 13, 14 and 15 of the above comprise together 56 feet of greenish-yellow sands of various shades, and which in this well were water-bearing throughout, but unfortunately the water was quite irony. The specimens from this interval prove that in this region, as at Salem, Woodstown and Quinton, there are next below the marl series 50 to 60 feet of water-yielding sands. These sands for localities near the intersection of the cross-roads in Marlton, furnish water too *irony* for household use, while the water therefrom in numerous wells one mile or more to the eastward, is quite free from iron and is generally considered satisfactory.

The reason for this difference in the quality of the water from the same horizon, within such a short distance, is probably explained by the fact that there is to the eastward, intervening between the marl series and the water-yielding sand, a solid non-permeable ironstone layer a few feet in thickness, which prevents the water in the true greensand marls from filtering into the underlying sands, while near the Marlton cross-roads, from information furnished by several well-drillers, this ironstone layer is either quite thin and broken, or is in some instances entirely wanting, and thus permits the contamination of the water in the quartzose sands with that from the overlying marl beds.

MARLTON WATER WORKS WELL AT MARLTON, ONE-HALF MILE SOUTH OF THE RAILROAD STATION.

Elevation, 115 feet; diameter, 6 inches; depth, 212 feet.
Water rises within 41½ feet of the surface.

Early in the summer a well was bored at Marlton by A. G. Dunphey, to supply the town with water. The Marlton horizon, that next below the marl beds, was found at the depth of 96 feet, but the water proved too *irony* to be entirely satisfactory. The boring was then continued 116 feet deeper, or to the depth of 212 feet, finding there an abundant supply of water deemed quite satisfactory. The following record of strata has been obtained:

Soil	9 feet =	9 feet.			
Yellow gravel	5 “ =	14 “			
Yellow quicksand	15 “ =	29 “			
Black mud	20 ‘ =	49 “			
Marl	25 “ =	74 “	Middle and Lower marl.		Cretaceous.
Brown mud (chocolate marl)	19 “ =	93 “			
Mud and shell	3 “ =	96 “			
Gray sand, with *abundance of water*, somewhat *irony*	10 “ =	106 “	Marlton water horizon.	Matawan clay marls.	
White sand	1 “ =	107 “			
Black sand-	1 “ =	108 “			
Whitish or gray sand	17 “ =	125 “			
Black sandy mud at		125 “			
Black clay at below		155 “			
Black muddy sand at		185 “			
Sandy marl at		196 “			
Light-colored sand at		208 “	Cropwell water horizon.		
Yellowish-white sand, with *satisfactory water*, at		212 “			

BORED WELL SOUTHEAST OF MARLTON, ON THE FARM OF THOMAS C. HAMMITT.

Elevation, 125 feet; diameter, 6 inches; depth, 135 feet.
Water rises within — feet of the surface.

Early in the summer of the present year a 6-inch well was bored by A. G. Dunphey, on the farm occupied by Thomas Wills, and owned by Thomas C. Hammitt, about one and one-quarter miles directly southeast of the cross-roads in Marlton. Through the courtesy and co-operation of the owner and of the contractor, we have been furnished with a full series of specimens of the borings, from an examination of which we compile the following record:

Gravel	8 feet	= 8 feet.		
Yellow quicksand	58 "	= 64 "		
Black mud	6 "	= 70 "	= Miocene (?).	
Black sand	2 "	= 72 "	Age (?).	Cretaceous.
Black marly mud	3 "	= 75 "		
Marl	7 "	= 82 "		
Black sand	1 "	= 83 "	Middle and Lower Marl beds.	
Hard crust of sand and shells, among the latter *Terrebratula harlani*	2 "	= 85 "		
Black mud	7 "	= 92 "		
Black sand	4 "	= 96 "		
Black sandy marl	2 "	= 98 "		
Green marl	1 "	= 99 "		
Black marl	4 "	= 103 "		
Black clayey marl	24 "	= 127 "		
Shell crust, containing *Belemnites* and *Exogyra*	5 "	= 132 "		
Sand, with water—*Marlton water horizon*	3 "	= 135 "	Matawan clay marls.	

This well draws water of satisfactory quality from the top of the Marlton water horizon, which occurs immediately below the marl series. The molluscan brachipod fossil *Terebratula harlani,* noted above, marks the upper part of the Middle Marl, while the *Belemnite,* a cephalopod fossil, as also the *Exogyra,* an ancient oyster, likewise mark the bottom of the Lower Marl.

ARTESIAN WELL NEAR JENNINGS MILLS AND ONE MILE EAST OF MILFORD.

Elevation, 70 feet; diameter, 3 inches; depth, 56 feet.
Water rises within 2½ feet of the surface.

During the summer a well was bored by A. G. Dunphey on the property of Peter Schwin, near Jennings Mills, and about one mile east of Milford.

Of this well the following record has been courteously furnished by the contractor:

Gravelly sand	28 feet	= 28 feet.	
Green mud	9 "	= 37 "	
Black sand	2 "	= 39 "	
Greenish sand	3 "	= 42 "	
Limesand rock and sand alternating,	11 "	= 53 "	Limesand layer at the top of the Middle Marl bed.
Sand, *water-bearing*	3 "	= 56 "	

The boring is said to have stopped on "something hard," which was probably another layer of limesand rock. The water probably comes from the porous layer of the limesand. Thus far but few wells have been finished to draw their supply from this limesand. Beside this one, they are as follows:

One well at Gibbsboro, one at Laurel Springs, one near Harrisonville, a few at Lindenwold, and *probably* one at Alloway station.

We designate this *Bryozoan* limesand water-yielding stratum as the *Lindenwold water horizon,* since there are several wells that draw from it at that locality.

BORED WELL AT MOUNT LAUREL AT THE BASE OF THE MOUNT.

Elevation, 70 feet; diameter, 3 inches; depth, 306 feet.
Water rises within 50 feet of the surface.

A well has been bored on the farm of Mrs. Samuel Shreeve, on the 70-foot contour, near the base of the southern slope of Mount Laurel. Wm. C. Barr, the contractor, has kindly furnished the following record and also some samples of the borings:

Commenced in the bottom of a dug well at the depth of		25 feet.		
Reddish-gray sand	31 feet	= 56 "	Matawan Clay marls.	Cretaceous.
Black clay	175 "	= 231 "		
A few *molluscan fossils* at about 100 feet.				
Numerous molluscs at 150 to 160 feet.				
Tough green clay	30 "	= 262 "		
Dark-bluish clay	42 "	= 304 "		
Gray sand, *water-bearing*	2 "	= 306 "	Sewell water horizon.	
Stopped on a whitish clay.				

The whitish clay on which this boring stopped is probably equivalent in horizon with certain alternating laminæ of whitish clays and sands that were found near the bases of the wells at the Wenonah Hotel and at Sewell. Beneath these laminæ, at the last two named localities, occur coarse sands and gravels with large pebbles, forming an open stratum from which an abundant and excellent supply of water is obtained. The water horizon reached at Mount Laurel may be considered as practically the same. We have designated this as the Sewell water horizon. Its position is at the base of the Matawan clay marls and the top of the Raritan plastic clay series, and has a thickness, if we may judge by the boring at Sewell, of at least forty feet.

Ripley Cretaceous Fossils at 150 feet. The Bed a Continuation of that Outcropping at Lenola.

The shells at 150 to 160 feet evidently represent the continuation of the fossiliferous horizon, outcropping in Reeve's clay bank, near Lenola station. At Lenola the fossils occur as casts, while here, however, the shell material has been well preserved. The smaller shells came from the boring in fairly perfect condition, but the larger ones were completely broken into small pieces; nevertheless it has been possible, by means of characteristic markings on these fragments, to identify the larger shells without difficulty.

We present below the list of species as determined by C. W. Johnson, of the Wagner Institute, there being twenty bivalve and fourteen univalve shells, including with the latter one cephalopod—an ammonite. In the study of these fossils and in the comparison of them with the shells now in the Wagner Institute from localities of the Ripley beds in Alabama, Mississippi and Texas, the writer was especially struck by the identity of this fauna with the typical Ripley fauna. In the list below we note, on the right, the locality of the forms of which there are specimens from the Gulf States, now preserved in the Wagner collections.

Among the forms there are four which are regarded by C. W. Johnson as new species, three of which he has named. These are included in the list below. A paper has been prepared by him describing them, and accompanied by illustrations which will appear in the forthcoming Proceedings of the Academy of Natural Sciences of Philadelphia, for the year 1898. In this connection we may state that Pugnellus densata, a species especially typical of the Alabama Ripley beds, has, we believe, never before been recorded from New Jersey.

LAMELLIBRANCHIATA.

	Occurrence in the Ripley Beds in the States named below.
Anomia tellinoides, Morton	Alabama.
Cardium eufaulensis, Conrad	Alabama.
Corbula foulkei, Lea. Probably synonymous, with Corbula eufaulensis, Conrad	Alabama.

	Occurrence in the Ripley Beds in the States named below.
Corbula crassiplicata, Gabb	Alabama.
Exogyra costata, Say	Alabama, Mississippi and Texas.
Leptosolen biplicata, Conrad	Alabama and Mississippi.
Legumen, sp.?	
Leda sp.?	
Lucina cretacea, Conrad	Alabama.
Nucula percrassa, Conrad	Alabama and Texas.
Nucula, sp.?	
Ostrea plumosa, Morton	Alabama.
Pinna, sp.?	
Pteria, sp.?	
Camptonectes (Amusium) burlingtonensis, Gabb	Alabama.
Pectunculus, sp.?	
Trigonia mortoni, Whitfield. Probably synonymous with T. thoracica, Morton	Alabama.
Trigoniarca cuneata, Gabb	Alabama.
Veniella conradi, Morton	Alabama and Texas.
Veleda lintea Conrad	Alabama.

GASTROPODA.

Alaria rostrata, Gabb.	
Anchura, sp.? (expansion of outer lip only). *Probably new species.*	
Anchura, sp.? Young.	
Dentalium, sp.?	
Lunatia halli, Gabb.	
Pugnellus densata, Conrad	Alabama.
Pyrifusus subdensata, Conrad	Alabama.
Cinulia costata, Johnson. New species*	
Scalaria sillimani, Morton	Alabama.
Trichotropis cancellaria, Conrad	Mississippi.
Turritella vertebroides, Morton	Alabama.
Turritella quadrilira, Johnson. New species,* resembles T. trilira, which has three raised spiral lines on each whorl, while this has four.	
Tuba (?) *reticulata, Johnson.* New species.* This is a small univalve, none of the specimens of which had the lip or aperature sufficiently perfect for positive generic identification; it resembles Tuba, to which it is referred with a question. The specific characters however, are very distinct.	

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*See New Cretaceous Fossils from Artesian Boring, Mount Laurel, N. J., in the forthcoming Proc. Acad. Nat Sci. of Phila. for 1893.

CEPHALOPODA.

Ammonites (Placentaceras) placenta, Dekay.

This occurs as casts twelve inches across at Lenola. Small broken fragments indicating a shell of similar size were found in this boring with the highly nacreous iridescent shell well preserved, and showing on the interior very plainly the complex and characteristic suture lines dividing the chambers.

VERMES.

Hamulus squamosus, Gabb (worm-tube).

CORAL.

Platytrochus speciosus, Gabb and Horn.

In addition to the above fossils there are *two ear-bones of fishes* probably representing two species, which, however, we are not able to determine. There is also one small, flat *vertebra,* hollow or saucer-shaped on both sides as in the *shark* family, which indeed it most likely represents. The type locality of the *Platytrochus* was in Tennessee, in beds probably belonging to the Ripley formation.

BORED WELL IN NORTH WOODBURY.

Elevation, 40 feet; diameter, 4 inches; depth, 128 feet.
Water rises within 28 feet of the surface.

This well is at the residence of H. G. Huey, closely adjacent on the westward to the point where the West Jersey railroad obliquely crosses the Gloucester and Woodbury turnpike. It was put down by Joseph W. Pratt, who states that the strata were the same as in the 118-foot well at South Westville (see page 267), which statement is in accordance with the following record of this well furnished from memory by H. G. Huey:

Red sand	12 feet	= 12 feet.
Black mud	60 "	= 72 "
Green marl	4 "	= 76 "
White shore sand, then gravel with blue pebbles, &c. (*water-bearing* at the base)	52 "	= 128 "

BORED WELL IN NATIONAL PARK, BELOW AND NEAR TO RED BANK, ON THE DELAWARE RIVER.

Elevation, 44 feet; diameter, 3 inches; depth, 78 feet.
Water rises within 48 feet of the surface.

This well is located on the gravel bluffs facing the Delaware river, about three-fourths of a mile southwest of Red Bank landing. It is within the National Park grounds, and is near the summit marked on the topographical sheet No. 11 as having an elevation of 44 feet. It was bored by Joseph W. Pratt, who has furnished the following generalized record:

Brown stone conglomerate at	5 feet	= 5 feet.	....
Hard brown sand and gravel	27 "	= 32 "	
Whitish boulder at		32 "	
Sand, shade of brown sugar	28 "	= 60 "	
Thin streak of white clay.			Raritan Cretaceous.
Coarse white gravel	18 "	= 78 "	

BORED WELL, ONE MILE SOUTHWEST OF WESTVILLE STATION.

Elevation, 40 feet; diameter, 3 inches; depth, 105 feet.
Water rises within 36 feet of the surface.

This well is at Capt. C. B. Platt's hotel, on the road from Westville to Thorofare, and at the southwest corner of the crossing of the said road and the trolley road from Woodbury to Gloucester, and is also about one mile southwest of the railroad station at Westville.

Capt. Platt furnished a series of specimens of the boring, together with the following record. The words in parenthesis being ours, however. On the right we append our geological interpretation.

Sand followed by a vein of yellow clay	12 feet	= 12 feet.	Comparatively recent.	
Black clay and marl	53 "	= 65 "	Matawan clay marls.	Cretaceous.
Gray sand	23 "	= 88 "		
Coarse gravel (blueish white)	3 "	= 91 "		
Sand (very slightly pinkish white)	3 "	= 94 "	Raritan plastic clays and associated gravels.	
Coarse gravel (yellowish white) water-bearing	11 "	= 105 "		

ARTESIAN WELL AT SOUTH WESTVILLE.

Elevation, 20 feet; diameter, 4 inches; depth, 118 feet.
Water rises within 23 feet of the surface.

This well was put down by Joseph W. Pratt, who furnishes the following record:

Black mud from near the surface to......		65 feet.	Matawan.	Cretaceous.
Dark-gray sand and coarse gravel.........	53 feet =	118 "	Raritan.	

Finished with a 9-foot strainer length at the base.

ANOTHER BORED WELL AT SOUTH WESTVILLE.

Elevation, 20 feet; diameter, 3 inches; depth, 59 feet.

This well is almost immediately adjacent upon the west to the well just noted at South Westville. It was hand-bored with an auger by George J. Stites at his own residence. We have been furnished with the following record:

Surface soil, &c....................................	12 feet	= 12 feet.	
Dark clay and marl..............................	18 "	= 30 "	Matawan clays and sands. Cretaceous.
Then gray gravel.................................	29 "	= 59 "	
Then dark sand..................................			
Then white gravel...............................			
The latter *water-bearing.*			

The boring was stopped upon a "log."

ARTESIAN WELL AT NEWBOLD.

Elevation, 15 feet; diameter, 4 inches; depth, 73 feet.
Water rises within 12 feet of the surface.

This well was bored by Joseph W. Pratt at the residence of Chas. A. Hilliard. The following record of strata was furnished by the contractor:

Sand	16 feet	= 16 feet.	
Black marl..	30 "	= 46 "	Matawan Cretaceous.
White gravel..	27 "	= 73 "	

TWO ARTESIAN WELLS AT WESTVILLE.

Elevation, 14 feet; diameter of each, 6 inches. Depth, No. 1, 112 feet;
No. 2, 114 feet.
Water rises within 15 feet of the surface.

Our information respecting these wells was obtained from Joseph W. Pratt, who bored them, and from J. W. Ladoux, C.E., of the American Pipe Company, who constructed the water plant at Westville.

A thin bed of black clay (Clay Marls) was encountered near the surface. A coarse gravel, bluish gray in color, occurred at 73 feet, and at the base of the well a very coarse gravel, yellowish white in shade, while between these two gravels there was a dark sand. The two gravels were *water-bearing*, the lower one, however, yielding much the most water, it only was utilized. The upper gravel is at the base of the Matawan clay marls, while the lower one may belong to the top of the Raritan series of plastic clays and interbedded gravels.

ARTESIAN WELL IN CAMDEN, AT REEVE'S OILCLOTH WORKS, TWELFTH AND PINE STREETS.

Elevation, 15 feet; diameter, 6 inches; depth, 93½ feet.
Water rises within 16 feet of the surface.

This well was bored by Joseph W. Pratt, who furnished the information tabulated above, and also the following record of strata:

Yellow sand and coarse gravel	12 feet	= 12 feet.	
Yellow sand	18 "	= 30 "	
Potters' clay, light yellow	2 "	= 32 "	Raritan Cretaceous.
Coarse, heavy gravel	31 "	= 63 "	
Plastic clay, yellow	2 "	= 65 "	
Coarse gravel	28 "	= 93 "	
Yellow clay penetrated 6 inches	½ "	= 93½ "	

This well was furnished with a strainer at the base 9 feet long.

TWO WELLS SOUTHEAST OF MERCHANTVILLE, ON THE FARMS OF JOSEPH HINCHMAN.

	Elevation	Depth
Well No. 1	50 feet	65 feet.
Well No. 2	50 "	58 "

These wells are both on the easterly side of the road leading from Merchantville to the Haddonfield and Moorestown road. Well No. 1 is about seven-eighths of a mile, and well No. 2 about one and one-quarter miles directly southeast of the railroad station at Merchantville. Intermediately between them, but on the other side of the carriage road, is the well on the property of James A. Eagle, noted in the Annual Report for 1896. Of the wells now being reported, well No. 1 was dug to the depth of 56 feet and then bored to the depth of 65 feet, increasing the water-supply considerably. Well No. 2 was put down to the depth of 58 feet and was discontinued on hard strata, "like rock." Both of these wells find water within the Matawan clay marls.

BORED WELL AT POINT BREEZE, PHILADELPHIA, NEAR THRTIETH AND BIGLER STREETS, ON THE PROPERTY OF THE ATLANTIC REFINING COMPANY.

Occurrence of nuts and stems of trees.

Through the courtesy of Dr. Samuel G. Dixon, President of the Academy of Natural Sciences of Philadelphia, we have been permitted to copy from a letter received by him from Morris W. Harkness, General Manager of the Atlantic Refining Company, the following record of a well put down on the line of Bigler street, about 50 feet east of Thirtieth street, as laid out on the city plan, though these streets are not yet opened:

Loam	3 feet	= 3 feet.
Brick clay	12 "	= 15 "
White gravel	15 "	= 30 "
Black mud	12 "	= 42 "
Gravel and sand	30 "	= 72 "
Dark mud with *rotten wood, bark and branches of trees, also nuts*	10 "	= 82 "
Fine sand with water	7 "	= 89 "

BORED WELL AT SPRECKELS' SUGAR-HOUSE, REED STREET WHARF, PHILADELPHIA.

Elevation, 5 feet; depth, 98 feet.

Philip Flaghouse informs us of a boring made some years since in Philadelphia at Reed street wharf, on the Delaware river, at Spreckels' sugar-house. He furnishes the following record:

Filled in	12 feet	= 12 feet.	
Black mud (*marine and fresh-water diatoms*)	24 "	= 36 "	Recent.
Gravel	13 "	= 49 "	Age?
Red and various-colored clays	39 "	= 88 "	Plastic clays. Cretaceous.
Cobblestone gravel containing water	10 "	= 98 "	

Subsequently a reservoir for the inflow of the river water was sunk at the same place into the black mud of the above record. Some of this mud was microscopically examined by John A. Shulze, and found to contain a *mixture* of *marine and fresh-water diatoms*, among which was a triangular form, *Triceratium favus*, which characterizes recent deposits upon the New Jersey coast and also elsewhere along the Delaware river. This exact form does not occur in the great Miocene diatom bed of the Atlantic coast. Its first appearance, according to investigation made by the writer of numerous clays of different geological ages, seems to be in Pleistocene beds, from which it extends upward to deposits of the present time, being still found in the Delaware river as far up as Philadelphia, though not found in mud from the river at Burlington which the writer has examined.

ARTESIAN WELL AT THE UNITED STATES NAVY YARD, LEAGUE ISLAND, PHILADELPHIA, PA.

Depth to gneiss rock	270 feet.
Depth in micaceous gneiss rock	330 "
Total depth from surface	600 "

This well was bored by P. H. & J. Conlan. It was noted in last year's report as having then reached a depth of 450 feet. It has since then been completed, with a total depth of 600 feet. Between the depth of 50 feet and the surface of the rock at 270 feet various alternations of typical Raritan Cretaceous plastic clays and interbedded gravels were penetrated. The gravels yielded water, but the design in putting down this well was to obtain a supply from the gneiss rock. We are informed that it yields about 25 gallons a minute. Details of the strata to the gneiss were published in last year's report (1896), page 114.

BORED WELL NEAR GRAY'S FERRY, IN SOUTHERN PHILADELPHIA, PA., AT EDMUND WEBSTER'S BRICKYARD.

Elevation, 25 feet; diameter, 6 inches; depth to gneiss rock, 95 feet. Total depth of well, 232 feet.

Marine microscopic fossils. Evidence of the former inland extension of Delaware bay with its saline waters to the latitude of Philadelphia and Camden.

Early in the year, a six-inch well was bored by Thomas B. Harper, at Edmund Webster's brickyard, in the southern part of Philadelphia, Pa., the exact location being near the intersection, as shown on the city survey maps of Thirty-second and Moore streets—the elevation of the surface being about 25 feet. This well passed through yellow clays and gravels to the depth of 95 feet, where the top of the micaceous gneiss belt of southeastern Pennsylvania was met with. The boring was continued in this rock to a total depth from the surface of 232 feet, where a satisfactory supply of water was obtained for the steam boilers used at the brick works.

Through the appreciative interest and courtesy of Edmund Webster, and also of the contractor, we have been furnished with a full series of the borings, which we describe below. It should be noted that at the depth of 40 to 45 feet there is a band of clay which shows on microscopic examination sponge spicules. No diatoms have been observed in any of these specimens. There have, however, been frequently found by the writer, mixed with sponge spicules, diatoms of both marine and fresh-water forms in clays interbedded in the extension of these same gravel beds beneath all that portion of Philadelphia south of the 40-foot contour line, and which may be broadly described as that portion of the city east, southeast, and south of the Reservoir hill at Fairmount water works.

We reason from this mixture of fresh and salt-water microscopic organic remains that the Delaware bay, with its saline waters, in comparatively recent geological times, extended inland as a much larger sheet of water than now to the latitude of Philadelphia, Pa., and Camden, N. J. It may be stated in passing that the writer has not found either of the micro-organisms noted above in any of the gravels or clays in the city above the elevation of 40 feet, nor has he observed them in any of the much older Cretaceous deposits, although he has frequently searched for them in clays of both these ages.

DESCRIPTIVE RECORD OF SPECIMENS.

Yellow clay at	25 feet.		Comparatively recent.
" " and gravel at	30 "		
" " at	35 "		
Reddish-yellow clay with a little gravel at	40 "		
Clay, light yellow, at	45 "	Sponge spicules in these.	Transitional.
Dark clay at	50 "		
" " and gravel at	55 "		Also comparatively recent, but a still older phase.
Fine gravel at	60 "		
Yellow gravel with some clay at	65 "		
Gravel, more decidedly yellow, at	70 "		
" " " " "	75 "		
" " " " "	80 "		
Yellowish-white gravel at	85 "		Raritan Cretaceous. ?
" " "	90 "		
Disintegrated micaceous rock at	95 "		Philadelphia belt of Azoic rocks.
" " " "	101 "		
" " " "	105 "		
" " " "	110 "	Whiter.	
" " " "	115 "	Some gravel dropped from above in this.	
Solid micaceous rock at	120 "		
" " " "	125 "		
" " " "	130 "		
" " " "	140 "		
" " " "	145 "		
" " " "	155 "		
" " " "	200 "		
" " " "	232 "		

Supply of *water* obtained at this depth.

RECORD OF STRATA IN PHILADELPHIA, AT FIFTEENTH AND CALLOWHILL STREETS.

Elevation, 37.7 feet, city datum; depth, 26 feet.
The occurrence of plant stems and sponge spicules.

In the course of the construction the present year of a subway in Philadelphia for the Reading railroad, a very considerable excavation was made comprising the whole block bounded by Broad, Callowhill and Fifteenth streets and Pennsylvania avenue. At a point just within the northeast corner of Fifteenth and Callowhill streets the following section was measured. We insert in the description of strata notes upon the fossil organisms contained therein, the result of a careful examination, both microscopic and otherwise, of specimens taken from each layer.

Loam, with a *few sponge spicules*	3 feet	= 3 feet.
Yellow loam, and iron, rusty mottled clay, with *sponge spicules*, some of them *pinhead* forms	12 "	= 15 ".
Black peaty clay, abundance of *vegetable stems, tissue*, &c.	3 "	= 18 ".
Clay, with *sponge spicules*	1 "	= 19 ".
Clay, no micro-organisms	1 "	= 20 ".
Thin lens of brown clay, below this at another point in the excavation.		
Yellowish gravel	6 "	= 26 "
Stopped on micaceous gneiss rock.		

At one place in the excavation there was a thin lens of brownish clay between the yellowish gravel and the micaceous gneiss.

The black peaty layer was traced along the line of the subway excavation from Thirteenth to Eighteenth street. The opportunity to trace it further did not occur, since the masonry beyond had already concealed the exposures of the beds.

BORED WELL AT THE PENNSYLVANIA RAILROAD SHOPS AT PAVONIA.

Elevation, 30 feet; depth, 154 feet.
Diameter, 6 inches to the depth of 56 feet, and 2 inches below that depth
Water rises within 22½ feet of the surface.
Revision of Record in Annual Report for 1897.

In the record of this well published in last year's annual report, we inadvertently stated that specimens of the borings had been furnished, whereas they are and then were in the possession of the master mechanic of the railroad company's shops at Pavonia. The well was bored by Philip Flaghouse, but through misapprehension we credited the work to another person. Philip Flaghouse has recently furnished a blue-print descriptive drawing of this well made to scale. We insert this record, as it is slightly fuller than that presented last year. The boring is two inches in diameter, and was commenced at the bottom of a six-inch boring, which was noted in the Annual Report for 1892 as having a depth of 60 feet, though this is now found to be but 55 feet. The first four lines of the following record are taken from the report for 1892:

Gravel	6 feet =	6 feet.	
White clay	10 " =	16 "	
Sand	19 " =	35 "	?
Gravel, *water-bearing* (*bottom of old well*)	20 " =	55 "	
Coarse white sand	13 " =	68 "	Raritan Cretaceous.
White sandy clay	5 " =	73 "	
Fine white sand	2 " =	75 "	
White sandy clay	3 " =	78 "	
Very fine white sand	1 " =	79 "	
Fine yellow sand	2 " =	81 "	
White sandy clay	6 " =	87 "	
Sand	1 " =	88 "	
White sandy clay	4 " =	92 "	
White sand	1 " =	93 "	
White clay	1 " =	94 "	
White sand	3 " =	97 "	
Yellow clay	2 " =	99 "	
Red clay	6 " =	105 "	
Yellow clay	4 " =	109 "	
White sandy clay	8 " =	117 "	
Sand similar to sandstone	5 " =	122 "	
White sandy clay	7 " =	129 "	
Fine white sand	9 " =	138 "	
Coarse white sand, *water-bearing*	4 " =	142 "	
Fine white sand	5 " =	147 "	
Gravel, *water-bearing*	7 " =	154 "	

The water-bearing horizons of this well are in the Raritan Cretaceous.

ARTESIAN WELL AT PAVONIA, AT THE ATLAS CEREAL MANUFACTURING COMPANY'S WORKS.

Elevation, 12 feet; diameter, 2 inches; depth, 124 feet.
Water rises within 11 feet of the surface.

This well was put down the present year by Philip Flaghouse, who has furnished the following record of strata penetrated:

Loam	4½ feet	= 4½ feet.	
Gravel	3½ “	= 8 “	
Sand and clay in small strata	11 “	= 19 “	
Fine white sand	27 “	= 46 “	Raritan Cretaceous.
Yellow clay	3 “	= 49 “	
Gravel	8 “	= 57 “	
Red clay.	5 “	= 62 “	
White clay	2 “	= 64 “	
Red clay	6 “	= 70 “	
White clay	12 “	= 82 “	
Red clay	8 “	= 90 “	
Yellow clay	7 “	= 97 “	
Fine white sand.	9½ “	= 106½ “	
White clay	4½ “	= 111 “	
Fine white sand	4 “	= 115 “	
Coarse sand and gravel, *water-bearing*	9 “	= 124 “	

All of this well below the depth of 46 feet, and possibly below the depth of 19 feet, is in strata belonging to the Raritan Cretaceous or the plastic clays and interbedded gravels.

BORED WELL AT BRISTOL, PA., NEAR THE PENNSYLVANIA RAILROAD STATION.

Elevation, 10 feet; depth, 114 feet; micaceous rock at the depth of 83 feet.

Early in the year a well was bored on the line of the Pennsylvania railroad, a short distance north of the station, at Bristol, Pa., for the use of the railroad company. The work was done by Stotthoff Brothers, who kindly furnished specimens of the borings, from an examination of which we compile the following record:

Brownish gravel, surface to		35 feet.	
Gravel not quite so brown	35 feet to	45 “	
Medium even-grained yellow gravel	45 “ “	55 “	Raritan Cretaceous.
Yellow gravel, slightly finer.	55 “ “	60 “	
Yellow (kaolin) clay	60 “ “	65 “	
Bluish-white (kaolin) clay	65 “ “	83 “	
Micaceous (?) rock, disintegrated	83 “ “	100 “	
Micaceous rock, solid	100 “ “	114 “	

SEVENTY ARTESIAN WELLS* NEAR MORRIS STATION FOR CAMDEN WATER-SUPPLY.

Elevation high-tide level; depths, 85 to 100 feet and 110 to 150 feet.
Water rises to tide-level, but pulsates with the tide about 15 inches.

In last year's annual report records were inserted respecting a number of wells put down north of Delair, preliminary to the sinking of a considerably larger number to furnish a water-supply to the city of Camden. During the present year 70 additional wells have been sunk to either one or the other of the two principal deep water horizons there indicated, viz., at the depth of 85 feet to 100 feet, and at the depth of 110 feet to 150 feet.

The wells now reported are on the meadows south of the mouth of the Pensauken creek, and are near Morris railroad station. A water works plant has been erected near this station, and large mains have been laid to the city of Camden, through which water is now being supplied to that city. As we conclude this report, additional wells are being sunk on the same tract of meadow land, but farther south.*

The water supplied by these wells comes from two horizons within the plastic clays and gravels of the Raritan division of the Cretaceous.

FOUR TEST WELLS AT WEST PALMYRA.

Elevation, high-tide level; depths, 30 to 46 feet.
Bored for the Palmyra Filtrated Water Company, to supply water filtered directly from the river.

Through the courtesy of Joseph H. Young, civil engineer, we have been furnished with the following information respecting four test wells put down at West Palmyra, on the level marshy margin of the Delaware river north of the mouth of Pensauken creek. The wells were drilled by Andrew Flemstrom for the Palmyra Filtrated Water Company, and are located along a straight line nearly directly across the strike of the Cretaceous beds which underlie the more recent surface gravels of this region, well No. 1 being to the east and No. 4 to the west. As well No. 1 is farthest out and No. 4 is farthest back on the

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*As this goes to print, 28 additional wells have been bored, making 98 in all.

dip of the Cretaceous, we insert the record in the reverse order of their numbers. Well No. 2, it will be seen, found two water horizons—an upper one which rose a few inches above the surface, while a lower one did not reach thereto by some ten inches. The upper water horizon only was reached by the other three borings, which did not go deep enough stratigraphically to open up the lower water horizon.

The lower horizon is in gravel of the Raritan Cretaceous age, while the upper horizon is in a clean, clear bed of medium to moderately coarse gravel of much more recent age, but what that age is the writer is not at present prepared positively to say beyond the fact that it *may* be either the Trenton gravel (so called) or the Pensauken, and is not older than the latter.

Well No. 4 is located near low-water mark;—No. 3 is 800 feet southeast of No. 4;—No. 2 is 700 feet southeast of No. 3;—No. 1 is 500 feet southeast of No. 2, and is on the edge of the bluff.

RECORDS.

Well No. 4 at West Palmyra.

Elevation, 3½ feet below high-tide level.

Peat	12	feet	= 12	feet.
Fine sand	3	"	= 15	"
Coarse gravel	2½	"	= 17½	"
Gravel	2½	"	= 20	"
Brown gravel	1	"	= 21	"
Brown sand	1	"	= 22	"
Brown gravel	5	"	= 27	"
Fine gravel	3½	"	= 30	"

Water-bearing strata at 12 to 30 feet.

Well No. 3 at West Palmyra.

Elevation, high-tide level.

Peat	8	feet	= 8	feet.
Clay	2	"	= 10	"
Sand and gravel	7	"	= 17	"
Coarse gravel	3½	"	= 20½	"
Sand and gravel	6½	"	= 27	"
Fine yellow sand	2	"	= 29	"
" " "	2½	"	= 31½	"
Gravel	2	"	= 33½	"

Water-bearing strata 10 to 32 feet.

Well No 3 at West Palmyra.

Elevation, high-tide level.

Two water horizons. Depth, 9 to 26 feet and 33 to 43 feet.

Loam and peat	9 feet	= 9 feet.	Most recent.
Sand and gravel (*first water horizon*)	17½ "	= 26½ "	Comparatively recent.
White clay	5½ "	= 32 "	Raritan Cretaceous.
Fine sand (*second water horizon*)	1 "	= 33 "	
Fine brown sand (*second water horizon*)	5 "	= 38 "	
Fine gravel (*second water horizon*)	5 "	= 43 "	
Yellow clay	3 "	= 46 "	

Water-bearing strata at 9 to 26 feet, from which water flowed 6 inches above the surface.

Water-bearing strata at 33 to 43 feet, from which water rose to within 8 feet of the surface.

Well No 1 at West Palmyra.

Elevation, high-tide level.

Peat	2 feet	= 2 feet.
Loamy clay	4 "	= 6 "
Sand and gravel	17 "	= 23 "
Clay	6 "	= 29 "
Fine sand	3 "	= 32 "

Water-bearing strata 6 to 28 feet.

The Palmyra Filtrated Water Company is an incorporated company, whose plan is to sink into the gravels revealed by these wells a series of eight basins, with a combined capacity of 2,000,000 gallons, into which basins the water of the Delaware river will be allowed to percolate by filtration, which it will probably do, since the river has cut its channel in these gravels, and has a depth of 30 to 40 feet between this point and the opposite shore. A full series of the borings from each well are in the office of the company. This horizon is higher than the two horizons utilized at Morris Station for Camden water-supply. (See page 276.)

ARTESIAN WELL AT SMITHVILLE, BURLINGTON COUNTY.

Elevation, 20 feet; diameter, 6 inches; depth, 112 feet.
Water rises 16 feet above the surface.
Overflows 30,000 gallons or more per day.

This well was bored by W. C. Barr, who furnishes the following record. The well is located at the H. B. Smith Machine Company's works, near the head of the pond:

RECORD.

Top filling of ashes, &c.	8 feet =	8 feet.	
Greenish coarse sand	20 " =	28 "	Clay marls.
Black clay	82 " =	110 "	
Gray sand, with *water*	2 " =	112 "	

A series of the borings was furnished by the President of the company, Wm. S. Kelley. They show a somewhat stony crust at the top of the water-yielding sand, at say, 110 feet, while from about the same depth there was obtained a fragment of a tooth, which may, perhaps, represent some reptile of Cretaceous times, but which we have not been able to have identified, though we have referred it to several specialists in such matters.

The location of this well is west of the outcrop of the Marlton water horizon. The strata penetrated below 8 feet are entirely within the clay marls of the Matawan division of the Cretaceous. The water sand reached is the Cropwell horizon, which occurs stratigraphically about 115 feet below the top of the Marlton horizon, and somewhat centrally within the clay marl beds.

BORED WELL NEAR VINCENTOWN.

Elevation, 50 feet; diameter, 5 inches; depth, 69 feet.
Water rises within 26 feet of the surface.

Wm. C. Barr informs that he has bored a five-inch well for Joseph A. Jones, on the road from Eayrstown to Vincentown, on ground with an elevation of 50 feet, and that the well has a depth of 69 feet. The boring was commenced in the bottom of a dug well having a depth of 28 feet, and was continued through marl to the depth of 64 feet from the surface, and then 5 feet farther into a coarse water-bearing sand, from which the water rose to within 26 feet of the surface. The supply comes from the Marlton horizon. More recently we have been informed that the water from this well is quite irony. If the boring were continued 100 to 115 feet farther it is probable that the Cropwell water horizon would be found, the quality of which has, we believe, generally proved satisfactory.

BORED WELLS AT JOBSTOWN.

No. 1...........	Elevation. — feet;	depth, 156 feet.		
No 2	"	85 "	"	356 "
No. 3	"	60 "	"	715 "

Three water horizons in well No. 3, viz, at the depths of 385, 602 and 660 feet.

Wells Nos. 2 and 3 are on the Rancocas Stock Farm of P. Lorillard, about one mile east of Jobstown, and well No. 1 is at the Park, not far distant.

Wells Nos. 1 and 2 were bored by Williard Blaisdell, and have been noted in the Annual Reports for 1879, 1882 and 1885 as at Columbus.

Well No. 3 was bored by Orcutt Bros. Its record, combined with that for well No. 2, was published in the Annual Report for 1892; likewise was stated to be near Columbus.

From Geo. H. Orcutt we have recently learned some facts concerning well No. 3 not heretofore published. He states that though this well was prospected to the depth of 715 feet, it was finished with a series of three strainers, so as to draw water from three horizons at or about the depths of 385 to 387 feet, 600 to 602 feet and at 660 feet. From a detailed record of this well, those interested may consult the Annual Report for 1892, page 305. We, however, now present a condensed record of the larger divisions met with, as revealed by a series of borings presented by Orcutt Bros.:

Recent (?) yellow, loamy sand..........	14 feet =	14 feet.		
Laminated sands and clay marls........	292 "	= 306 "	= Matawan.	Cretaceous.
Plastic clays and interbedded sands...	409 "	= 715 "	= Raritan	

The three water horizons noted appear to be all of them within the plastic clays or Raritan divisions of the Cretaceous, although the upper one is near its top and shortly below the base of the clay marls.

We are informed by Dr. Carter, the present superintendent, that the water from these wells is quite satisfactory in quality.

BORED WELL NEAR YARDVILLE.

Elevation, 70 feet; depth, 271 feet; water-bearing horizon at from 256 feet to 271 feet.
Water rises within 56 feet of the surface.
Diameter, 6 inches to 147 feet and 4 inches to 258 feet.

This well is on the Magnolia Stock Farm, and was bored last year to a water horizon between the depths of 143 and 159 feet, as was noted in the annual report for that year (1896), page 144.

This year the boring was continued to a lower horizon, which was found between the depths of 256 and 271 feet. The water rises to within 56 feet of the surface. The boring, both last year and this, was done by Stotthoff Bros., who, on both occasions, furnished specimens of the borings and some notes respecting them. For completeness, we present the record of the entire boring from the surface downward, though for the first 159 feet it is but a repetition of that published last year:

Bottom of dug well at			20	feet.		
Blue marl	20	feet to	35	"	Base of the Matawan clay marls.	Cretaceous.
"Shore" sand	35	" "	42	"		
Chocolate marl, sand and gravel	42	" "	60	"		
Fine black sand and lignite	60	" "	70	"	Intermediate sands.	
"Shore" sand	70	" "	98	"		
Clay marl at			140	"		
Fine white kaolin clay, with some mica	143	" "	147	"	Raritan plastic clays	
Sand, with *water*	147	" "	159	"		
Dark, coarse, sandy clay	159	" "	172	"		
Dark clayey sand, not quite so coarse	172	" "	192	"		
Medium, coarse, clean white sand, "which, however, yielded but *little water*"	192	" "	206	"		
Dark fine clay, with lignite	206	" "	218	"		
Fine sandy clay, lighter shade	218	" "	223	"		
Coarse sandy clay	223	" "	256	"		
Water-bearing sand	256	" "	271	"		

II.

BORED WELLS, MOSTLY IN NORTHERN NEW JERSEY,

In Red Sandstone, Gneiss and Other Rocks, and in the Glacial Moraine, mainly in Essex, Hudson, Somerset and Middlesex Counties, and on Staten Island and Long Island, and along the Delaware River.

Sec. 1. Bored Wells Reported by P. H. & J. Conlan.

P. H. & J. Conlan write as follows respecting wells put down by them during the past year. These wells are in Essex and Hudson counties, and parts outside of New Jersey, nearly adjacent. In their report there is also, however, included one well in Maryland. These wells are mostly in the red shales and sandstones of the Newark system, though a few of them are in gneiss rock. A well put down by them at the United States Navy Yard, League Island, Philadelphia, has been placed among the wells classified under the heading "Wells in the Southern Part of the Cretaceous Belt." (See page 270):

WELLS IN NEWARK.

One well, depth, 529 feet; one well, depth, 326 feet.
Both these wells are in red shale.

"We put down a well for P. Ballantine & Sons' ale brewery, 12-inch pipe to rock, which is 30 feet from surface. The rock is red shale. Depth of well, 529 feet, and yields about 150 gallons of water per minute."

"We put down a well for Zeigel, Eisman & Co., tanners, adjoining the meadows. We found clay and quicksand to rock, which was met with at 75 feet from surface. The balance of well is drilled in red shale. There is a good supply of water. Depth of well, 326 feet."

WELL AT ARLINGTON.

In red sandstone. Depth, 270 feet.

"We recently completed a well for the Arlington Manufacturing Company, Arlington, a suburb of Newark. Sunk 10-inch pipe to rock, which is about 30 feet from surface. The balance of well is drilled through red sandstone. It is 270 feet in rock, and produces 375 gallons of water per minute."

WELL AT SOHO.

In red sandstone. Depth, 120 feet.

"We put down a well for Mr. C. Northrop, at Soho, a suburb of Newark. Rock was met with at 18 feet from surface. Well is 120 feet deep. The rock is red sandstone formation. A good supply of water."

WELL IN JERSEY CITY.

In red sandstone Depth, 1,400 feet. Well not finished.

"We are putting down a well for the Consolidated Traction Company, at Jersey City. Rock was met with at about 150 feet from surface; it is red sandstone. We are down about 1,400 feet. It is not yet finished."

WELL ON JERSEY CITY HEIGHTS.

In trap rock. Depth, 275 feet Well not finished.

"We are putting down a well on the heights of Jersey City for J. Mehl & Co. We are down about 275 feet. Formation is trap rock as far as we have drilled. The rock was met with at about 20 feet from surface. It is not yet finished."

WELL AT BAYONNE.

In red shale. Depth, 600 feet.

"The well of the Martin Kalbfliesch Chemical Company, at Bayonne, was mentioned in a previous report; was drilled to a depth of 600 feet, with a very small supply of water."

WELL AT FORT LEE.

In trap rock. Depth, 850 feet. Well not finished.

"We are drilling a well at Fort Lee, N. J., through trap rock. We are down about 850 feet, and no sign of change in rock. It is a curious thing that at a quarter of a mile distant the red sandstone crops out at the surface."

FOUR WELLS IN LONG ISLAND CITY, N. Y.

Depths, 100 to 135 feet.

"We have put down four wells for the Nichols Chemical Company, Long Island City, adjoining Brooklyn. The average depth is from 100 feet to 135 feet. There was encountered fine sand, clay and boulders to the water-bearing stratum, which was met with in coarse gravel. They yield on an average from 75 to 125 gallons of water per minute, and the water is of a good quality."

WELLS NEAR BRIDGEPORT, CONN.

In gneiss rock. Depth, 300 to 800 feet.

"We have drilled several wells in Connecticut, especially near Bridgeport. They vary in depth from 300 feet to 800 feet. Rock was generally met with very near the surface. Formation, granite, with good results for water."

WELL AT DUNWOODIE, N. Y.

In gneiss rock. Depth, 775 feet.

"We have just completed a well at Dunwoodie, about eight miles north of New York City. Rock was found about 25 feet from the surface. The rock is of very hard granite formation, and the same character all the way. It is 775 feet deep, with a moderate supply of water."

WELL AT ARBUTUS, MD.

In rock. Depth, 775 feet. Well not finished.

"We are at present drilling a well at Arbutus, for the Manual Industrial School for Boys, about eight miles south of Baltimore. Rock was met with at 28 feet from the surface. We are down about 465 feet, with very little water. The rock is of the hardest character, but we are going deeper."

II.

Sec. 2. Bored Wells Reported by W. R. Osborne.

In response to our request, W. R. Osborne has kindly furnished the following information respecting wells put down by him during the year in Somerset and Middlesex counties, and on Staten Island. We insert his descriptions verbatim.

Some of the wells draw their supply of water from the glacial drift, and some from the red shale and sandstone formation belonging, according to the nomenclature of last year's report, to the Newark system. A well at Runyon, put down by him, has been incorporated with the wells classified under the heading of "Wells in the Northern Part of the Cretaceous Belt." (See page 246.)

BORED WELL IN NEW BRUNSWICK.

In red shale. Depth, 146 feet.

"I also drilled a six-inch well for Mrs. B. Zimmerman, Burnet street, New Brunswick; 16 feet to shale; finished at 146 feet. Some of the shale was very hard in this well, unlike any others I have drilled in New Brunswick."

BORED WELL AT WOODBRIDGE.

Diameter, 4 inches; depth, 56 feet.

"This well was bored for M. D. Valentine & Co., at a dwelling south of their Woodbridge factory. It was drilled through sand and gravels to a gravel bed, where water was obtained. The water-bearing gravel is reddish."

TWO BORED WELLS NEAR VALENTINE STATION, LEHIGH VALLEY RAILROAD.

Well No. 1..............Diameter, 4 inches; depth, 140 feet.
Well No. 2.............. " 4 " " 136 "

RECORD OF WELL NO. 1.

"Commenced in bottom of dug well		18 feet.
Fine sand	60 feet =	78 "
Red shale to water at		140 " "

"Well No. 2 is about 300 yards south of No. 1, with about the same record except that water was found in larger quantities. Well No. 1 was torpedoed with dynamite after the well was completed. These wells developed the *red shale deposit much farther* east than I expected to find it."

BORED WELL AT SAND HILLS, BETWEEN AMBOY AND BONHAMTON.

Soft strata to 100 feet; red shale to 202 feet.

"I have bored a well for David Brown on top of the ridge on Sand Hills road, between Amboy and Bonhamton. Sand, gravel and clays to 89 feet, where coarse sand was met with, and some water. Being unable to keep the sand down, the drilling was resumed, and at 100 feet red shale was found. After drilling to 202 feet water in sufficient quantity was discovered to supply the needs of the dwelling and barn. I may add that this well is the farthest east of any well I have found red shale in of all the wells I have sunk in the neighborhood. Water stands at 90 feet from the surface."

BORED WELLS IN TOTTENVILLE, STATEN ISLAND, N. Y., OPPOSITE PERTH AMBOY, N. J.

Depths, 28, 51 and 54 feet.

"During July of this year I sunk some test wells for the town of Tottenville, Staten Island, just across the sound from Perth Amboy. After passing through 20 feet of sand and gravel, I found a gravel bed at 21 feet giving quite a flow of water; then, passing on down, at 51 feet there was another layer of gravel. The material above this stratum of water was composed of hardpan.

"Since I sunk the test wells, a number of 3-inch pipes were sunk to the depth of 28 feet by the parties who have the contract for building the water works. These wells were non-productive. Since then they have sunk one 6-inch well to 54 feet, finding the same bed of gravel I found at 51 feet."

FOUR BORED WELLS AT PLEASANT PLAINS, STATEN ISLAND.

Diameter of each, 4 inches; depths, 28 to 56 feet.

"Recently I have sunk four 4-inch wells at Pleasant Plains, Staten Island. These wells all obtain water at from 28 to 56 feet, according to the elevation of the surface. I find the drift about the same over all the lower portions of the island composed of sands and gravels:

"No. 1 well, at Methodist Episcopal parsonage. Depth, 37 feet.

"No. 2 well, at Mr. Winant's, near Staten Island Rapid Transit railroad. Depth, 28 feet.

"No. 3 well, at W. W. Maull's dwelling, on the Amboy road. Depth, 33 feet.

"No. 4 well, at the residence of Wm. Androvet, on the hill, east of north of the public school building. Depth, 56 feet.

"A peculiarity of Mr. Maull's well is this, the water is very soft, while just across the fence, in the next lot, there is an open well, 21 feet deep, with water quite hard. I have noted this fact in several neighborhoods, and have wondered if there is not something in the surface formation which affects the water passing into the open wells."

II.

Sec. 3. Wells Reported by Stotthoff Bros. Mostly in the Red Sandstone Region, Though a Few are Along the Delaware River, below Morrisville, Pa.

The following thirty-three wells are reported by Stotthoff Bros. as having been drilled by them the past year:

LAFAYETTE, FOR HENRY BREMER.

"Commenced in bottom of old well at the depth of	20 feet.
Limestone	20 "
	40 " "

ANDOVER, FOR P. J. CRISPEL.

"Dark-gray sand to the depth of	42½ feet.

"Water, 10 gallons per minute."

ALLAMUCHY, FOR JOHN JILSON.

" Loose stones and gravel	32 feet.
Gray rock	6 "
	38 "

" Water, 2 gallons per minute."

ALLAMUCHY, FOR JOHN MARTIN.

" Loose stones and gravel to the depth of	64 feet.

"At the bottom, fine sand; had to use screen. Water, 6 gallons per minute."

HUGHESVILLE.

" Sand and gravel	29 feet.

" Water, 12 gallons per minute."

FLANDERS, FOR W. S. YEAGER.

" Commenced in the bottom of a dug well at the depth of	20 feet.
Sand and loose stones	28 "
	48 " "

LAKE VIEW, FOR FERDINAND DU LAC.

" Earth and sand	23 feet.
Red sandstone	37 "
	60 "

" Water at 30 feet, 10 gallons per minute."

CLIFTON, FOR P. J. KIPP.

" Dark-yellow sand	40 feet.
Sandstone	61 "
	101 "

" Water 12 feet from the surface at 15 gallons a minute."

CLIFTON, AT MRS. HENRIETTA ROSENBERG'S.

" Clay and sand	37 feet.
Sandstone	58 "
	95 "

" Water 10 gallons per minute 10 feet from the surface."

PASSAIC, AT LYMAN CISCO'S.

" Started in the bottom of a dug well at the depth of	21 feet.
Red sandstone	90 "
	111 "

" Water came within 29 feet of the surface and yields 10 gallons per minute."

PASSAIC, FOR S. N. DE FRIES.

" Sand and clay	26 feet.
Sandstone	49 "
	75 "

" Water rose to 24 feet, pumps down to 31 feet, at 10 gallons per minute."

PASSAIC, FOR LOUIS LOCKER.

" Red sandstone to	47 feet.

" Water, 4 gallons per minute."

PASSAIC, FOR JOHN ALNOR.

" Clay and sand	24 feet.
Red sandstone	23 "
	47 "

" Well pumped to the bottom, 3 gallons per minute."

FORT LEE, FOR CHARLES WENZEL.

" Earth and stones	12 feet.
Trap rock	..... "
	.... "

" Water, 2 gallons per minute."

AFTON, NEAR MADISON, FOR MRS. D. D. JENNINGS.

" Sand and coarse gravel to the depth of	67 feet.

" Water 43 feet from the surface at 10 gallons per minute."

BASKING RIDGE, FOR B. A. BEAL.

" Commenced in old well at a depth of	35 feet.
Red rock and yellow shale	77 "
	112 "

" Water, 2 gallons per minute."

BASKING RIDGE, FOR I. H. TUNIS.

" Red and yellow shale rock, surface to the depth of	81 feet.

" Water, 2 gallons per minute."

MILLINGTON, FOR W. W. ARMFIELD.

" Earth	25 feet.
Red shale	66 "
	91 "

" Water, 8 gallons per minute, at 53 feet from the surface."

BAYWAY, FOR JOHN STEVENSON CAR COMPANY.

Diameter, 8 inches.

" In red shale and rock to	250 feet.

" Water, 60 gallons per minute, at 23 feet from the surface."

BAYWAY, FOR JOHN STEVENSON CAR COMPANY.

Diameter, 8 inches.

" Red rock and shale to	300 feet.

" Water, 95 gallons per minute, at 28 feet from the surface.

" We have presented samples in glass tubes from these two wells to the Geological Survey."

CASTLETON CORNERS, STATEN ISLAND, N. Y., SOUTH OF BERGEN POINT, N. J., ACROSS THE KILL VON KULL.

" Earth	33 feet.
Hardpan and shale rock	53 "
Soapstone (*serpentine*)	64 "
	150 "

" Water rises to 63 feet from the surface at 8 gallons per minute."

BOUND BROOK, FOR THE MIDDLEBROOK HEIGHTS ASSOCIATION.

" Earth	15 feet.
Red shale rock	102 "
	117 "

" Water at 15 feet from the surface, 60 gallons per minute."

NESHANIC STATION, FOR MISS DORA BEITLER.

" Earth	12 feet.
Soft red shale	73 "
	85 "

" Water rose to 16 feet from the surface, pumped to 24 feet, at 15 gallons per minute."

THREE BRIDGES, FOR JOHN A. VAN FLEET.

" Earth	14 feet.
Red shale	60 "
	74 "

" Water, 10 gallons per minute, at 52 feet from the surface."

FLEMINGTON, FOR E. W. BARNES.

" Loose earth	4 feet.
Red bastard shale and sandstone, very seamy	98 "
	102 "

" Water rose to 44 feet, pumped down to 53 feet, at 10 gallons per minute."

FLEMINGTON, FOR H. E. DEATS.

" Earth	12 feet.
Red shale	84 "
	96 "

" Water, 30 gallons per minute, 60 feet from the surface."

PRINCETON, FOR F. A. DOHM.

" Bluestone, very hard, to the depth of	80 feet.

" Water, 12 gallons per minute."

YARDVILLE, FOR DAVID HENDRICKSON.

"Sand, &c., to	271 feet.

"Water rose 65 feet from the surface; yielded 20 gallons per minute." (See page 281.)

[The following five wells are at localities on the Pennsylvania side of the Delaware river, and near or on the line of the New York division of the Pennsylvania railroad.—L. W.]:

MORRISVILLE, PA., FOR CASE & CAIN.

"Started in bottom of dug well at the depth of	26 feet.
Sand and blue clay	39 "
Hard gray granite rock	71 "
	136 "

"Water came within 24 feet of the surface, but pumped down to 65 feet, at 10 gallons per minute."

BRISTOL, PA., FOR SOLOMON WILDE.

"Sand and gravel, surface to	122 feet.

"Water rose within 9 feet of the surface, but pumped down to 40 feet, at 35 gallons per minute."

CROYDON, PA., FOR W. H. VANDEGRIFT.

Earth to	24 feet.
Mica rock, with hard and soft seams	124 "
	148 "

"Yields 25 gallons per minute."

CORNWELLS, PA., FOR CHARLES M'FADDEN.

"Earth and sand to	31½ feet.
Soft mica rock	58 "
	89½ "

"Water rose to 18 feet from the surface, but pumped down to 28 feet, at 10 gallons per minute."

TORRESDALE, PA., FOR E. D. MORRELL.

" Earth and loose gravel	32 feet.
Mica rock	169 "
	201 "

" Water rose to within 3 feet of the surface, and pumped 12 gallons per minute, at 100 feet from the surface."

II.

Sec. 4. Wells.—Information Communicated by George E. Jenkins and Others.

WELLS AT DOVER AND VICINITY.

George E. Jenkins, of Dover, N. J., writes as follows respecting wells at that place and vicinity:

No. 1. " In reply to your favor for information in reference to the artesian wells sunk in Dover, I would say that Mr. S. T. Smith sank a well on his property, located on the top of the terminal moraine, elevation above tide 630 feet, west of Dover, on the south side of the road leading from Dover to Mine Hill, and about three-fourths of a mile from the Delaware, Lackawanna and Western depot. This well was sunk in 1886, and was put down 135 feet. The record was as follows:

45	feet sand, cobbles, boulders and such materials as found in terminal moraine.
80	feet quicksand.
8	feet blue potters' clay.
2	feet quicksand. and at this point struck bed-rock.
135	

" The well is not a flowing well, but the water raised to within 60 feet of surface. The water was not satisfactory, as it was always 'roily.' "

No. 2. " The well at the stove works was driven 60 feet, when a flowing well was secured. The size of the well was 6-inch. The record was as follows:

11 feet of soft mud and boulders..
10 feet hardpan.
5 feet quicksand.
31 feet sand, mud and boulders.
—
57

"At 57 feet struck rock and drove into it 3 feet, when a flowing well was secured. Mr. William Cramer, of Paterson, N. J., did the work."

No. 3. "The well at the Delaware, Lackawanna and Western railroad was put down 153 feet, striking rock at 145 feet. It is a 6-inch well.

"Two 5-inch wells, Nos. 4 and 5, below, were put down at the car shops."

No. 4. "The one in the paint shop was a 6-inch well, and put down 214 feet, when a flowing well was secured. The record of the well was about as follows:

50 feet hardpan.
60 feet quicksand.
16 feet rock (evidently boulders).
88 feet gravel.
—
214

"Bed rock was not developed, and as the well was producing excellent water in quantity, the work was carried on no farther."

No. 5. "The second well was sunk about 800 feet farther east, and was of the same size as the first one, but it was put down 224 feet before a flowing well was secured. The character of the material through which the well was driven was much the same as in the first well. David Salkind, of Morristown, put down these three wells" (Nos. 3, 4 and 5).

No. 6. "The well put down by the city of Dover was driven over 200 feet, but no water was secured. Mr. William G. Cramer drove this well also."

No. 7. "In 1896, David Salkind put down a 5-inch well at the Dover Rolling Mill for a distance of 130 feet, but it is not a flowing well."

WELLS AT MOUNT ARLINGTON AND DENVILLE.

George E. Jenkins also writes respecting wells at the above locations as follows:

"In 1891 David Salkind put down a 5-inch well at Mount Arlington station, on the Delaware, Lackawanna and Western railroad. He drove down 267 feet, through sand, when he struck shaly material of graphite (?) composition. The well was not a flowing well; the water rose to within 60 feet of the surface.

"I believe a well was also put down by this man at St. Francis Sanitarium, Denville."

[The records at Dover and vicinity, and at Arlington and Denville, are especially interesting as showing the great thickness of the glacial drift in this region of northern New Jersey.—L. W.]

ARTESIAN WELLS AT UNION, NORTHWEST OF ELIZABETH.

35 sand wells, depth of each about	103 feet.
10 rock wells, " " " "	500 "

All said to be flowing wells.

We are informed forty-five wells have been put down at Union, three and one-half miles northwest of Elizabeth station. Thirty-five of these were put down to the depth of about 103 feet to rock, finding an abundance of water at that depth. The other ten were continued into the rock (Triassic) to the depth of about 500 feet. All the wells are reported as flowing wells. The total overflow is said to be 2,000,000 gallons in twenty-four hours. We are also informed that a pumping test was made, showing 6,000,000 gallons per twenty-four hours, the water being then lowered to from 13 to 28 feet from the surface. The wells are in a marsh, which the borings show to have a depth of 20 feet. The record, in brief, is as follows:

Marsh mud	20 feet =	20 feet.
Alternations of sand, clay and gravel to rock, water at the base	83 " =	103 "

Rock Newark (Triassic).

PART V.

DRAINAGE
OF THE
HACKENSACK AND NEWARK TIDE-MARSHES,

BY

C. C. VERMEULE.

DRAINAGE OF THE HACKENSACK AND NEWARK TIDE-MARSHES.

This project, on which a preliminary report was made last year, has received some attention from the communities interested during the year. The reasons for making this improvement, urged in our last report, were that the metropolitan district of the State, comprising a population of about one million people, would thereby experience material relief from mosquitoes, which now breed in large quantities on the marshes; that the malarious exhalations of this great area of brackish marsh would be mitigated, and the prejudice which it creates in the minds of the multitude of people who annually cross it on the great trunk lines leading to all parts of the country would be removed. It was also pointed out that there is a marked tendency to an accumulation of nuisances of all kinds, such as manure-piles, slaughter-houses and fat-rendering establishments. The gradual saturation of the marshes with sewage and manufacturing wastes is also steadily increasing the danger to the healthfulness of the surrounding communities. As the population within the influence of the marshes, between the Orange mountains and the Hudson river, is now increasing at the rate of about four hundred thousand people each ten years, all of these evils will be greatly aggravated during the next twenty years, in which time the population will practically double.

The enterprise is not urged as an agricultural measure. Whatever advantage the improvement may have in this direction is to be regarded as entirely incidental. When a district becomes as populous as this, and is growing at so rapid a rate, it requires a reasonable amount of foresight to preserve its prosperity. The city of New York had only about half as much population when it established its great Central Park, and many similar enterprises, undertaken with proper foresight, have contributed to the prosperity of that city.

The uplands all about this meadow district are admirably adapted for residential purposes. Indeed, we find here unquestionably the most attractive suburbs accessible to the four millions of people comprised within a radius of fifteen miles of the New York City Hall. Manufacturing and commercial enterprises naturally seek the lower levels of a district, and proximity to navigable waters. The water front about New York harbor is being rapidly taken up, and much of it has become too valuable to be used for large manufacturing sites. These great industries should be given an opportunity to locate about Newark bay, the Passaic and Hackensack rivers. This is far preferable to having them scattered throughout residential districts, or driven elsewhere, and the application of this waste marsh land to such purposes will add very largely to the wealth of the State. Every such great community must have its commercial and manufacturing center, and the marshes are admirably fitted to serve this purpose, leaving the upland for residences.

It would, of course, be desirable that the drainage of the marshes should be done by private enterprise, if it could be so accomplished successfully. There is no doubt that some favorably-situated portions of the meadows can be reclaimed very profitably in this way. There are difficulties, however, in the application of private enterprise to the whole area of marsh lands. Private companies cannot exercise condemnation powers; and, excepting where large tracts are held under a single ownership, this will interpose serious difficulties. It is also certain that private enterprise would select only the most favorably situated tracts, and improve these, thereby aggravating the unwholesomeness of the portions left unimproved. Another difficulty which tends to discourage piecemeal improvement by private enterprise is that such improvement is made directly in the face of surrounding nuisances which depreciate the value of the improvement. A visit to the borders of the marshes, where they have been filled up and occupied, on the outskirts of Newark and Jersey City, will satisfy one as to this. The unsanitary conditions and the uninviting aspect presented by the surrounding unimproved marsh lands is sufficient to deter purchasers of any land improved upon their borders. If private enterprise should operate on a large enough scale, undoubtedly some of these difficulties would be removed.

The above objections apply equally to independent action on the part of the municipalities. It is true that the city of Newark has within its limits a large tract of meadow, the improvement of which would be a great benefit to that city. But if this is improved separately by the city of Newark, there is a considerable area of marsh lying immediately adjacent to it on the south, within the limits of Clinton township and the city of Elizabeth, and also the great tract in Kearny township, which, if left unimproved, will tend to depreciate the value of the Newark improvement. If, on the other hand, the whole tract of marsh land is wiped out at one stroke, as it may be through a public improvement, Newark and Jersey City will then have no difficulty in finding occupants for their improved lands; and if they will acquire and gradually improve the water front within their limits, and lease it as fast as a market is found for it, they will ultimately secure great pecuniary and commercial benefits.

The conditions, therefore, seem to favor a comprehensive public improvement, and naturally the question that is uppermost in the minds of the interested parties is, by what means can the improvement best be accomplished? It consequently appears proper to outline herewith a method of treatment which seems most feasible, and calculated to secure the largest measure of advantages. With a plan of this kind in mind, we can later take up some of the details and consider the engineering problems more intelligently.

The first important question is, by whom shall the cost be borne? A careful study of the problem indicates that while under a judicious scheme of improvement a considerable part of this land will speedily find a market at profitable prices, nevertheless this cannot be true of the whole twenty-seven thousand acres. So large a tract cannot be marketed advantageously for many years. To throw the whole cost of the improvement upon the marsh land, therefore, will probably defeat the enterprise. It is doubtful if drainage bonds, which are simply a lien on the drained marsh land, can be marketed. While unquestionably these lands will, in a reasonable period of time, be worth very much more than the cost of the improvement, they could not be quickly marketed for the necessary amount, consequently might not offer tempting security for the necessary issue of bonds. The benefits which we have outlined, and which will accrue to the adjacent upland communities, will be very substantial, and will result in making them much more attractive, and increasing their real estate values. It is only proper that these advantages should be recognized in adjusting the assessments.

The impression seems to have got abroad that it is proposed to condemn the entire area of marsh land and hold it under public ownership, to be sold at a profit after executing the improvement. However great the pecuniary advantages of forming a great public trust, like the Clyde Trust, or the Mersey Docks and Harbor Board, of Liverpool, might be, such a measure has the appearance of a great speculative enterprise, and therefore it might not be favorably received by the people of the State or the communities directly interested. A much more conservative plan, and one which we think would commend itself to the public, is to leave the property in the hands of its present owners so far as possible, giving the proposed drainage commission power to condemn only the small amount of land needed in building the embankments, the main ditches, pumping plants and other structures essential to the improvement. Should Newark, Jersey City and the other municipalities wish to take over and own the water front and improve it on the lines which have been followed with such marked financial success by the city of New York, and which have secured such benefits to its commerce, they should certainly be given the opportunity to do so. There can be no question that such a policy would be ultimately advantageous.

We therefore suggest in outline the following plan of improvement as best calculated to meet the conditions and to secure public support:

Let the necessary legislation recognize the metropolitan district of the State, lying between the Orange mountains and the Hudson, and extending from Elizabeth northward to Paterson, Hackensack and Englewood, to be what it unquestionably is rapidly becoming, one community with identical interests. Let a drainage district be created including the whole. Next create a drainage commission either under a new law or by judicious amendment of the law of 1871. Let this commission have power to issue four per cent. bonds, payable in twenty-five years, to cover the cost of the improvement, such bonds to be a lien on the land drained and on the assessments. Provide for interest on the bonds and a sinking fund sufficient to retire them, when due, by assessment; one-half of the necessary amount to be levied upon the lands drained, and the other half upon the surrounding upland communities. Let all cost of maintenance, pumping and administration be levied upon the lands drained. The commission would first prepare comprehensive plans of drainage; and should also have power to fix, in concert with the United States authorities, pier and bulkhead lines and plans of improvement for the navigable channels. In order that future improvements shall not interfere with the drainage plans, the commission should have power to fix street lines and grades, the grades of sewers, and its approval should be necessary to the alignment and grade of future railway lines crossing the marshes. The ultimate improvement of the water front, either by the cities or the individual owners, should also be made subject to the approval of the drainage commission. The actual execution of the plans by the commission, however, should be limited to constructing the embankments to exclude the tides, the sluices and pumping plants, and the main ditches needed for effective drainage of the entire area. The commission should also maintain and operate these works indefinitely. As soon as the marsh has been rid of water the commission should have the power to compel the owners of the land to ditch and improve it to an extent which will rid it of all stagnant water lying on the surface. From a sanitary point of view it would be desirable to have the whole area either brought under cultivation or seeded to grass, which should be grazed or mowed regularly. If the owner of the land should fail to put it in proper condition the commission should have the power to do so, and to assess the cost upon the land. This done, the district would present an inviting aspect and wholesome conditions. While the commission would see that its plans were conformed to, the further improvement, such as the grading of streets, sewering, building of wharves and filling up of the water front, should be left either to the municipalities or to the owners of the marsh land.

Our estimate of the cost of this preliminary improvement, in last year's report, did not cover the cost of necessary lands, of pumping plants or administration. The pumping plants would, in many cases, not be needed for from five to ten years after embanking, as the drainage could be effected by sluices. In other cases they should be introduced at once. To cover these additional items liberally we may double our estimate, placing the cost of preliminary improvement at $2,500,000. We have for interest, therefore, $100,000, and for sinking fund, $60,000, to be raised annually. One-half of the total, or $80,000 annually, we have proposed to assess upon the surrounding communities. The assessed valuation of the proposed drainage district is $430,000,000. The assessment, therefore, would amount to about twenty cents on each $1,000, added to the present tax rate. It would cost the average head of a family about forty cents annually, at the beginning, decreasing to twenty cents as the population increased, and entirely ceasing in twenty-five years. This would represent the cost of obtaining a very large measure of relief from the mosquito nuisance and a very substantial increase in real estate values throughout. Indeed, on the whole, the addition to property values which would result, would go far to reduce even this slight charge.

The cost to the owners of the marsh land would average $3 per acre annually, and to this there would have to be added for maintenance about $1, and later on, when pumping becomes general, $3.75 more, or a total charge per acre of $7.75 until the bonds are retired, when the cost falls to $4.75 per acre annually. It is safe to say that, with the appreciation of values of the marsh land, this annual charge would not be burdensome. Of course, these are only average figures. The assessment upon the lands drained should be upon a careful valuation, and not by the acre.

There has been some surprise expressed that the estimated cost of the improvement should be so small, but it should be borne in mind that the plan which we have outlined calls only for such a preliminary improvement as will put the marshes in good sanitary condition and place them on an equal footing with adjacent upland. It is not proposed that there shall be any outlay for the building of wharves, filling of land, or other expensive improvements. This is to be left for the owner of the marsh land, and need not be done until a market is opened for the land thus improved. It is also intended that the final ditching and clearing up of the land shall be done by the owners or lessees. This part of the improvement is very important as a sanitary measure. No matter how well the preliminary work of the commission may be executed, or how good an outlet for drainage may be provided, if the owner of the land does not put the surface in good condition, the full benefits of the improvement will not be enjoyed. For this reason we would make such an improvement compulsory.

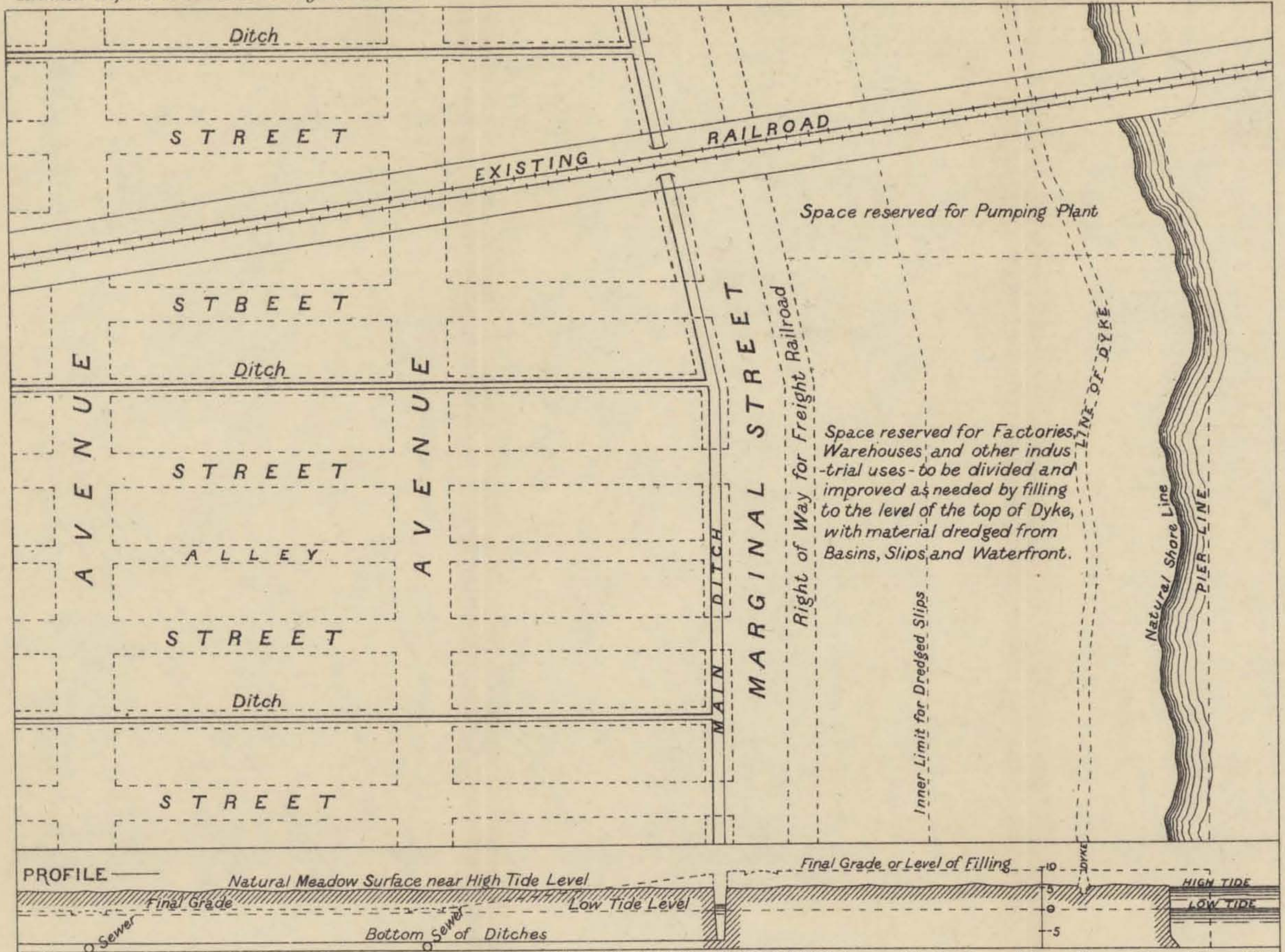
In order to place clearly before the reader the successive stages of the improvement, as we believe it should be conducted by the proposed drainage commission, we have prepared the three accompanying illustrative plans. These are intended merely as suggestions. First, in order that the drainage work may be adapted to future requirements, and may be permanently successful, the nature of the ultimate improvement of the marshes, and the general lines on which the improvement should be executed, must be carefully studied, and a comprehensive plan adopted by the drainage commission, so that every step taken may keep in view a wise and successful permanent improvement. The proposed commission should first survey carefully and lay out the marsh district in the general manner indicated in Plate X. Pier and bulkhead lines should be established along the rivers, leaving ample waterways. A belt of land extending back from 600 to 1,000 feet from the pier lines should be set aside for factory sites, wharves and business enterprises requiring both ample space and water frontage. Along the inner margin of this belt there should be a right of way set apart for a freight railroad connecting the shore front with the various railway lines. On the land side of this railway strip there should be a highway, and next to this should be the main drainage channel to receive the drainage of the lands within. Inland from this the marsh district should be laid out in streets and building lots. Along the railway lines there should be ample space reserved for factory sites and other industrial enterprises. The system of grades should be so fixed by the commission as to provide for the filling up of the water front, back to the main drainage channel, to the level of the top of the dikes, or somewhat above the highest known tides. Inland from the main drainage channel the grades should be adjusted to allow for subsidence of the marsh land. There should be no extravagant outlay in filling up these lands. The cost of maintaining the dikes and pumping will not exceed $4 75 per acre annually, and this is interest at 5 per cent. on $95. To fill the lands up to a level which would do away with the necessity of pumping would cost twenty-five or thirty times this amount.

The marshes having been laid out and the grades fixed as in Plate X., the commission would execute only that portion of the work shown in Plate XI., namely, the dikes, the principal ditches and sluices, and, as fast as they are needed, the pumping plants. Let all the rest of the work be done by the owners or the municipalities. The cities, for instance, would open up and grade the streets and build and maintain the sewer system as they do elsewhere, although these would all conform to the plans laid down by, or be subject to the approval of the drainage commission. The water frontage would be improved by the owners of the land, or, if acquired by the cities, under the direction of the city authorities, but subject to the plans adopted by the drainage commission. The drainage commission would remain in control of all its original drainage works, and this control should be extended to the supervision of all of the private ditches. The drains would ultimately have to be faced with stone, and some of them might be arched over and covered in. No sewage should be allowed in them.

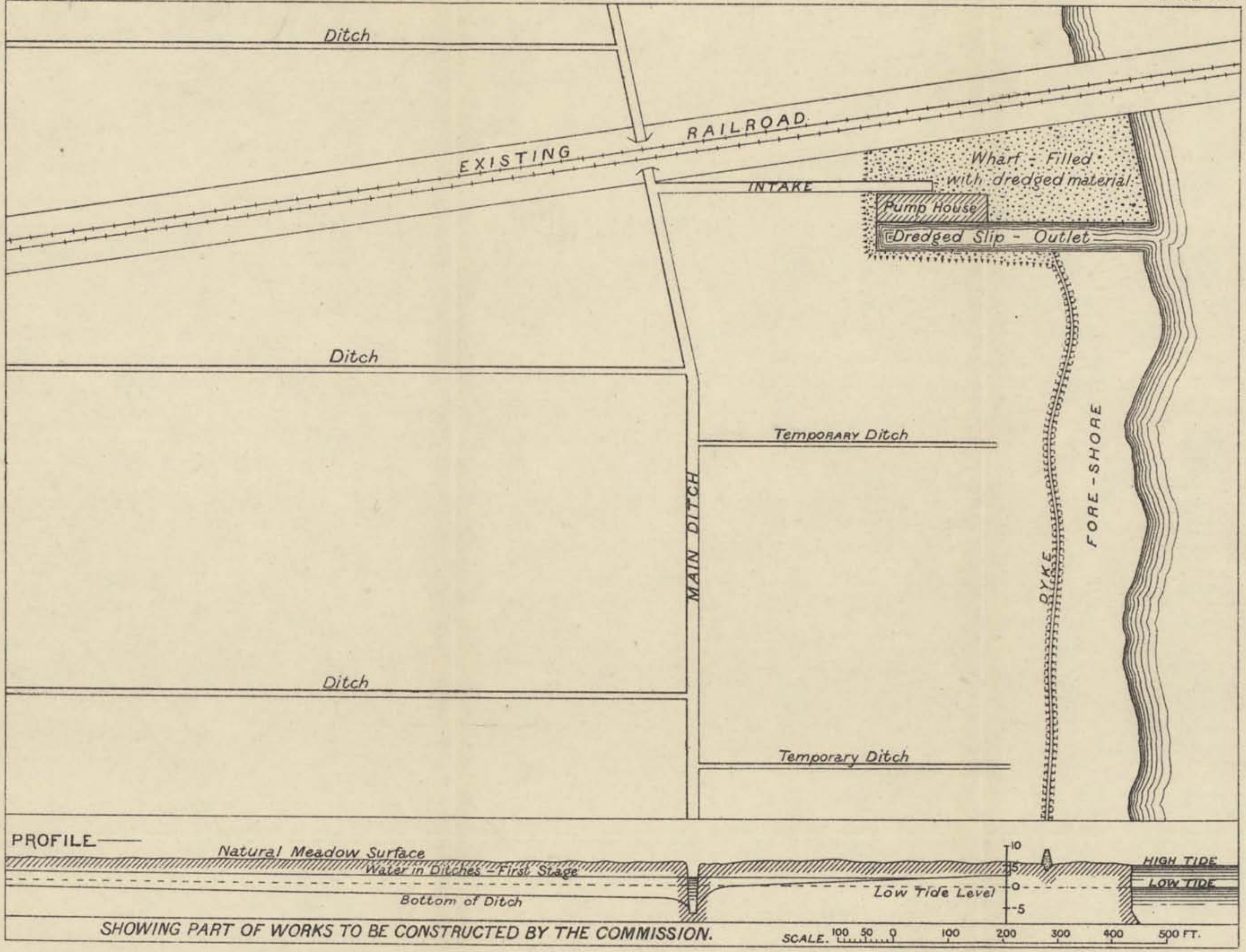
The ultimate stage of the improvement, indicated in Plate XII., will be largely effected by private or municipal enterprise. The work of the commission will pave the way for it by removing those nuisances and prejudices to which the neglected marshes give rise; but immediately following the execution of the work of the commission, as shown in Plate XI., nearly all of the meadows will be devoted to agriculture. Dairying, market-gardening and such other agricultural pursuits as have been successfully followed in Holland, should succeed here in the interval which will occur between the reclamation of the marshes and their occupation for industrial and residence purposes. The ultimate development shown in Plate XII. would begin at once near Newark and Jersey City, and in other favorably-situated parts, but many years must elapse before it would extend over the entire 27,000 acres; for this area is ample to accommodate the homes and industries of over one million people. The rate of increase which has prevailed during the past quarter of a century, if continued, will produce a total population of four millions in the metropolitan district of this State by 1940, so that, if the meadows are reclaimed as herein suggested, it is entirely within the bounds of probability that many adults of the present day will live to see the entire reclaimed area occupied as a city.

Plate XII. shows how a comprehensive and carefully-planned scheme of development would result in giving both rail and water transportation for large industrial enterprises along the entire water front. It will also be seen that it is not proposed to burden the enterprise with a heavy interest charge by a development in advance of actual needs. So soon as the marsh lands are brought into good sanitary condition and so improved that they cease to be a nuisance threatening purchasers or lessees of improved lands, there need be no further expense incurred until a market is immediately available for the property improved.

It will also be noted that there is no need that the drainage commission shall interfere with private enterprise to any greater extent

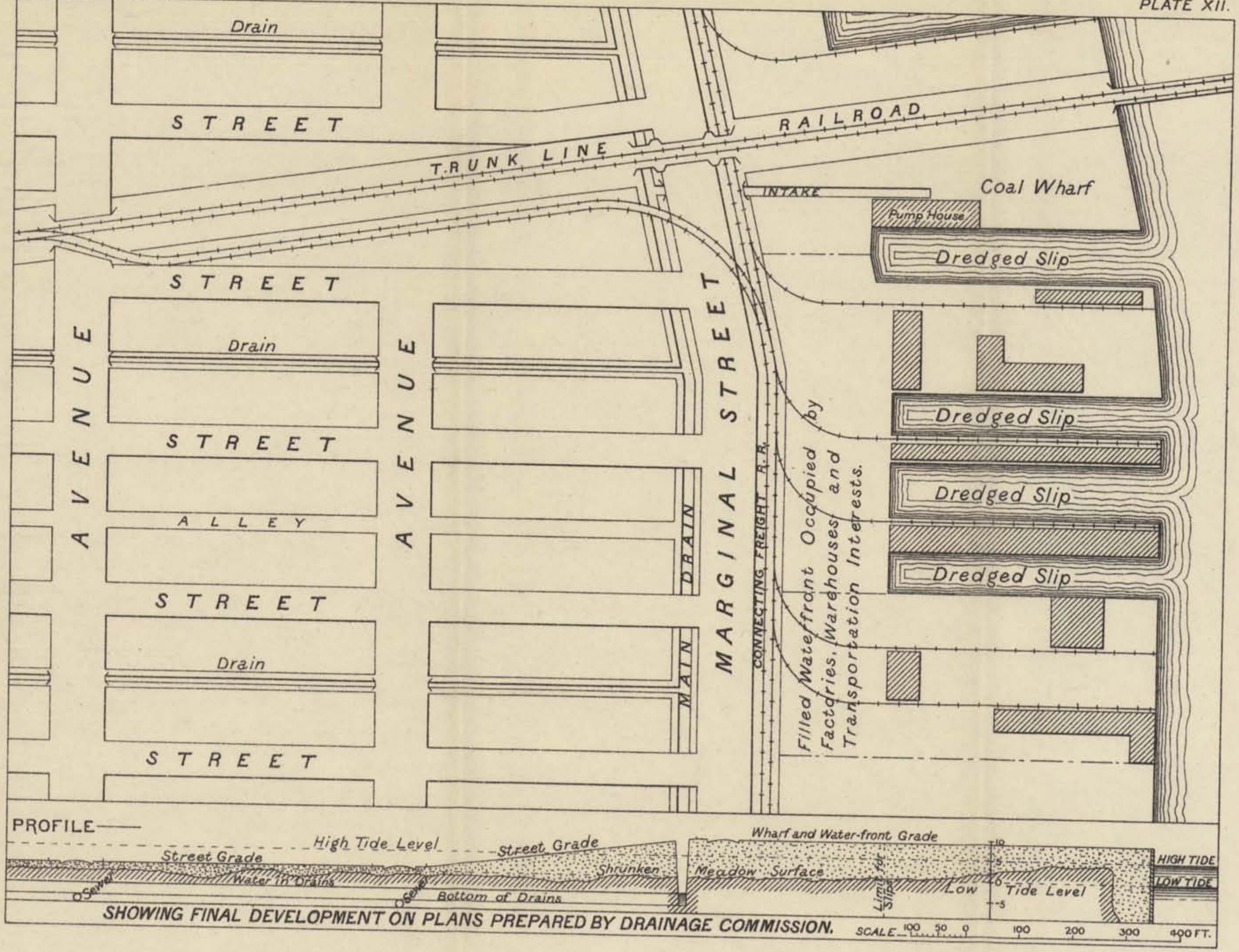


SHOWING SCOPE OF PLANS TO BE PREPARED BY DRAINAGE COMMISSION.



SHOWING PART OF WORKS TO BE CONSTRUCTED BY THE COMMISSION.

PLATE XII.



SHOWING FINAL DEVELOPMENT ON PLANS PREPARED BY DRAINAGE COMMISSION.

than our cities do at present when they lay out and adopt a general system of streets and grades, construct sewers, &c. The functions of the drainage commission would be very similar to those of a municipal department of public works, yet it would not interfere with existing municipal government more than would be absolutely necessary to secure the best sanitary and economic results.

Some of the evils of leaving such a great undertaking as this for independent action, by municipalities or private parties, with no comprehensive plan, are illustrated in the history of the reclamation of marsh lands in Sacramento valley, California. (See the Report of the Commissioner of Public Works for 1894.) The State of California became the owner of about one and three-quarter million acres of these swamp, tide and salt-marsh lands by a grant of the United States in 1850. This grant was made in order that the lands might be reclaimed. After various grants had been made by the State to private parties undertaking to reclaim portions of the land, a law was finally passed which resulted in the formation of a series of ill-planned drainage districts, to be operated upon separately. Under this law the State parted with about one million acres of its land, which was taken up for reclamation, in tracts of all sizes, by private parties. We quote the following from the commissioners' report, page ix: "Many of the parties acquiring these lands have made strong efforts to reclaim their possessions. Some have impoverished themselves in such efforts. Where naturally favorable conditions and persistent work have been combined, a reasonable success has been attained, so far as land protection is concerned, but the important feature of adequate channel capacity for floods has been neglected." Again we quote: "Most of these operations have met with but partial success. Where successful it has been from a combination of vigorous work and favorable circumstances, or an ability on the part of the owners on one side of the river to construct more powerful levees than there are on the other side." Speaking of the cost of these works, the report says: "Upon these lands and adjoining river channels vast sums of money have been expended, much of which is generally acknowledged to have been without adequate return. Instead of treating the subject as a whole, which it is, it is divided into several hundred reclamation swamp land or protection districts. These districts sometimes have natural boundaries, although most of them are arbitrarily bounded by property or other lines. The authorities of each district have been supreme, so far as the works in that district are concerned, and have located and built them in many instances irrespective of the effect upon the river or other lands." He sums up the total cost of the work done thus far at $18,090,748.65. The commissioner says further: "Should the State only prescribe a system and furnish the supervision and advice necessary to secure unity of action on the part of the disjointed interests now at stake, a great advance toward ultimate success would at once be made." The commissioner recommends that the whole improvement be now taken up and carried to a successful conclusion by the State, under a comprehensive plan, and the aggregate cost of the necessary works is estimated at $9,287,000. In submitting this estimate, the consulting engineers, Messrs. Manson and Grunsky, say: "It will be borne in mind that there has already been expended upon the lower rivers more than $17,000,000 for reclamation and protection purposes, without adequate returns, and that from a quarter to a half million dollars is being annually spent. It is needless to further urge the necessity for the adoption of a general drainage system looking to the control of flood waters. The execution of the works involved in such a system would vastly increase the wealth of the State." They further say (page 70): "In devising means for the carrying out of these works, provision should be made to have their cost fall upon the entire area benefited thereby; not upon swamp and overflowed land alone, but upon all land subject to or in danger of periodical inundation in the Sacramento valley, and upon all districts, even though already better protected than adjacent territory, where the contemplated works will reduce the danger to overflow in times when the river is at flood stages; * * * but above all things unity of action is essential and a supervision of the work by competent State authority is requisite to make the project a success."

We should not fail to benefit by this extremely costly experience in the Sacramento valley. It is striking testimony to the necessity of having the Hackensack meadows works under a single board, and having them carried out upon a comprehensive and carefully-designed general plan.

Some of the difficulties thought to be in the way of the utilization of these marshes have been greatly overrated in the popular mind. For instance, it is a common belief that the failure of the enterprise in Kearny township, along the Pennsylvania and Delaware, Lackawanna and Western railroads, was due to the riddling of the banks by muskrats. This is not the case. These drainage works of the Pike estate, as we stated in our last report, while they have not been kept in thoroughly good condition, are nevertheless so effective that from personal observation we find the water-level on that property to be fully three feet below the level of high tide outside of the banks. If somewhat larger sluices had been provided this level might have been further reduced, but with the present sluices all has been accomplished in the way of lowering the water-levels in the marsh that could reasonably be expected, and no serious leakage through the banks is indicated. The real difficulty with that improvement is that the marsh land has shrunk with the fall of the water until it has become again saturated. All that the improvement needs at present to make it thoroughly effective is a moderate amount of repair of the banks, a further opening of the ditches, and the lowering of the water-level by pumping. The expedient of introducing cast-iron plates in the heart of the dyke was a costly one. This was done to prevent the burrowing of muskrats. We believe that sheet-piling of creosoted lumber would answer every requirement. Again, we propose that the embankments shall be placed at a considerable distance from the river bank, not less than 100 feet, and we would also avoid the cutting of any ditch near the inner toe of the embankment. The habit of the muskrat is to enter the river bank, or the bank of a ditch, just below the water surface, and to dig inward and upward, forming his house above the water-level. If the dike is placed close to the river bank he burrows through it during this operation and causes a serious leak, but if it is placed well back, the probabilities are that he will not reach it at all, and this simple expedient would of itself remove this difficulty, even without the sheet piling. A liberal fore-shore, or space between the river bank and the dyke, also protects the bank from wash.

When we keep in mind that a part of the plan is the filling up of the whole shore, level with the top of the embankments, there can be no objection to liberal margins outside of the banks. The river bank is, moreover, as a rule, the firmest and best-drained portion of the marsh in its natural condition, so that there is no objection to be made from a sanitary standpoint to leaving it outside of the dyke.

Another difficulty which has been overrated is the question of securing foundations for buildings upon these marshy areas. It should be recalled that some rather important structures, such as the Pennsylvania railroad shops, already stand upon the marshes. The map published in last year's report showed the depth of the mud from actual soundings. A reference to this will show that over large areas this depth ranges only from seven to nine feet, and for all but an insignificant portion it is less than fifteen feet. The question of foundations presents no serious difficulties.

Something may be suggested as to the feasibility of the proposed work of reclamation by recalling what has been done on similar lines elsewhere. The reader is referred to a full description of the reclaimed lands of Holland, contained in the Annual Report of the State Geologist for 1892. We find that 840,000 acres of land have been so reclaimed in Holland, the most of which lies below the level of the sea. Perhaps the most interesting of the works of Holland is the drainage of the Haarlem mere southwest of Amsterdam. This great enterprise resulted in reclaiming 45,000 acres of land which was covered by a great body of water averaging 13 feet deep, and a portion of the land reclaimed lies over 20 feet below sea-level. The mere was navigable, and had a commerce amounting to over 700,000 tons annually. This commerce had to be provided for by a canal built around the margin of the lake, this canal being used also for drainage purposes. The removal of the water alone, which amounted to 832,000 tons, required a very heavy and expensive pumping plant and over four years of steady pumping. The total cost of reclamation was $3,600,000, or $80 per acre. The pumping, of course, has to be continued to remove the surplus rainfall, and the annual cost of maintenance amounts to about $1.62 per acre. The returns from land sold covered the cost of drainage, and eighteen years after removal of the water the value of the land was estimated to be $8,640,000, or considerably over double the cost of drainage. It will be seen that the difficulties in this case were much greater than the proposed work on the Hackensack meadows. Here the land will be free from water at the start; and instead of being at an average level 13 feet below the sea, it is slightly above high tide. There is no commerce to be provided for by navigable canals. As we showed last year, the amount of surplus rainfall to be removed is greater. In Holland the rainfall exceeds the evaporation by about 8 inches, whereas here the average excess is about 22 inches, or nearly three times as much; but, on the other hand, the lift of the pumps for the Haarlem mere is about three times greater than it will be on the Hackensack. This offsets the greater rainfall, and maintenance of the Hackensack meadows improvement should not be greater, excepting for such increase as may be due to the higher scale of wages prevailing in this country.

The extensive drainage works of the Fen country in England have also been carried out in the face of much greater obstacles and on a much larger scale than will be necessary on the Hackensack meadows. The area drained by the Bedford level of the Fens amounts to 300,000 acres. These Fen lands were noted sources of fever and ague until drained, after which they became much more healthful. The late Prof. Cook made a careful inquiry in this district about twenty-five years ago, and stated that he could not learn that the drained lands were considered less healthful than the drier uplands. Other instances of beneficial drainage works in England are the Romney marsh improvement and the drainage of the wet lands along the Stour, Medway and Thames, all of which works have had a most favorable sanitary result. Indeed, we have instances in our own State of sanitary benefits resulting from drainage works. In Salem county 15,225 acres of tide-marshes have been drained for agricultural purposes. Before drainage these brackish marshes caused malaria to such an extent that some of the old residents reported some years ago to the present State Geologist that there were not enough well people to take care of the sick. Since drainage malaria in that region has been quite uncommon.

The examples of drainage works which we have cited, and which have been successful from a financial and sanitary standpoint, are sufficient to justify us in expecting equally good results from the drainage of the Hackensack meadows. In none of those cases is the situation more favorable as regards nearness to great centers of population, or accessibility to navigable waterways. In none of the cases were the sanitary and other benefits extended to a larger number of people.

The statements which we have heretofore made as to the dangerous sanitary conditions now existing and likely to arise in the future from these marshy areas had been founded upon general experience. We have not heretofore thought it necessary to quote authorities in support of our position, believing that the danger of malarious exhalations is almost self-evident. There is, however, much to be found in a "Report of the State Board of Health of Massachusetts upon the Improvement of the Neponset River, 1897," which coincides with the views which we have hitherto expressed. For instance, in relation to the evil effects of malaria extending to the neighboring upland ridges, we find the following on page vi: "While it might be expected that the meadows should be uninhabited, as they are, it is not at first so easy to understand why the higher grounds in the vicinity should be still unoccupied by the rapidly-increasing suburban population which seeks and finds acceptable building sites at distances from the business center of Boston more considerable than any portion of the area in question. The facilities for transportation by convenient railroads are at least as good as can be found in other directions from Boston, and the towns which make up the district appear to be desirable places of residence. There has, however, for years existed a popular belief that the meadows have become a source of sickness, and this feeling seems recently to have increased. Intelligent observers report that these meadows are at times the source of disagreeable odors and the direct cause of much sickness." Also on page vii: "One farmhouse was found not far removed from the meadows, but lying many feet above their level, which, well built and well cared for, had failed to offer adequate protection against an influence which, originating beyond the immediate surroundings of the house itself, was sufficiently potent to affect more than half of the ten occupants of the house." We have also called attention to the danger of sewage contamination increasing the unhealthfulness of the region. The report above cited says as to similar conditions on the Neponset meadows: "The waste matters of human life, and the refuse of manufactories, when added to the waters of the stream, become efficient fertilizers for the vegetable substances that find a home there, and * * * by their decay give to the atmosphere odors which common experience as well as scientific knowledge declares to be injurious to health." An exhaustive examination of the Charles river, in the same State, also gives some evidence as to the increase in intermittent fever due to the increasing pollution of the stream, and its effect upon the flats bordering upon the river. (See Report of the Joint Boards upon the Improvement of Charles River, 1894.) This is of importance in considering what the result of leaving the Hackensack river marshes in their present neglected condition must be in the future upon the large population growing up about their borders. The rapid increase of sewage pollution in the Passaic river and Newark bay has been sufficiently considered in previous reports of this survey and also, more recently, in the report of the Passaic Valley Sewerage Commission of 1897.

In addition to this, we have a large number of smaller public and private sewers emptying directly upon the marshes throughout almost the entire extent of their borders. This condition of things, taken together with the fact that the marshes are frequently subject to a slight overflow of the tides, and are kept constantly saturated with water, is a sufficient warning to all who are familiar with the origin of malarial diseases.

In a paper read before the New Jersey Sanitary Association, in 1896, we pointed out that deaths from remittent and enteric fevers and diarrhœal diseases, for that half of the population of the State which lives within the influence of these marshes, are more numerous by fifty per cent. than for the rest of the State. Attention was then called to the fact that malaria causes much misery and a loss of human energy which is not represented by the death-rate, and that the aim of the sanitarian should be not only to diminish the death-rate, but to make life better worth living. The report upon the improvement of Charles river, above cited, says (on page ix): "The medical profession believes that the gases arising from decomposing organic materials are injurious to health; it has not been proved, however, that these causes do produce some one distinct disease, but rather that the continued breathing of them lowers the vital resistance and predisposes the person exposed to them to diseases of various kinds and all degrees of severity." This quotation expresses the same general condition of things which we had in mind in attributing some of the increased death-rate spoken of to the influence of the marshes. We cite these recent reports bearing upon the sanitary question because they present conclusions of a board which has come to be considered a high authority on questions of this nature, but the evidence bearing upon the unfavorable sanitary influence of such marshes may be almost indefinitely increased. Probably most of our readers will be disposed to accept our indictment of the marshes from a sanitary standpoint, but perhaps not all take into account how rapidly the danger increases with the increase of the surrounding population.

In claiming that the effect of reclamation of these marshes will be to greatly diminish the number of mosquitoes, we had not thought it necessary to set out our reasons for this belief. To one familiar with the tide-marshes of the Atlantic coast and the mosquito question, the relation of the one to the other is too apparent to suggest the necessity for any argument. It is a matter of common experience that the number of mosquitoes increases almost everywhere as we approach the edge of the salt marshes. It is also well known to the people in our proposed drainage district, between the Orange mountains and the Hudson river, that the mosquitoes are always more numerous when the wind blows from the marshes, and that these tide-marsh mosquitoes are of a much more vigorous and voracious nature than mosquitoes bred on the uplands. There are, to be sure, a few mosquitoes scattered widely over the upland areas of the State, but they are easily distinguished from those found in the neighborhood of the marshes. They are comparatively harmless. The point has been raised, as fatal to the theory that mosquitoes originate in the tide-marshes, that they do not breed in salt water. This is entirely beside the question. It is well known that they do breed largely in shallow pools of fresh water. The Hackensack tide-marshes are tidal but not salt to any marked degree. The large influx of fresh water from the Passaic and Hackensack keeps even the water of Newark bay comparatively fresh, and especially fresh during such a wet season as the past summer. The meadows directly upon the Atlantic coast, in Ocean, Atlantic and Cape May counties, are, in the main, very decidedly salt as compared with the Hackensack marshes, but even these are in many places only brackish, and everywhere along the border of the upland they are quite fresh from the seepage into them of spring-water. We may readily concede, therefore, that mosquitoes do not breed in salt water. Anyone who has spent a few days on the Hackensack meadows, or the tide-marshes of Barnegat bay or Delaware bay, or upon the immediately-adjacent upland, in July or August, when the weather is reasonably warm and the wind not too high to permit the mosquitoes to be abroad, should have no difficulty in accepting the tide-marshes as the principal cause of the mosquito pest.

The objectionable feature of the marshes which we have above emphasized should outweigh æsthetic considerations. It is true that at times they present an attractive and somewhat unusual landscape, richly varied in coloring and with a pleasing effect of spacious openness, in sharp contrast to the nearby cities. On this account some are not disposed to favor their utilization for manufacturing and commercial purposes. But only those with a highly-developed artistic sense, and the ability to forget the evil sanitary influences lurking beneath the waving reeds and grasses, can appreciate these beauties. The larger number who look upon the marshes carry away with them an impression highly unfavorable to the sanitary reputation of the State. It must also be remembered that neglect will not preserve the present aspect of the marshes. If unimproved, they will gradually come to be put to the basest possible uses, and will present a far less inviting appearance in the future than they will if judiciously improved and developed in the manner which we have suggested.

PART VI.

SUPPLEMENTAL NOTES

ON

THE MINING INDUSTRY OF NEW JERSEY.

BY

GEORGE E. JENKINS, C.E., Dover, N. J.

SUPPLEMENTAL NOTES ON THE MINING INDUSTRY OF NEW JERSEY.

The mines in operation during the past year include only the old and well-known mines at Hibernia, Richard, Hurdtown and Port Oram.

The demand for iron ore has not been at all strong, and the general conditions of the trade have not been favorable for a large yield of product. While the outlook for the coming year does not give very great encouragement, it is to be noted that prices have reached the bottom limit and the operating plants are in the position to increase their respective outputs if the demand should warrant it. Of the mines in operation only two place their product upon the market. The remaining operators consume the mines' product in their own furnaces.

The mines in operation during the year are embraced in the following review:

Hurdtown Mine.

Owned by the Hurd heirs, operated by The Hurd Mining Company;
Benj. Nicoll, President and Manager.

The mining operations that have been carried on in this well-known mine consist of "robbing" all the available ore from the roof and sides. In the past two years all the mine's production has come from the deposit which had been left standing in the old workings in the form of supports. All the ore has been removed from the bottom to a point 2,200 feet from the surface. Here the old workings are 160 feet from cap to bed-rock and sixty feet from hanging to footwall-rock, and in order to reach the bunches of ore along the sides under the cap-rock the mine was pumped full of water up to the height of the ore deposit. Floats were then launched upon which the machinery was placed and the attack made upon the ore. Blasts loosen the material, and by lowering the water the ore is secured and the work continued downward. The plan has proved successful, and an area of over two hundred feet has been worked over and the ore removed. There still remains about 1,400 feet of ground to be worked over before reaching the territory to which the "robbing" was done under the old plan of operation.

It is estimated that it will require about two years in which to remove the available ore under this plan, but there remain large pillars and other supports of ore in the upper regions of the mine which will yield large quantities of ore and require some years in their removal.

The quality is all that can be desired in richness of metallic iron, but the phosphorus is too high to pass Bessemer limit.

The product during the past year has been from 1,500 to 2,000 tons per month and this is sold in open market.

Richard Mine.

The Thomas Iron Company, owners and operators; James Arthur, Superintendent of Mines.

The developments in the body of ore lying upon the footwall and which were partially opened upon last year, have been extended and the explorations show a remarkable deposit of ore. The two prospecting drifts started last year have been extended along the course of the deposit in a westerly direction for three hundred feet or more to near the throw or offset in the footwall; in the easterly direction the drifts were driven about one hundred feet to where the walls had begun to approach each other, and as there was some danger of disturbing the No. 2 shaft the drift was continued no further. The average width of the vein along the drifts is seventeen feet. In the upper drift the workings were carried upward about one hundred and fifty feet through a uniform thickness of ore. In the lower level the "backstopping" is now sixty feet above the level and the deposit is fully twenty feet thick. Great care has to be exercised in removing the ore and every precaution taken not to disturb the old footwall-rock, to which all the timbering and supports in the old workings are secured.

The new slope started in 1896 has now reached a depth of 460 feet on an angle of fifty-two degrees. Cross-drifts are now being planed to intersect the ore-body and the operations, as stated in last year's report, will then be inaugurated. The ore will then be removed with greater facility and at a much reduced cost.

Near the foot of No. 1 slope and close to the bottom rock-level a large bunch of ore was discovered during the past year, but no developments have as yet been made to determine if it is only an isolated pocket of ore broken off from the main body or a regular shoot dipping under the rock which has apparently been cutting out the old vein.

The workings in the Mount Pleasant or north vein have been extended during the year, but the deposit is "bunchy" and irregular and displays the same characteristics as in the old working in the Mount Pleasant mine.

The method of mining upon this vein through the main Richard vein is to be abandoned, and a new slope is being sunk so as to come down upon the ore-body near the eastern end of the deposit. This improvement will increase the output from the north vein and greatly reduce the cost of operating.

If the market warranted it, the monthly product during the year would have been over 11,000 tons, but as only from three to four of the company's furnaces have been in blast, the product has been only such as supplied the demand.

Edison.

The concentrating plant of the New Jersey and Pennsylvania Concentrating Company has been in operation for short runs during the year but no manufactured product has been shipped, and the work of the year has consisted in perfecting the different departments of the works.

Hibernia Mines.

Lower Wood Mine; Andover Iron Co., owners and operators;
S. B. Patterson, Superintendent.

No changes in the workings of the mine have taken place during the year, and the depth of workings, width of vein, &c., are about as reported last year. A new sink about 300 feet east of "Reed Shaft" was sunk and stopes driven eastward from this shaft. The Church Mine Lot is now under lease to the Andover Iron Company and it is being operated upon through the workings of the Lower

Wood Mine. The product has been large, some months reaching nearly 7,000 tons. The dullness of the iron market has, however, curtailed the yearly product of the mine.

Wharton Mine.

Joseph Wharton, owner and operator; Edward Kelley, Superintendent.

Mining operations have been vigorously pushed in the past year and the output has probably been the largest in the history of the mine. The yield is now 6,000 tons per month.

Additional improvements have been made in the mine plant. In the No. 1 shaft, a new skip hoistway 920 feet long has been put in, giving the mine the advantage of two well-equipped hoistways.

Prospecting with reference to ascertaining the further easterly extension of the ore-body now worked is being contemplated, and encouraging results have been obtained from a magnetic survey of the territory about 1,000 feet east of the No. 3 shaft, and the attraction would justify the hope of finding new shoots of ore east of the old deposit. Test pits will be sunk and these will no doubt determine the extent of the ore-body.

The deepest working is now 990 feet, and the sink put down during the year past has opened stopes carrying from nine to ten feet of pure ore, showing without doubt that the large shoots of ore which were encountered in the mines to the westward are now being opened upon in this mine. The working area of the mine is comprised in nine stopes, but only four are now being operated upon.

The Hurd Mine and New Sterling Slope.

New Jersey Iron Mining Company, owners and operators; L. C. Bierwirth, Secretary and Superintendent.

The year's work consists of a sink about fifty feet deep and the working of three stopes.

The cross-cut on No. 5 level was driven seventy-nine feet through the Harvey offset and a fine body of ore has been developed east of the offset and under the old Hurd mine workings. A drift has been driven along the deposit 170 feet and the vein has an average width of ten feet.

A second drift has been driven on No. 6 level, and the vein just opened upon shows a fine deposit of clean, bright, rich ore, and the chemical analyses show that it is much lower in phosphorus than the Sterling shoot. In the offset a chimney of ore two or three feet thick was cut on No. 5 level, and in driving the lower cross-cut the ore was ten feet wide and twenty feet high. The indications are that this is a chimney of ore increasing in size as the workings deepen. Further prospecting will be necessary to determine the exact nature of the deposit, but, at all events, the indication of a paying body of ore is promising, whether it be a chimney or shoot of ore.

The Sterling shoot is now worked nearly down to the bed-rock of the deposit, and in all probability the most productive area of the shoot has been worked out.

The concentrating plant which has been in operation for the past five or six years was operated up to July, when it was destroyed by fire. The company has never rebuilt the plant, and only about 1,700 tons of concentrates were passed through the mill in the past year. The total product of the mine and mill has been about 2,000 tons per month.

Franklin Zinc Mines.

The zinc mines have been in active operation throughout the year. The Sterling Iron and Zinc Co. and The New Jersey Zinc Co. have combined their interests, and the North Mine Hill working as well as the old southwest opening and the Taylor mine are all operated under the management of the new organization, with headquarters at No. 52 Wall St., New York. Mr. Joseph A. Van Mater is superintendent of North Mine Hill, and Mr. James B. Tonking of the Taylor mine. The Passaic Zinc Co. has also been absorbed by The New Jersey Zinc Co., and the mines at Sterling hill have been stopped in consequence of this change. The entire zinc mining enterprise of the State is now under the one management and in the control of The New Jersey Zinc Co.

CLAY AND BRICK INDUSTRY.

INTRODUCTION.

The brick and clay manufacturing plants in New Jersey comprise an industry of no small proportions, and as there are many localities in our State where extensive clay deposits are found, it is hoped that the following information will be of service to capitalists and others interested in the industries of the State.

ATLANTIC COUNTY.

INDUSTRIAL BRICK COMPANY.

City office, No. 411 Bullitt Building, Philadelphia; Samuel Fulton, President George Fulton, Secretary, Treasurer and General Manager; George Grob, Superintendent at works, at Mays Landing.

Clay-bed is located at works and is seven feet deep of superior brick clay. Product consists of pressed ornamental brick. Full capacity of plant is 25,000 per day.

Plant consists of two boilers, each 150 horse-power; one engine, 125 horse-power; two wet pans; one crusher or dry pan; one Penfield brick machine, having a capacity of 60,000 per day; seven kilns, three of which are "Euadaily Down Draft" and four are Muffle. Capacity of "Euadaily," 95,000 each; capacity of Muffle, 55,000 each.

The plant is operated all the year, employing eighty-five men, who are paid one to two dollars per day. The works have been in operation since 1892. The product is disposed of in New York, Philadelphia and Atlantic City.

A new plant for making brick from sand has been built during the year, and some experiments have been made with very satisfactory results, it is claimed. Under this process new, specially-designed kilns have been constructed in which the green brick are burned only from eight to ten hours, whereas the clay pressed brick is usually "fired" from six to eight days.

ROBERT MUFFETT, BAKERSVILLE.

Plant and clay-beds are located one mile north of railroad station. Clay is found seven feet thick and only common building brick is made. Capacity of yard 550,000 per year.

Plant consists of one engine, 12 horse-power; one boiler, 35 horse-power; two Dutch kilns having a capacity of 75,000 each; one Latterette brick machine (made in Marion, Ohio) having a capacity of 8,000 per day.

Plant is operated six months in the year, employing six men, paying $1.25 per day.

The amount of capital invested is $1,800 and the product is sold in the immediate neighborhood.

JULIUS EINSIEDEL, EGG HARBOR CITY.

Small yard, making 100,000 hand-made brick. Has from $1,000 to $2,000 invested.

One kiln, Dutch oven pattern, having a capacity of 20,000. Occasionally makes sewer pipe. Employs in addition to his own labor one man.

The clay-bed is two to three feet thick and requires stripping of from two to three feet of top soil.

BERGEN COUNTY.

M. B. & L. B. GARDNER, HACKENSACK.

Clay-bed and yard at Little Ferry. Controls 100 acres of clay-land, finding the clay twenty feet deep. Capacity of yard from 8,000,000 to 9,000,000.

Plant consists of four tempering wheels and four brick machines. Employs about thirty men for six months in the year.

One-half the year's product usually shipped to New York City and the remaining half sold in local market.

CHARLES E. WALSH, HACKENSACK.

Clay-bed and yard at Little Ferry. Owns the plant once operated by Benjamin Cooper & Co., also controls five acres of clay deposit in which the bed is from seven to twenty feet thick.

Capacity of plant from 4,000,000 to 6,000,000. Employs about thirty-two men six months in the year, paying $1.35 to $2 per day.

Plant consists of three tempering wheels and three machines, all run by steam-power.

COOPER YARD.

Plant consists of six tempering pits and wheels and three machines. Has been in the brick business for twelve years, shipping product to New York.

I. & W. FELTER, LITTLE FERRY.

Clay-bed at Little Ferry, controlling nineteen acres in which the deposit averages 35 feet.

Capacity of plant 10,000,000 per year.

Employ thirty men for six months in the year, paying from $1.35 to $2 per day.

Plant consists of one engine, 70 horse-power; six tempering pits and wheels; six Wiles machines.

Been in business twelve years, and dispose of product in Paterson and Passaic.

MEHRHOFF BRICK COMPANY, LITTLE FERRY.

Nicholas Mehrhoff, Treasurer and Manager.

From artesian well borings, the clay deposit has been found in these works to be eighty feet deep. The deposit is worked, however, to a depth of thirty-five feet. Capacity of the plant is 30,000,000 per year.

Plant consists of three steam engines, 85, 60 and 45 horse-power respectively; eighteen tempering pits and wheels; eighteen machines. Employs 100 men at rate of $1.25 to $2.25 per day.

The plant has been in operation since 1872 and product is sold in New York, Paterson and the New England States.

NICHOLAS MEHRHOFF & CO., LITTLE FERRY.

Clay-bed is ninety-eight feet deep, but worked to a depth of twenty feet. On account of water pressure this is about the limit of depth that it is safe to work the Hackensack clay deposit.

Capacity of yard is 10,000,000 per year.

Plant consists of one 80-horse-power engine; seven tempering wheels and pits; seven machines.

Employs seventy men when working full force, but for past few years only thirty-five men have been employed.

Product has been sold in New York, Paterson and Passaic.

EDWARD SCHMULTZ, HACKENSACK.

Yard located at Hackensack, close to clay-bed. The depth of deposit is worked from six to thirty-five feet.

Capacity of yard is 4,000,000 per year.

Plant consists of 24-horse-power engine, three tempering wheels and pits, two machines.

Has operated the yard since 1887 and ships to New York and Brooklyn and to the retail market.

PHILIP MEHRHOFF, LITTLE FERRY.

(Formerly Thomas Malley's yard.)

Clay-bed located close to yard at Little Ferry and the deposit worked to a depth of fifteen feet on an average.

Capacity of yard 5,000,000 per year.

Plant consists of 35-horse-power engine, three tempering wheels and pits, three machines.

Employs twenty-eight men at an average price of $1.50 per day.

JAMES W. GILLIES, HACKENSACK.

Yard and clay banks at Little Ferry. Clay-bed is fifty feet deep.

Capacity of plant 10,000,000 per year.

Amount of capital invested, $40,000.

Employs sixty-five men at average of $1.50 per day for six months in the year.

Plant consists of one 200-horse-power engine; one 500-horse-power boiler; four Waldrous Haverstraw machines having a capacity of 3,000,000 each.

BURLINGTON COUNTY.

PHILIP H. BRAKLEY, BORDENTOWN.

Gave up the manufacture of brick in 1894 and yard is now for sale.

SYLVESTER GRAHAM & CO.

(Firm made up of S. Graham and W. A. Shreve.)

Office in Bordentown and clay-bed and yard between Kinkora and Fieldsboro.

JOHN BRAISLIN & SON, CROSSWICKS.

Clay deposit is four feet deep.

Manufacture drain tile, hollow brick and common brick.

Capacity of plant 20,000 per day, and operate 150 days in a year, employing seven to eight men at $1.25 to $1.75 per day.

Plant consists of one machine (Braislin pattern); two kilns, capacity of 150,000 per kiln.

Been in business at Crosswicks for thirty-one years and dispose of product in Newark, Philadelphia and New York. Carting to Bordentown, three miles.

HOWARD L. NEWELL, BORDENTOWN.

Brickyard and clay-bed located at Florence, but it is not now in operation, being for sale, as the present owner is practically out of the manufacturing business.

The clay deposit consists of two qualities. The common red brick clay is seven feet deep, and underlying the red clay is a stiff buff clay, about twenty feet deep.

Plant consists of one Chambers machine, size B; two kilns, capacity 150,000 each.

MERRILL DOBBINS, CLAY-BED AND YARD AT KINKORA.

No. 24 South Seventh street, Philadelphia.

Controls twenty acres of clay land, having an average depth of four feet, but has to remove about six feet of soil. The clay is too stiff to work alone and it is found necessary to mix about one-third loam.

Capacity of works is 3,500,000 per year.

Employs forty-five men for six months in the year, paying from $1.25 to $2 per day.

Plant consists of two Chambers "D" machines; one 75-horsepower boiler; five kilns, Dutch pattern, each of a capacity of 165,000.

The plant has been operated for forty years, but Mr. Dobbins has had the works only seventeen years.

BURLINGTON ARCHITECTURAL TERRA-COTTA CO., BURLINGTON.

Philip D. Buchanan, President and Superintendent.

Clay is purchased from pits located at Whitings and Tuckerton.

Plant consists of one 25-horse-power engine, one dry pan of a capacity of fifteen tons per day, one pug mill of a capacity of fifteen tons per day, two kilns of eight and twenty-two tons respectively.

Employs twenty-five to thirty men, paying wages from $1.25 to $5 per day. The works have been operated for two years and the manufactured product is shipped principally to Philadelphia.

THE SANITARY ENAMEL CLAY CO., BURLINGTON.

H. G. Green, President; Thos. W. Milner, Treasurer.

Works at Burlington. Purchase the clay used from clay dealers and miners. Manufacture enamel brick and the plant has a capacity of 15,000 per week. Value of product from $90 to $100 per 1,000.

Plant consists of one 90-horse-power boiler; one wet pan, fifteen tons capacity per day; one Freg, Sheckler & Hoven brick machine; one press; one kiln of a capacity of 7,000.

At present employ six men.

The company is only just entering the field and is not, therefore, as yet, a very heavy producer.

Product is shipped to New York and Philadelphia.

FIRMAN DUBELL, MOUNT HOLLY.

Clay-bed and works are located one mile west of Mount Holly. The clay deposit is worked to a depth of from four to five feet; at about seven feet a stratum of quicksand is found underlying the clay.

Capacity this year 500,000.

Plant consists of one Brewer machine, made in Tecumseh, Mich., having a capacity of 40,000 per day; one 50-horse-power engine; two Dutch kilns having a capacity of 100,000 each.

Employs fifteen men for six months at $1 per day.

MRS. CHARLES H. HULMES.

Clay-bed and yard adjoining Dubell's, and has been in operation during the year, making only 90,000 bricks.

McINNIS BRICK CO., RANCOCAS.

Works located on Rancocas Creek at McInnis Landing, and was worked up to 1896, since which time the company has been in litigation over title to property. Manufactured hard and hollow brick and have an extensive plant.

ELSWORTH BERRYAM, RANCOCAS.

This is a small yard making common and paving brick.

The clay-bed is six feet deep and is used only in making common brick.

Capacity of yard 200,000 to 250,000.

Plant consists of one Martin machine, horse-power; one Dutch kiln, capacity 55,000.

WILLIAM SCATTERGOOD, RANCOCAS.

Clay-bed and works located three-quarters of a mile north from Rancocas and three miles from Burlington. Clay-bed has been worked to a depth of eighteen feet, but the bottom of the deposit has not been reached. The product of the works consists of common brick and drain tile.

The capacity of the yard is 200,000 bricks and 180,000 tile, and this has been the past year's product.

Plant consists of one 25-horse-power engine; one 40-horse-power boiler; one Little Wonder brick machine; two kilns, Dutch, capacity 70,000 each, and one kiln 40,000.

Four men are employed at a per diem rate of $1.25 and yard is in operation six months of the year.

The product is sold in local market.

SYLVESTER GRAHAM & CO., BORDENTOWN.

The plant and clay-bed are located two miles below Bordentown, between White Hill and Kinkora. The clay is from five to twenty feet deep and of extended area.

The plant consists of one 100-horse-power engine; one 180-horse-power boiler; one Chambers machine, having a capacity of 40,000 per day.

The yearly product is 8,000,000 brick. About $20,000 are invested in the enterprise and employ forty men at the rate of $1.50 per day.

A. A. ADAMS, WOODMANSIE.

Clay-bed is located one and one-half miles east of Woodmansie, just across the Ocean county line, in the township of Manchester.

The deposit is from six to twenty-two feet deep, and about 16,000 tons are mined and shipped each year.

The amount of capital invested is $5,000.

Seventy-five men are employed at $1.10 per day.

Machinery consists of one 10-horse-power engine and boiler with derrick.

HENRY C. ADAMS, EDGEWATER PARK.

Clay-beds at Edgewater Park, a short distance east of railroad depot.

The deposit is about six feet deep and is of such a tenacious character that it requires an addition of sand to about one-third in quantity.

The capacity of the yard is 1,500,000 per year.

Plant consists of one 25-horse-power engine; one 35-horse-power boiler; one Wallace & Co. "Wonder" brick machine; three Dutch kilns, each 100,000 capacity; two Dutch kilns, each 125,000 capacity.

Twenty hands are employed for six months in the year and are paid at the rate of $1.25 to $1.75 per day.

The whole product supplies the local market.

CAMDEN COUNTY.

AUGUSTUS REEVES, CLAY DEPOSIT AND BRICKYARD AT FISH HOUSE STATION.

No. 31 Market street, Camden; William Hancock, Superintendent.

The deposit is from three feet minimum to seventeen feet maximum depth. The capacity of a common brickmaking plant is 2,500,000 per year and that many brick have been made in 1897. About 2,000 fire-brick are also made. Sewer-pipe from two-inch sizes to fifteen-inch as well as chimney tops, vases, &c., are also manufactured.

Plant consists of Chambers brick machine; three pipe kilns of a capacity of 1,000 each; two Dutch brick kilns, 220,000 capacity.

The brick is sold principally in Camden city.

AUGUSTUS REEVES (SECOND YARD).

Located where Camden and Burlington railroad crosses the Pensauken Creek, between Maple Shades and Lenola. The clay deposit is here found to be twenty-five to thirty feet deep.

The capacity of the yard is 4,000,000 per year.

Plant consists of one 30-horse-power engine; one 75-horse-power boiler; one pug mill and crusher; one Chambers machine of a capacity of 25,000 per day; two Dutch kilns, having a capacity of 185,000 each.

From eighteen to twenty men are employed and the yard it run six months in the year, but it will now run all the year, as a steam dryer has just been added to the plant.

HATCH BROTHERS, CAMDEN.

Clay-beds and works at Fish House station. Clay-bed about seventeen feet thick.

Capacity of plant is 8,000,000.

Plant consists of Chambers brick machines; four kilns of 260,000 capacity.

About fifty men find employment.

BUDD BROTHERS, CITY LINE STATION.

Clay deposit is eighteen feet thick, and 3,000,000 brick per year are manufactured and used in Camden.

Plant consists of four Dutch kilns, having a capacity of 180,000 each; one 70-horse-power engine; one 100-horse-power boiler; Chambers brick machines are used.

Thirty-five men are employed for six months in the year.

JAMES C. DOBBS, COLLINGSWOOD.

Clay-beds about one-half mile out of Collingswood. The depth of the deposit is 36 feet maximum, and 1,000,000 brick, as well as 300,000 to 400,000 drain tile are manufactured.

The plant consists of one 25-horse-power engine; one 40-horse-power boiler; one Noland & Madden brick machine of the capacity of 20,000 per day; one Dutch kiln of capacity of 150,000.

The establishment has been operating for the past thirty years, and the product is disposed of in Collingswood and Haddonfield.

Has another yard at Woodbury of same capacity as above, but it has not been in operation in 1897.

About eighteen men are employed in both yards at an average pay of $1.25 per day.

CHARLES HOLLOWELL, CLAY DEPOSIT AND WORKS AT CITY LINE STATION, CAMDEN.

No. 1222 Christian street, Philadelphia.

The deposit of clay averages seven feet thick. The capacity of the yard is 20,000 per day.

Plant consists of 30-horse-power engine, 40-horse-power boiler one Wiles brick machine, one tempering wheel and pit, three Dutch kilns of a capacity of 125,000 to 200,000.

Employs thirty men from April to November. Some hand-made "specials" are also manufactured.

THE EASTERN HYDRAULIC PRESSED BRICK COMPANY.

City office, Nos. 401–406 Builders' Exchange, No. 18 South Seventh street, Philadelphia; G. S. Turner, Superintendent at works, Winslow Junction.

CAPE MAY COUNTY.

ZOLOT BROS. & CO., WOODBINE.

The clay-bed is from six to ten feet, averaging eight feet thick of red and buff brick clay. From the lower stratum of the deposit a very excellent buff pressed brick is made, worth from $18 to $20 per 1,000. The year's product was 400,000.

The plant consists of one 15-horse-power engine; one 20-horse-power boiler; one Kelk & Son brick machine (made in Adrian, Mich.), having a capacity of 8,000 brick per day; one Dutch kiln of a capacity of 75,000.

The amount of capital invested is $4,000. Product is sold in Cape May county.

CUMBERLAND COUNTY.

BENJAMIN ERRICKSON, BRIDGETON.

No. 283 South avenue.

Clay-bed and brickyard located in Bridgeton. The deposit of clay is from seven to eleven feet deep and this yard owns five acres of the deposit.

This year 900,000 bricks were made, having an average value in the yard of $7 per 1,000, and all used in the city of Bridgeton.

Plant consists of one 35-horse-power engine; two 40-horse-power boilers; one Leghorn brick machine, made by the Eastern Machine Co., of New Haven Conn.; one tempering wheel and pit; one crusher; three Dutch kilns, two of which have a capacity of 165,000, and one 180,000.

Hand-made and pressed brick are also manufactured.

The amount of capital invested is $10,000, and the works are usually in operation from April to November. Eighteen hands are employed at the rate of $1.25 per day. The plant has been established for thirteen years.

T. S. SIMMONS, MILLVILLE.

Clay-bed is located five miles below Millville, on the Maurice River, and is from ten to twelve feet deep, and is the ordinary red brick clay. The product is all hand-made and the capacity is 1,200,000 per year, and is sold at Millville. No brick has been manufactured for the past two years.

Two Dutch kilns, having a capacity of 150,000 and 160,000 respectively, are in operation when the works are in operation, and from twelve to fifteen men are employed at $1.50 to $2.50 per day.

The amount of capital invested is $4,000.

SMITH & GREENLEE, BELLE PLAIN.

Clay-bed is three-fourths of a mile from brickyard and brickyard is located close by railroad station. The deposit is ordinary brick clay of an average thickness of six feet.

The brick are all hand-made and 400,000 is the yearly product of the plant. The plant is operated from April to November, employing fifteen hands at the rate of $1.10 to $1.50 per day.

The kiln is of cupola pattern, down draught, wood-burning and of a capacity of 75,000. The plant has been in operation for the past six years.

A. E. BIRCHAM, MILLVILLE.

Clay deposit and brick works are located at Manantico, along the Maurice River. The deposit is from twelve to fourteen feet deep, of ordinary red brick clay.

The capacity of the yard is 1,000,000 bricks per year.

The plant is operated by steam, and consists of engine and boiler and brick machine of the owner's own make.

The amount of capital invested is $8,000, and about twenty men are employed at the rate of $1.50 per day.

There are two kilns of Dutch-oven pattern, and one down-draught kiln. The product is mostly disposed of in Millville.

THE GLOBE FIRE-PROOFING COMPANY, SOUTH VINELAND.

Norman W. Cramp, President, Philadelphia; Geo. H. Sheble, Secretary, Philadelphia; T. Milton Shafto, General Manager, Bourse Building, Philadelphia; H. F. Smith, Jr., Superintendent of Works, Philadelphia.

THE PHILADELPHIA FIRE-PROOF AND BRICKING COMPANY, P. O. SOUTH VINELAND, CLAYVILLE.

Chas. H. Fowler, President, Gloucester.

The above-mentioned company own the plant and clay-beds, but lease the plant to the Globe Fire-proofing Company and supply them with clay from their deposit about one mile east of the works.

Thirty men are employed at $1.25 per day.

The clay is from eight to twenty-three feet thick.

The amount of capital invested in both manufacturing plant and clay lands is $125,000.

J. A. HOBART, VINELAND.

Clay-bed and brick manufacturing plant are located on East avenue, north of Oak road. The clay deposit is five feet deep, of ordinary red brick clay. Only hand-made brick are made and this year the product was 400,000.

The yard is equipped with three kilns of ten arches each.

The capital invested is $6,000.

KILBORN & DARE, ROSENHAYN.

The clay deposit is overlaid by a covering of earth about five feet deep and therefore requiring stripping to this amount. The clay deposit is of ten feet average thickness and underlaid by a deposit of kaolin sand, which, when used with the clay, makes an excellent buff brick.

The capacity of the plant is 1,500,000 per year.

The works are equipped with the following plant: One 40-horse-power engine; one 50-horse-power boiler; one side-cut auger brick machine, of manufacturer's own pattern; one crusher and pug mill; two down-draught kilns of 60,000 capacity each.

Some vitrified paving bricks are also made.

The number of men employed is thirty, at an average of $1.50 per day. The plant is operated for about six months in the year and the amount of capital invested is about $8,000.

The product is shipped to New York, Boston and Philadelphia.

GLOUCESTER COUNTY.

CHARLES B. THACKARA, WOODBURY.

The clay-bed and brickyard are one-quarter of a mile out of the city, along the line of the West Jersey Railroad.

The deposit of clay is worked to a depth of seven feet, where an inferior quality of clay is encountered.

The capacity of the plant is 800,000 per year.

The entire product is hand-made.

The works are operated six months in a year and employ eight men at from $1.25 to $1.80 per day.

About 20,000 tile are also made each year.

Brick has been manufactured here for the past forty years.

JAMES C. DOBBS, COLLINGSWOOD.

Yard and clay-bed about one-half mile east of the Chas. B. Thackara yard at Woodbury. No product in 1897.

HUNTERDON COUNTY.

A. G. PEDRICK, FLEMINGTON.

The clay deposit covers twelve acres and is from three to seven feet deep.

The product is from 300,000 to 400,000 brick annually.

The plant consists of one Hall moulding machine and one tempering wheel operated by horse-power.

The product is sold in local market.

The amount of capital invested is $6,000.

Coal dust has to be mixed with the clay, and the bricks are burned in open arches.

From six to seven men are employed at from $1.25 to $2 per day.

The yard has been in operation since 1853.

THEODORE O. DANIEL, LAMBERTVILLE.

No brick has been made in this yard in 1897. All the brick is hand-moulded and fired in open arches, using wood for fuel.

The number of men employed is seven, at the rate of from $1.50 to $2 per day.

The deposit is blue clay and runs from four to six feet deep.

The yard is an old one, having been here for a great many years.

FULPER BROS. & CO., FLEMINGTON.

Manufacturers of stoneware. The clay is purchased from Perrine & Son, of South Amboy, and from 2,000 to 2,500 tons per month are used.

The plant consists of one 50-horse-power boiler and one 80-horse-power, one 25-horse-power engine, three moulding machines, five ovens and down-draught kilns.

Capital invested is from $40,000 to $50,000. The plant was established in 1804, but the present firm has been in business for nine years past.

Forty-five to fifty men are employed at $16 per week.

MERCER COUNTY.

B. H. REED & BROS., HIGHTSTOWN.

Clay-beds and brick works are located along the line of the Camden and Amboy division of the Pennsylvania Railroad in Cranbury township. The deposit has from nine to twenty-five feet of clay. The yearly output of the plant is 300,000 brick and 75,000 tile.

Seven men are employed at an average rate of $1.35 per day.

The amount of capital invested is $4,000.

The plant is as follows: One 25-horse-power engine; one 25-horse-power boiler; one Frey, Sheckler & Co. brick machine, having a capacity of 15,000 per day.

P. J. CAHILL, HOPEWELL.

The clay deposit is about three feet thick and the owner controls about ten acres, and from 600,000 to 800,000 are made annually.

Plant consists of one tempering wheel (horse-power), one hand pressing machine, and all brick is hand-made.

Nine men are employed at an average rate of $1.75 to $2 per day.

MONMOUTH COUNTY.

DRUMMOND BROTHERS, ASBURY PARK.

The deposit of clay is about one mile from Asbury Park. It is covered with a deposit of sand eight feet deep, and the stratum of clay is from four to five feet deep and is black in color. It is underlaid by a deposit of sea-sand.

The product of the yard is 1,000,000 per year.

From twenty to twenty-five men are employed at from $1.50 to $2.25 per day.

The plant consists of one 85-horse-power boiler; one 75-horse-power engine; one Martin brick machine, and one Michigan brick and tile machine; one tempering wheel and pit.

The clay is not of the best quality, and, in order to insure proper burning, coal dust has to be mixed with the clay. The firing is done in open arches.

The plant has been operated for eighteen years.

SAMUEL LUDLOW, ASBURY PARK.

Clay-bed exhausted and brick manufacturing abandoned.

SAMUEL BROCKLEBANK, POST-OFFICE HOWELL.

Clay-beds and yard are located at Jerseyville.

The deposit, which has a thickness of six feet, is overlaid by soil to a depth of three and one-half feet, requiring that amount of stripping, and about two acres of clay land have been worked over.

The capacity of the yard is 800,000 brick and 5,000 tile.

The plant is operated by horse-power and consists of one Hall tempering and moulding machine, one Olcott tile machine.

The brick and tile are fired in open arches, using wood fuel.

Coal dust is mixed with the clay before burning.

Six men are employed at the rate of $1.25 per day.

The plant has been in operation since 1853.

EDWARD LIPPENCOTT, FARMINGDALE.

The clay deposit is four feet deep, but requires stripping from six inches to four feet.

The capacity of the plant is 5,000 per day. In the past year the product was 200,000 brick and 70,000 drain tile.

The plant consists of a Hall hand-press operated by horse-power.

Four men are employed at from $1.25 to $1.50 per day.

The plant has been in operation since 1857.

PETER LIPPENCOTT, SHARK RIVER STATION.

The yard is abandoned and no product for some years.

MORRIS COUNTY.

SILAS L. ARMSTRONG, MORRISTOWN.

The plant is located about one and one-quarter miles from Morristown, on the Bernardsville road, and has been in operation for the past forty years.

From five to six acres of the deposit have been uncovered and it is found to be from fourteen to sixteen feet deep. The yearly product is 3,000,000.

The yard is equipped with one 40-horse-power boiler and engine, two tempering wheels and pits, three moulding machines, one pressing machine.

The plant is operated about six months in the year and employs thirty men.

The amount of capital invested is $20,000.

The entire product is sold to builders in Morristown.

CHARLES L. KELLEY & CO., CHATHAM.

This firm began operations in 1869 and worked their plant for about twenty-two years. The clay was strong and of a good quality for making brick, and the deposit covers about two acres of clay, having a depth of from four to fifteen feet.

The location of the plant is such as to require heavy expenses in operating, and consequently it could not be run on a paying basis. It has been abandoned and no brick has been made in the past six years.

WATNONG BRICK COMPANY, MORRISTOWN.

E. T. Caskey, President; W. T. Headley, Secretary; Fred. Schmidt Treasurer.

The clay-bed and brickyard are located near Morris Plains, on the site of an old brickyard which was operated fifty years ago. The deposit covers an area of eighty acres under the control of this company, and is from four to five feet deep.

The plant consists of one 80-horse-power boiler and engine, two tempering wheels and pits, one press machine.

No brick has been made in the past five years. When in operation the capacity is 3,000,000 per year.

BERNARD J. FALLON, SUMMIT.

Mr. Fallon commenced making brick in 1891, with a daily capacity of from 15,000 to 20,000, and continued up to 1895, when the plant was abandoned and is now in this condition.

The clay was found south of the town on the Stony Hill road and was found to a depth of from four to five feet. It was not of good quality and was not uniform, being very stony and gravelly.

THE WHIPPANY BRICK AND CLAY MANUFACTURING COMPANY.

Bernard J. Fallon, Manager.

This company has purchased a tract of thirty-two acres of clay-land at Whippany, and the test borings that have been made, show a superior quality of clay to a depth of thirty feet. The company is just beginning operations and is not, therefore, at this time, a producer of manufactured product.

OCEAN COUNTY.

AYERS BROTHERS, TOMS RIVER.

This yard has made no brick this year and the firm has abandoned the business. The clay-bed is twenty feet thick.

JOHN C. BROWN, LAKEWOOD.

The clay-bed is located two and a half miles from Lakewood, at Southard, Monmouth county. The deposit is from two to six feet deep and is a fire clay. The works have not been operated for three years. The capacity is 100,000 to 125,000 per year.

PASSAIC COUNTY.

SINGAC BRICK CO., LITTLE FALLS.

W. H. Robert and W. Beatty members of the firm.

The clay deposit is from six to thirteen feet deep, of good quality and of uniform texture.

The product of the plant has been 2,000,000 for the past two years. The plant is capable of producing 5,000,000 brick per year.

The plant consists of one 60-horse-power steam plant, three tempering wheels and pits, two Talcott machines, one Wiles machine.

The firing is done in open kilns, using wood for fuel.

The clay, being of such a tenacious character, requires about one-third part sand in order to make the best brick.

The capital invested is about $12,000.

About forty-two men are employed at from $1.50 to $2 per day.

JOHN M. POWERS, PATERSON.

Office No. 226 Marshal street.

The clay-bed and plant are located at Singac, and have been operated since 1861.

The deposit of clay is from ten to fifteen feet deep and so stony that the product is first dried and then passed through rolls. The product is then put through the tempering mill and thence to the brick machines.

The plant located at Singac consists of one 50-horse-power engine and boiler, one Talcott machine, rolls and pug mill.

The product of the yard is 2,000,000 to 3,000,000 per year, but none have been made in the past two years.

Twenty-one men are employed at the rate of $1.45 to $2 per day.

The amount of capital invested is between $15,000 and $20,000.

The product is disposed of at Paterson and neighboring markets.

STANDARD BRICK COMPANY, NEWARK.

No. 172 Market street. Alex. McKirgan, President; William Farrely, Treasurer.

The clay deposit and brickmaking plant are located at Mountain View. One and one-half acres have been opened and the depth of clay found to vary from ten to twenty-five feet.

The capacity of the plant is 5,000,000 per year.

The plant consists of one 75-horse-power boiler and engine; three tempering wheels and pits; six brick machines, five of which are Wiles and one "New Haven," the capacity of each machine being about 40,000 per day.

Thirty-six men are employed for six months in the year at $1.40 to $2 per day.

The amount of capital invested is $40,000.

GEORGE ADDY, PATERSON.

No. 15 Ryle avenue.

The clay-bed and yard are located at Mountain View and were formerly owned and operated by the Mountain View Brick Manufacturing Company. The present owner has been operating the plant for the past two years, making 2,000,000 brick per year.

The capacity of the plant is 5,000,000 per year and consists of one 30-horse-power engine; one 40-horse-power boiler; two tempering wheels, Wiles pattern; three moulding machines, one a Wiles and the other two Waldrous Haverstraw.

The clay deposit is twenty feet deep, of uniform quality, but requiring the addition of sand in order to work properly.

Forty men are employed for about six months in the year and are paid $1.60 to $2.10 per day.

About $10,000 are invested in the plant.

SALEM COUNTY.

DAVID F. HAINES, YORKTOWN.

Clay-bed and brickyard are located one mile south of Yorktown, on the road to Elmer. The deposit is a blue clay, from ten to fifteen feet deep.

The capacity of the yard is about 800,000 per year.

The plant consists of one 20-horse-power engine; one 40-horse-power boiler; one brick and tile machine, made by E. M. Freese & Co., of Galion, Ohio; two Dutch kilns, having a capacity of 60,000 and 100,000 respectively.

The plant is in operation usually from April 15th to November 1st, and from four to five men are usually employed at the average rate of $1.50 per day.

Drain tile is also manufactured.

HILES & HILLIARD, SALEM.

The clay-bed is located at Penn's Neck, along Salem Creek, about one mile out of Salem.

About nine acres of clay have been worked over and the deposit is shallow, not mining more than two feet deep, and underlaid by quicksand. The clay is "short" and difficult to work.

The plant consists of one 50-horse-power Westinghouse engine; one 90-horse-power boiler; one Chambers brick machine, size B; three Dutch kilns, having a capacity of 200,000 each.

Eight hundred thousand bricks are made every other year and sold in the local market.

The company is incorporated with the following officers: D. F. Henry, President; William H. Graham, Treasurer; W. D. Henry, Secretary and Manager; P. F. Reid, Superintendent at works.

The clay shale or slate is of extended area and this company controls two hundred acres.

The depth of deposit has not been determined, but it has been found to be continuous for a distance of sixty feet, to which depth test was made. The company mines about one hundred tons of the material per day.

The plant consists of one 200-horse-power engine, three Scotch marine boilers of three hundred and twenty-five horse-power, three dry pans and screens, three tile machines, twenty-two down-draught kilns.

From eight to ten carloads of material are shipped per day.

Sixty to seventy men are employed.

DAVID E. COLE, KARRSVILLE.

A small hand-made brick establishment, making from 25,000 to 30,000 bricks per year, and selling to neighboring farming district.

JOHN C. BENWARD, WASHINGTON.

Clay-bed and brickyard are located one mile from Washington, at Brass Castle. About seventeen acres have been worked out, leaving six acres now opened up, and the deposit is from two to six feet deep.

The capacity of the yard is 50,000 and this has been the product for the past two years.

The plant is operated by horse-power, and consists of one tempering pit and wheel. All brick are hand-mould.

Three men are employed at from $1.25 to $1.50 per day.

The yard has been operated for the past fifty years and the product disposed of in local market.

The following list of brickyards, terra-cotta works and clay-banks is taken from the notes on these clay-working industries and clay products collected by Prof. William S. Myers, of Rutgers College, in the course of a survey of the same, made to get the statistics of said industries. They are mainly in Middlesex and Union counties, a few only being from Monmouth. Practically they represent the Middlesex county clay district.

List of Operators in Terra-cotta Works, Fire-Brick Works, &c.

Operators.	Location of office.	Location of works.	County.
Tellmic Manufacturing Co	Carteret	Carteret	Union.
L. B. Beerbower & Co	Elizabeth	Elizabeth	Union.
New York and New Jersey Fire-proofing Co	156 Fifth Ave	Keyport	Monmouth.
Dunn, Dunlop & Co	Matawan	Matawan	Monmouth.
Matawan Terra-cotta Co.	108 Fulton St	Matawan	Monmouth.
Henry Maurer & Son	420 E. 23d St	Maurer	Middlesex.
Menlo Park Ceramic Works		Menlo Park	Middlesex.
Robert Richardson	New Brunswick	New Brunswick	Middlesex.
New Brunswick Pottery Co	New Brunswick	New Brunswick	Middlesex.
Old Bridge Enameled Brick and Tile Co	Old Bridge	Old Bridge	Middlesex.
New Jersey Terra-cotta Co	108 Fulton St	Perth Amboy	Middlesex.
Ostrander Fire Brick Co	Troy	Perth Amboy	Middlesex.
C. Pardee's Works	Perth Amboy	Perth Amboy	Middlesex.
Perth Amboy Terra-cotta Co	Perth Amboy	Perth Amboy	Middlesex.
Theo. Simmons	Perth Amboy	Sand Hills	Middlesex.
Standard Fire-proofing Co	Perth Amboy	Sand Hills	Middlesex.
Standard Terra-cotta Co	Perth Amboy	Sand Hills	Middlesex.
Silas Leonard	Rahway	Rahway	Middlesex.
C. W. Boynton	Sewaren	Sewaren	Middlesex.
Bay View Pottery, Samuel Locker & Co	South Amboy	South Amboy	Middlesex.
H. C. Perrine & Son	South Amboy	South Amboy	Middlesex.
American Enameled Brick and Tile Co	14 E. 23d St	South River	Middlesex.
Adam Weber	633 E. 15th St	Weber	Middlesex.
Salamander Works.	39 Cortlandt St	Woodbridge	Middlesex.
Staten Island Clay Co			Middlesex.
The M. D. Valentine & Bro. Co	Woodbridge	Woodbridge	Middlesex.
Excelsior Terra-Cotta Works	Rocky Hill	Near Rocky Hill	Somerset.

The plant is operated about six weeks and twenty-five men are employed at from $1.25 to $2.50 per day.

The amount of capital invested is probably $5,000.

SMITH B. SICKLER, SALEM.

Clay-bed and brick works are located at Penton, in Upper Alloways Creek township, about three miles from Salem.

The clay-bed is from three to seven feet deep and the owner controls fifty acres.

The brick is all hand-made and the capacity of the yard 15,000 per day.

Grinding machines are used to temper the clay, and these are operated by horse-power.

Eight men are employed at $2 per day for moulders and $1 per day for laborers.

THOMAS TAYLOR, WOODSTOWN.

Clay-bed and brickyard are located at Fenwick.

This is a small yard, making brick by hand, operating one Dutch kiln. No bricks were made in 1897.

SOMERSET COUNTY.

WILLIAM ROSS, JR., SOMERVILLE.

The clay-bed and brickyard are located about one-half mile out of town.

The deposit is covered with about eight inches of soil and is worked to a depth of twelve feet. The total depth of the clay stratum is much greater than twelve feet, but this is the limit of depth to which work can be carried without encountering water. In the twenty-five years that the works have been operated, about fourteen acres of clay have been worked over.

The average output of the yard is 3,000,000 per year.

Forty men and boys are employed at a scale ranging from $1 to $1.75 per day.

The bricks are burned in open kilns, using wood for fuel.

The plant is operated by horse-power, and consists of two tempering pits and one grinding and moulding machine.

Mr. Ross is also the owner of the plant formerly operated by Arthur S. Ten Eyck. This is a steam-power plant, but has not been operated in the past year. The clay deposit was from four to five feet deep.

SUSSEX COUNTY.

FRANK E. LOSEY, NEWTON.

Clay-bed and brickyard are located in Newton, along the creek. The clay deposit is eight feet deep and underlies the meadows along the Paulinskill Creek.

The capacity of the yard is over 1,000,000 brick per year. The supply is sold in the local market.

The plant is operated by horse-power and consists of two tempering wheels and pits and two moulding machines.

WARREN COUNTY.

AMERICAN BRICK AND TILE CO., PHILLIPSBURG.

This was an incorporated company with Hon. Henry Green, of Easton, Pa., as President.

The company's plant covers about five acres of land, upon which was located machinery for crushing slate and converting it into a material used in making fire-proof building tile under a patent process.. The material used was the refuse slate from Bangor, Pa. The works seemed to be experimental, and upon their destruction by fire about a year ago the company went out of existence.

PITTSBURG TERRA-COTTA AND LUMBER CO., PITTSBURG, PA.

Works and clay shale deposit at Port Murray, along the line of the Delaware, Lackawanna and Western railroad.

This company began operations in 1896 and has expended a large sum of money on a plant for making porous terra-cotta and Deuse tile for fire-proof construction, plain and ornamental building blocks, hollow, pressed and paving brick.

Operators in Common Brick Works.

Operators.	Location of office.	Location of works.	County.
Cliffwood Brick Co., J. D. Avery	Cliffwood	Cliffwood	Middlesex.
Alexander Gaston	Cliffwood	Cliffwood	Middlesex.
Dunellen Brick Works	Dunellen	Dunellen	Union.
Jacob Hammer	Elizabeth	Elizabeth	Union.
——— ———		Kingston	Middlesex.
Edward Farry	Matawan	Matawan	Monmouth.
John J. Reid	Netherwood, 825 Leland Ave.	Netherwood	Union.
Macavoni & Verett		Berkeley Heights	Union.
Raritan Hollow and Porous Brick Co.	874 Broadway	Perth Amboy	Middlesex.
R. A. Boyce	Somerset St., Plainfield	Plainfield	Union.
D. Hand & Son	Plainfield	Plainfield	Union.
W. F. Fisher & Co.	Sayreville	Sayreville	Middlesex.
Edwin Furman Co., J. J. Cathcart, Secretary	Sayreville	Sayreville	Middlesex.
Sayre & Fisher Co.	Sayreville	Sayreville	Middlesex.
Theo. Willetts	South River	South River	Middlesex.
Yates Bros.	South River	South River	Middlesex.

Operators in Clay Works.

Operators.	Location of office.	Location of works.	County.
——— ———		Hardenbergh's Corner	Middlesex.
John Pfeiffer	Fords	Fords	Middlesex.
Chas. S. Edgar	Metuchen	Metuchen	Middlesex.
Raritan Ridge Clay Co., A. Campbell, President	Metuchen	Metuchen	Middlesex.
J. L. Kearney*	Perth Amboy	South Amboy	Middlesex.
Milton A. Edgar	Perth Amboy, Box 66	Perth Amboy	Middlesex.
Raritan River Clay Co., John C. Goodridge, Jr., President	113 E. 25th St.	Weber	Middlesex.
Watson Firebrick Co., U. C. Watson, President†	Perth Amboy	Sand Hills	Middlesex.

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* One bank (owned by J. L. Kearney).

† Clay only.

Operators.	Location of office.	Location of works.	County.
W. F. Taylor†	Red Bank	Red Bank	Monmouth.
W. P. Ferguson†	253 Broadway.		
A. H. Furman	South Amboy	South Amboy	Middlesex.
N. A. Chemical Co	South Amboy	South Amboy	Middlesex.
Leonard Furman	South Amboy	South Amboy	Middlesex.
J. R. Crossman	South Amboy	South Amboy	Middlesex.
T. B. Roberts	South Amboy	South Amboy	Middlesex.
C. P. Rose	South Amboy	South Amboy	Middlesex.
J. R. Such	South Amboy	South Amboy	Middlesex.
A. O. Ernst	South Amboy	South Amboy	Middlesex.
Geo. W. Benner	Metuchen	South River	Middlesex.
James Bissett, Agent	Main St., South River	South River	Middlesex.
Pettit & Co	South River	South River	Middlesex.
Whitehead Bros. Co	517 W. 15th St	South River	Middlesex.
C. A. Campbell	Woodbridge	Woodbridge	Middlesex.
William H. Cutter	Woodbridge	Woodbridge	Middlesex.
Warren Drummond	Woodbridge	Woodbridge	Middlesex.
David A. Brown	Woodbridge	Woodbridge	Middlesex.
B. Dunigan	Woodbridge	Woodbridge	Middlesex.
David A. Flood	Woodbridge	Woodbridge	Middlesex.
John H. Leisen	Woodbridge	Woodbridge	Middlesex.
Albert Martin	Woodbridge	Woodbridge	Middlesex.
Lewis C. Potter	Woodbridge	Woodbridge	Middlesex.
D. P. Dunham, Jr	Woodbridge	Woodbridge	Middlesex.
G. W. Ruddy	Woodbridge	Woodbridge	Middlesex.
Jas. P. Prall	Woodbridge	Woodbridge	Middlesex.
Patrick L. Ryan	Woodbridge	Woodbridge	Middlesex.
Joshua Little & Sons	Woodbridge	Woodbridge	Middlesex.
R. & S. H. Valentine	Woodbridge	Woodbridge	Middlesex.
E. W. Valentine	Woodbridge	Woodbridge	Middlesex.

Brickyards in Trenton.

Donahue & Nolan, Trenton, front brick and common brick.
J. S. Heath, Trenton, front brick and common brick.
B. P. Walton Buff Brick Co., Trenton, common brick.
Oliphant & Pope Co., Trenton, front brick, paving brick and fire brick.
H. C. Kafer & Co., Trenton, common brick, front brick and moulded brick.
Wm. W. Fell, Trenton, common brick and front brick.
Fell & Roberts, Trenton, common brick, front brick and ornamental brick.
Applegate & Co., Trenton.

MINERAL STATISTICS.

For the Year 1897.

IRON ORE.

	Gross Tons.
The total production of the mines, as reported by the several ore-mining companies, was	257,235
The total production, as gathered from the shipments of the several railway companies, from mines in the State, and reported to the office of the Geological Survey was	239,634
The total production in 1896, as reported by the several carrying companies, was	262,070

The decrease in the production which began in 1892, has been slight through the years 1895, '96 and '97. The table given below shows the production annually since 1870 and at irregular intervals as far back as to 1790. It has an interest historically, and is reprinted from last year's report. These statistics are from the shipments reported by the several railway companies which carry ore from mines in the State, and from reports of mines where the ore is used in furnaces and is not included in any railway company's shipments.

ZINC ORE.

	Gross Tons.
The production of the zinc mines of the State in 1897 is indicated by the total ore shipments for the year; the total shipments, as reported by Mr. A. Heckscher, general manager of the New Jersey Zinc Company, amounted to	76,973

The statistics for a period of years are given in the table reprinted from last year's report.

TABLE OF STATISTICS.

IRON ORE.

1790	10,000 tons	Morse's estimate.
1830	20,000 tons	Gordon's Gazetteer.
1855	100,000 tons	Dr. Kitchell's estimate.
1860	164,900 tons	U. S. census.

1864	226,000 tons	Annual Report State Geologist.
1867	275,067 tons	" " "
1870	362,636 tons	U. S. census.
1871	450,000 tons	Annual Report State Geologist.
1872	600,000 tons	" " "
1873	665,000 tons	" " "
1874	525,000 tons	" " "
1875	390,000 tons	" " "
1876	285,000 tons*	
1877	315,000 tons*	
1878	409,674 tons	" " "
1879	488,028 tons	" " "
1880	745,000 tons	" " "
1881	737,052 tons	" " "
1882	932,762 tons	" " "
1883	521,416 tons	" " "
1884	393,710 tons	" " "
1885	330,000 tons	" " "
1886	500,501 tons	" " "
1887	547,889 tons	" " "
1888	447,738 tons	" " "
1889	482,169 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	" " "

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	" " "

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* From statistics collected later.

† Estimated for 1868 and 1871. Statistics for 1873 to 1890, inclusive, are from reports of the railway companies carrying the ores to the market. The reports for 1890, 1891, 1892, 1893, 1894, 1895 and 1896 were from the companies working the mines.

1884	40,094 tons	Annual Report State Geologist.
1885	38,526 tons	" " "
1886	43,877 tons	" " "
1887	50,220 tons	" " "
1888	46,377 tons	" " "
1889	56,154 tons	" " "
1890	49,618 tons	" " "
1891	76,032 tons	" " "
1892	77,298 tons	" " "
1893	55,852 tons	" " "
1894	59,382 tons	" " "
1895*		
1896	78,080 tons	" " "

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

STATISTICS OF CLAYS, BRICKS, TERRA-COTTA AND OTHER CLAY PRODUCTS.

The growth of the industries which use clays has been so large since the publication in 1878 of the Report on Clays as to attract general attention and suggest the value of a census showing the extent and the output of the establishments producing the various kinds of bricks, tile, terra-cotta and other art products using clays and clayey materials. For the purpose of getting accurate data directly from these manufacturing establishments, Mr. George E. Jenkins, of Dover, and Professor Wm. S. Myers, of New Brunswick, were engaged to collect the statistics. The Middlesex county clay district, with adjacent parts of Monmouth and Union counties, was traversed by Professor Myers, and the remaining part of the State was visited by Mr. Jenkins. Circular letters with request for answers were used in a few cases only. Answers were obtained generally, and from official sources, so that they are authoritative and reliable. The few estimates, where no answers were had, are based upon important statements of shipping officials, and comparative data from similarly-situated establishments, and are believed to be altogether reliable, so that the totals as here given are as nearly accurate as it was possible to get at this time. The communications have been regarded as confidential and have been used in making up totals for the State only. Unfortunately it was impossible to get statements as to the amount of capital invested and the cost of materials and labor, which would have shown more clearly the condition of these industries than is done by the facts of production and the number of men employed. The summary for the various branches of the clay industries is here given:

1. Common Brick—Building Brick—Red Brick.

Number of men employed	2,861
Number of bricks made	283,898,000
Value	$1,271,342

2. Front Brick—Pressed Brick.

Number of men employed	535
Number of brick made	26,978,500
Value	$519,077

3. Fire Brick.

Number of men employed	800
Brick made	13,827,000
Value	$256,652

4. Ornamental and Enameled Brick.

Number of men employed	176
Brick made	2,608,724
Value	$182,900

5 Paving or Vitrified Brick.

Number of men employed	——
Brick made	575,000
Value	$7,600

6. Terra-Cotta and other Structural Material, including Roofing-Tile.

Number of men employed	1,900
Value of product	$2,635,700

7. Miscellaneous Manufactures of Clay.

Men employed	150
Value of product	$91,350

8 Clays Dug and Mined, including Pottery, China, Paper, Stoneware, Fire and Retort Clays.

Number of men employed	863
Tons of clay	318,736
Value	$456,781

General Summary.

Total number of men employed	7,285
Total number of bricks made	327,887,224
Total clay, including all brick-clay, tons	940,236
Total value	$5,421,402

At the time of the publication of the Report on Clays, 1878,* it was estimated that there were 72,000,000 bricks made on the Raritan river and bay and on the Matawan creek, and 10,000,000 on the

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* "Report on the Clay Deposits," Trenton, 1878, page 315.

Delaware river at Trenton and Kinkora. The terra-cotta manufacture had not assumed any importance. In 1880 * the total production of red brick was estimated at 100,000,000. In 1882 † the statistics of the several brick-making districts were reported to amount to 150,000,000. The output of the Middlesex county clay district that year of clays of all kinds (except that used in red brick) and fire-sands, *kaolin* and *feldspar*, amounted to 300,000 tons. In 1888 ‡ the statistics reported were

Common brick	160,000,000
Fire-brick	14,550,000

These figures show that the amount of clay dug, other than for common brick, has not increased to any considerable extent. The fire-brick manufacture also remains almost stationary. The statistics of front or pressed brick on the Delaware do not show any increase. The statistics of common brick for 1897 show a large increase over that of 1882—nearly doubling in fifteen years. The manufacture of terra-cotta and of the various styles of brick for fronts and for interior and ornamental construction has grown to large proportions, and at localities beyond the older centers of brick-making, and clays heretofore regarded as not refractory and of little value or importance have become valuable in their manufacture.

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*Annual Report State Geologist for 1880, pages 181, 182.

†Annual Report State Geologist for 1882, pages 172, 173.

‡Annual Report State Geologist for 1888, pages 79, 80.

PUBLICATIONS.

The demand for the publications of the Survey is continuous and active, and several of the reports are out of stock. So far as possible, requests are granted by giving the reports to such requests.

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

By the act of 1864 the Board of Managers of the Survey is a board of publication with power to issue and distribute the publications as they may be authorized. The Annual Reports of the State Geologist are printed by order of the Legislature as a part of the legislative documents. They are distributed largely by members of the two houses. Extra 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, notably those of 1868, 1873, 1876, 1879, 1880 and 1881 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 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 third volume is now being distributed from the office of the State Geologist. The fourth volume is in press. 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, as usual, distributed without further expense than that of transportation, except in a single instance of the maps, where a fee to cover the cost of paper and printing is charged as stated.

CATALOGUE OF PUBLICATIONS.

GEOLOGY OF NEW JERSEY, Newark, 1868. 8vo., xxiv. + 899 pp. Out of print.

PORTFOLIO OF MAPS accompanying the same, as follows:

1. Azoic and paleozoic formations, including the iron-ore and limestone districts; colored. Scale, 2 miles to an inch.
2. Triassic formation, including the red sandstone and trap rocks of Central New Jersey; colored. Scale, 2 miles to an inch.
3. Cretaceous formation, including the greensand marl beds; colored. Scale, 2 miles to an inch.
4. Tertiary and recent formations of Southern New Jersey; colored. Scale, 2 miles to an inch.
5. Map of a group of iron mines in Morris county; printed in two colors. Scale, 3 inches to 1 mile.
6. Map of the Ringwood iron mines; printed in two colors. Scale, 3 inches to 1 mile.
7. Map of Oxford Furnace iron-ore veins, colored. Scale, 3 inches to 1 mile.
8. Map of the zinc mines, Sussex county; colored. Scale, 3 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. Out of print.

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, by Cornelius Clarkson Vermeule. Vol. III. of the Final Report of the State Geologist. Trenton, 1894, 8vo., xvi. + 352 and 96 pp.

BRACHIOPODA AND LAMELLIBRANCHIATA of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. Trenton, 1886, quarto, pp. 338, plates, XXXV. and Map. (Paleontology, Vol. I.)

GASTEROPODA AND CEPHALOPODA of the Raritan Clays and Greensand Marls of New Jersey, by Robert P. Whitfield. 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 1 mile to an inch.

No. 1. Kittatinny Valley and Mountain, from Hope to the State line.
No. 2. Southwestern Highlands, with the southwest part of Kittatinny valley.
No. 3. Central Highlands, including all of Morris county west of Boonton, and Sussex south and east of Newton.
No. 4. Northeastern Highlands, including the country lying between Deckertown, Dover, Paterson and Suffern.
No. 5. Vicinity of Flemington, from Somerville and Princeton westward to the Delaware.
No. 6. The Valley of the Passaic, with the country eastward to Newark and southward to the Raritan river.
No. 7. The Counties of Bergen, Hudson and Essex, with parts of Passaic and Union.
No. 8. Vicinity of Trenton, from New Brunswick to Bordentown.
No. 9. Monmouth Shore, with the interior from Metuchen to Lakewood.
No. 10. Vicinity of Salem, from Swedesboro and Bridgeton westward to the Delaware.
No. 11. Vicinity of Camden, to Burlington, Winslow, Elmer and Swedesboro.
No. 12. Vicinity of Mount Holly, from Bordentown southward to Winslow and Woodmansie.
No. 13. Vicinity of Barnegat Bay, with the greater part of Ocean county.
No. 14. Vicinity of Bridgeton, from 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.

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, should be made to Mr. Irving S. Upson, assistant in charge of office, New Brunswick, N. J., who will give all orders prompt attention.

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 for the year 1866. Trenton, 1867, 8vo., 28 pp. Out of print.

REPORT OF THE STATE GEOLOGIST, Prof. Geo. H. Cook, for the year 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.

ANNUAL REPORT of the State Geologist of New Jersey for 1870. New Brunswick, 1871, 8vo., 75 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1871. New Brunswick, 1872, 8vo., 46 pp , with maps.

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.

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.

ANNUAL REPORT of the State Geologist of New Jersey for 1879. Trenton, 1879, 8vo., 199 pp., with maps Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1880. Trenton, 1880, 8vo., 220 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1881. Trenton, 1881, 8vo., 87+107 +xiv. pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1882. Camden, 1882, 8vo., 191 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1883. Camden, 1883, 8vo., 188 pp.

Annual Report of the State Geologist of New Jersey for 1884. Trenton, 1884, 8vo., 168 pp., with maps.

Annual Report of the State Geologist of New Jersey for 1885. Trenton, 1885, 8vo., 228 pp., with maps.

Annual Report of the State Geologist of New Jersey for 1886. Trenton, 1887, 8vo., 254 pp., with maps.

Annual Report of the State Geologist of New Jersey for 1887. Trenton, 1887, 8vo., 45 pp., with maps.

Annual Report of the State Geologist of New Jersey for 1888. Camden, 1889, 8vo., 87 pp., with map.

Annual Report of the State Geologist of New Jersey for 1889. Camden, 1889, 8vo., 112 pp.

Annual Report of the State Geologist of New Jersey for 1890. Trenton, 1891, 8vo., 305 pp., with maps.

Annual Report of the State Geologist of New Jersey for 1891. Trenton, 1892, 8vo., xii.+270 pp., with maps. Scarce.

Annual Report of the State Geologist of New Jersey for 1892. Trenton, 1893, 8vo., x.+368 pp., with maps.

Annual Report of the State Geologist of New Jersey for 1893. Trenton, 1894, 8vo., x.+452 pp., with maps.

Annual Report of the State Geologist of New Jersey for 1894. Trenton, 1895, 8vo., x.+304 pp., with geological map.

Annual Report of the State Geologist of New Jersey for 1895. Trenton, 1896, 8vo., xl.+198 pp., with geological map.

Annual Report of the State Geologist of New Jersey for 1896. Trenton, 1897, 8vo., xxviii.+377 pp., with maps of Hackensack meadows.

Annual Report of the State Geologist for 1897.

INDEX.

INDEX.